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INDEX TO VOLUME XI.

		Page
Air for Street Car Traction, Compressed,		162
Air in Steam Engine Cylinders, Compressed,		415
Alberger, Louis R.: Condensation Without Water Supply, Illustrated.		205
Armour Plates, The First,		510
Artificial Ice Skating Rink, An, Illustrated.	George Hill,	450
Batteries for Street Railway Power Stations, Storage,		240
Battle Ships, Defects in the New U. S.,		246
Baxter, Wm., Jr.: The Present Status of Electricity,		20
Bazin Roller Boat, The, Illustrated.	Johannes H. Cuntz,	279
Bernard, E. G.: Electric Ship Lighting, Illustrated.		298
Bicycle Building, Cut-and-Try Methods in,		74
Bicycle Inventions,		508
BIOGRAPHICAL SKETCHES:		
Dwelshauvers-Dery, Victor,	Dr. R. H. Thurston,	222
Ferranti, Sebastian Z. de., Illustrated.	H. Scholey,	315
Holloway, J. F., A Tribute to,	Chas. H. Loring,	47
Melville, George W.,	W. L. Cathcart,	459
Reuleaux, Professor Franz,	Prof. Hans Zopke,	133
Swasey, Ambrose, Illustrated.	John A. Brashear,	399
Birkinbine, John: American Blowing Machinery, Illustrated.		109
Commerce on the Great American Lakes, Illustrated.		487
Boat, The Bazin Roller, Illustrated.	J. H. Cuntz,	279
BOILERS:		
Accidents, Illustrated.		166
Ancient Pompeiian, Illustrated.	W. T. Bonner,	268
Coal Burnt Under,		412
Efficiency of Combustion in Marine, Illustrated.	J. R. F. Fothergill,	129
Feed Pump Efficiency,	A. F. Nagle,	195
Insurance and Inspection,	W. A. Carlile,	65

		PAGE
Bonner, W. T.: Ancient Pompeiian Boilers, Illustrated.		268
Brashear, John A.: Ambrose Swasey, Illustrated.		399
Bridges, Ready-Made		166
Bright, Charles Tilston, With Portrait.		414
Bryan, Wm. H.: Steamboats on Western American Rivers, Illustrated.		260
Buildings, Preserving Iron and Steel Work in Tall,		336
Carlile, W. A.: Boiler Insurance and Inspection,		65
Cathcart, Wm. L.: Biographical Sketch of Com. Geo. W. Melville, Illustrated.		459
Coal Burnt Under Boilers,		412
Coal for Steamship Propulsion,		511
Combe, Abram: Rope Driving,		33
Commerce on the Great American Lakes, Illustrated.	John Birkinbine,	487
Condensation Without Water Supply, Illustrated.	Louis R. Alberger,	205
Copper Mining in the United States, Illustrated.	William P. Kibbee,	215
Couplers, Car,		336
Craft, Some Early American Steam, Illustrated.	Prof. F. R. Hutton,	357
Crane, A Pneumatic Travelling, Illustrated	W. G. Starkweather,	483
Crosby, F. W. and W. O.: The Sea Mills of Cephalonia, Illustrated.		388
Cuntz, Johannes H.: The Bazin Roller Boat, Illustrated		279
Dam, at Bouzey, France, The Failure of the Masonry, Illustrated.	W. C. Unwin, F.R.S.,	9
Deficiencies in Engineers' Pocket Books,		75
Dougherty, Chas. J.: Electrically Annealing Harveyised Armour Plates on a Battleship, Illustrated.		406
Drawings, Shop		168
Dredging, Hydraulic, Illustrated.	A. W. Robinson,	37
Drills, Oil-Fed Twist,		416
Duncan, Dr. Louis: Power Transmission by Alternating Electric Currents,		104
Modern Methods of Electric Energy Transmission,		505
Dunlap, Orrin E.: Power Transmission from Niagara Falls, Illustrated.		197

ELECTRICITY:

Electricity, The Present Status of,	Wm. Baxter, Jr.,	20
Electric Power Installation, A Notable,		77
Electric Water Power Plant, Economising Water in an,		77
Electric Cords, Fire Dangers in Flexible,		165
Electric Wires, A New Danger from Overhead,		243
Electric Railway Statistics,		245
Electric Switching Locomotives, Illustrated.	E. H. Mullin,	274
Electricity in Agriculture, Illustrated.	John McGhie,	285

PAGE

ELECTRICITY—*Continued.*

Electric Ship Lighting, ... E. G. Bernard, . . 298
Illustrated.

Electricity, The Age of, ... Nikola Tesla, . 378
Illustrated

Electrically Annealing Harveyised Armour Plates on a Battleship, ... Chas. J. Dougherty, . 406
Illustrated.

Electric Traction in City Streets, ... N. W. Perry, . 419
Illustrated.

Modern Methods of Electric Energy Transmission, . Dr. Louis Duncan, . 505

An Induction Coil Explosion, ... 511

Ellington, E. B., M. Inst. C. E : Hydraulic Power in London, ... 95
Illustrated.

Engineering, The Mysterious in. 333

Engineering Progress, Twenty-five Years of, . . . Sir Douglas Fox, Vice-Prest. C. E., . . 339
Illustrated.

Engine Parts, Interchangeability in, ... 74

Engine Rooms, The Artistic Element in, ... 79

Engineers in the United States Navy, ... 242

Evaporators, Marine, ... D. B. Morison, . . 56
Illustrated.

Exhibit, Does it Pay to, ... Prof. Wm. T. Magruder, 386

Fire Dangers in Flexible Electric Cords, ... 165

Fire Engines, Self-Propelling, ... 510

Forbes, W. D.: The Ideal Engine Lathe, ... 502
Illustrated.

Forging Machine, A Handy, ... 241
Illustrated.

Fothergill, J. R. F.: Efficiency of Combustion in Marine Boilers, ... 129
Illustrated.

Fox, Sir Douglas, Vice-Prest. Inst. C. E.: Twenty-five Years of Engineering Progress, ... 339
Illustrated.

Francois, Eugene: American Machine and Engine Building Seen Through European Eyes, ... 141
Illustrated.

Friction of Shafting, ... 507

Fuel in the United States, The Manufacture of Compressed, John R. Wagner, ... 23
Illustrated.

Gas and Oil Engines, New Fields for, ... 164

Hill, George: An Artificial Ice Skating Rink, ... 450
Illustrated.

Horseless Carriages, Power for, ... 512

Hutton, Prof. F. R.: Some Early American Steam Craft, ... 357
Illustrated.

Independent Driving of Machinery, ... 507

Induction Coil Explosion, An, ... 511

Interchangeability in Engine Parts, ... 74

Jail, A Water Tube, ... 412

Kerr, Walter C.: Small Refrigerating Plants, ... 171
Illustrated.

Kibbee, William P.: Copper Mining in the United States, ... 215
Illustrated.

Lake and Ocean Steamship Models, American, . Joseph R. Oldham, N. A., M. E., . 229
Illustrated.

Lakes, Commerce on the Great American, . . . John Birkinbine, . 487
Illustrated.

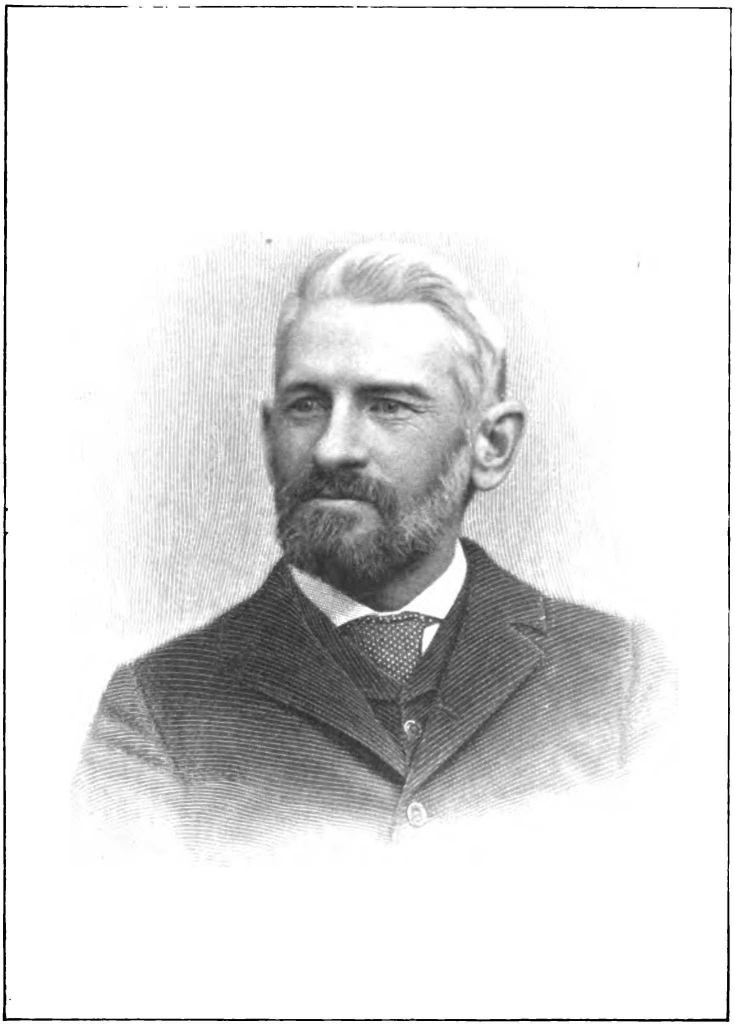
		PAGE
Lathe, The Ideal Engine, Illustrated.	W. D. Forbes,	502
Leeds, Dr. Albert R.: Water Purification and Filtration in the United States, Illustrated.		304
Locomotives, Armoured, Illustrated.		246
Locomotives, Electric Switching, Illustrated	E. H. Mullin,	274
Loring, Chas. H.: A Tribute to J. F. Holloway,		47
Metric System from a Mechanical Point of View,	Samuel Webber,	447
Machine and Engine Building Seen Through European Eyes, American, Illustrated.	Eugene Francois,	141
Machinery, American Blowing, Illustrated.	John Birkinbine,	109
Machinery, Buying,		80
MacIntyre, Robt.: Shipbuilding in Great Britain, Illustrated.		437
Magruder, Prof. Wm. T.: Does it Pay to Exhibit?		386
McCulloch, Richard: Steam Engines for Power Houses,		481
McGhie, John: Electricity in Agriculture, Illustrated.		285
Milling Cutter, A New Form of, Illustrated.		243
Mining in the United States, Copper, Illustrated.	William P. Kibbee,	215
Morison, D. B.: Marine Evaporators, Illustrated.		56
Moyer, R. B.: The Whitehead Automobile Torpedo, Illustrated.		251
Mullin, E. H.: Electric Switching Locomotives, Illustrated.		274
Nagle, A. F.: Boiler Feed Pump Efficiency,		195
Oldham, Joseph R., N. A., M. E.: American Lake and Ocean Steamship Models, Illustrated.		229
Paint from Metal Work by the Sand Blast, Removing Old,		332
Perry, N. W.: Electric Traction in City Streets, Illustrated.		419
Pistons, Explosions of,		412
Pneumatic Travelling Crane, A, Illustrated.	W. G. Starkweather,	483
PORTRAITS:		
Dwelshauvers-Dery, V.,		170
Ferranti, Sebastian Z. de,		250
Holloway, J. F.,		2
Melville, George W.,		418
Reuleaux, Prof. Franz,		82
Swasey, Ambrose,		338
POWER:		
Hydraulic in London, Illustrated.	E. B. Ellington, M. Inst. C. E.,	95
Hydraulic in Switzerland, Illustrated.	Henry Harrison Suplee,	3
Power for Horseless Carriages,		512

PAGE

POWER—*Continued.*
Transmission by Alternating Electric Currents, . Dr. Louis Duncan, . 104
Transmission from Niagara Falls, ... Orrin E. Dunlap, . 197
Illustrated.
Power Houses, Steam Engines for, ... Richard McCulloch, . 481
Processes, The Reversibility of Natural, ... 335
Product in the World, The Most Expensive, ... 413

PUMPS:
Economy in Steam, ... 78
Vacuum, ... 78
Rail Problem, The Continuous, ... 416
Railroad, A Curious Defect in the Buda-Pesth Underground, ... 335
Railroad Without Cars, A, ... 508
Illustrated
Railroad Without Telegraph Instruments, A, ... 166
Railway Statistics, Electric, ... 245
Refrigerating Plants, Small, ... Walter C. Kerr, . . 171
Illustrated.
Robinson, A. W.: Hydraulic Dredging, ... 37
Illustrated.
Rope Driving, ... Abram Combe, . . 33
Rust, Protection Against, ... 411
Saw Mill, The Modern, ... W. H. Trout, . 83-184
Illustrated.
Saw Mill Work, Quick, ... 165
Scholey, H.: Biographical Sketch of Sebastian Z. de Ferranti, ... 315
Illustrated.
Sea Mills of Cephalonia, The, ... F. W. and W. O. Crosby, 388
Illustrated.
Shipbuilding in Great Britain, ... Robt. MacIntyre, . 437
Illustrated.
Ship Lighting, Electric, ... E. G. Bernard, . . 298
Illustrated.
Shooting Under Water, ... 511
Skating Rink, An Artificial Ice, ... George Hill, . . 450
Illustrated.
Smoke Pollution, ... 414
Soho Works of Boulton & Watt, The Old, ... 413
Illustrated.
Starkweather, W. G.: Pumping Water for Irrigation, ... 49
Illustrated.
A Pneumatic Travelling Crane, ... 483
Illustrated.
Steamboats on Western American Rivers, . . . Wm. H. Bryan, . 260
Illustrated.
Steam Engine Designs, Odd, ... 508
Steam Engines for Power Houses, ... Richard McCulloch, 481
Steam Pipe, Dangers of Cast Iron, ... 334
Illustrated.
Steam Pressures, High, ... 509
Steamship Propulsion, Coal for, ... 511
Suplee, Henry Harrison: Hydraulic Power in Switzerland, ... 3
Illustrated.
Technical Education, The Economic Element in, ... 509
Telegraph Instruments, A Railroad Without, ... 166

PAGE
Tesla, Nikola: The Age of Electricity, ... 378
Illustrated.
Texas, The U. S. Battle Ship, ... 241
Illustrated.
Thurston, Dr. R. H.: Biographical Sketch of Victor Dwelshauvers-Dery, . . 222
Torpedo, The Whitehead Automobile, . . R. B. Moyer, . 257
Illustrated.
Tracklaying Traction Engine, A, ... 163
Illustrated.
Traction, Electric, in City Streets, ... N. W. Perry, . 419
Illustrated.
Trees as Vegetable Pumping Engines, ... 164
Trolley Road Construction, Modern Overhead, . Benjamin Willard, . 367
Illustrated.
Trout, W. H.: The Modern Saw Mill, ... 83–184
Illustrated.
Tunnels, The Cost of Four Great, ... 79
U. S. Battle Ship Texas, The, ... 241
Illustrated.
United States Navy, Inconsistencies in the, ... 75
Unwin, W. C., F. R. S.: The Failure of the Masonry Dam at Bouzey, France, . 9
Illustrated.
Voltages, High, ... 411
Wagner, John R.: The Manufacture of Compressed Fuel in the United States, . 23
Illustrated.
Water for Irrigation, Pumping, ... W. G. Starkweather, 49
Illustrated.
Water Purification and Filtration in the United States, . Dr. Albert R. Leeds, . 304
Illustrated.
Water Supply from Geneva Lake, City, ... 248
Webber, Samuel: The Metric System from a Mechanical Point of View, . . 447
Whitehead Automobile Torpedo, The, ... R. B. Moyer, . 251
Illustrated.
Willard, Benjamin: Modern Overhead Trolley Road Construction, ... 367
Illustrated.
Wilson-Squire Naval Engineering Bill in the United States, The, ... 244
Zopke, Prof. Hans: Biographical Sketch of Professor Franz Reuleaux, . . . 133



FROM A PHOTOGRAPH BY BECKWITH, CLEVELAND.

Yours truly
J. F. Holloway

CASSIER'S MAGAZINE.

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HYDRAULIC POWER IN SWITZERLAND.

By Henry Harrison Suplee.

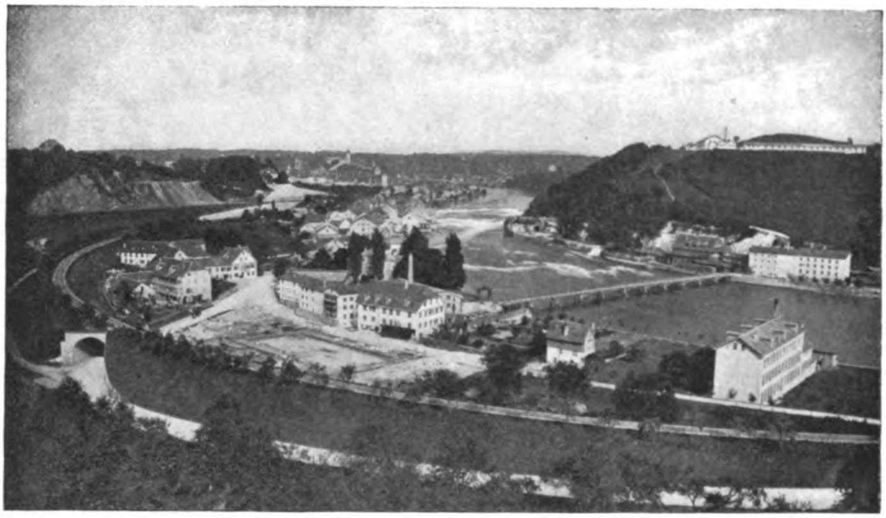
SWITZERLAND has aptly been described as a country whose principal business capital consists of a large stock of natural scenery; but while this is, doubtless, true, she also possesses another source of wealth in the stock of hydraulic power which she has so skilfully utilised. The tourist is usually impressed by the scenery; and well he may be; but to the eye of the engineer the many water power installations are no less attractive and interesting.

Perhaps the combination of picturesque scenery and successful engineering is nowhere so well exhibited as at Schaffhausen. As the traveller approaches from Zurich and Winterthur, he sees suddenly through a break in the foliage on his left a glimpse of seething foam and a burst of spray over water-worn rocks, and then the train plunges into a tunnel from which it emerges only to cross the arches of the bridge across the Rhine. The impression made by this first view of the Falls of the Rhine is heightened by the nearer scene, for while the famous falls are exceeded by many in magnitude and height, yet for wildness and beauty they are unsurpassed.

To the engineer, however, this picturesque country is doubly interesting, since for the past thirty years Schaffhausen has been known as the location of the greatest hydraulic power installation in Europe, and one in which the power of the Rhine is not only utilised, but also transmitted, at first by wire cables, and later by electricity over considerable distances.

While the original installation at Schaffhausen has been eclipsed by that at Niagara, it is still one of great value and interest, in view of the fact that it was there that the first extensive attempts were made to apply long distance transmission of power.

The transmission of power by means of wire cables originated, as is well known, with the experiments of Hirn, in 1850, but the early attempts were of quite small magnitude, not over 100 horse-power being transmitted, and the distance not reaching half a mile. In 1862, after the successful application of the principle had been fully assured, the "Compagnie d'Utilization des Forces du Rhin Superieur" was formed to de-



A VIEW OF SCHAFFHAUSEN.

velop the power of the Rhine above Schaffhausen and to transmit it over the neighbouring country for industrial purposes.

The Rhine at Schaffhausen is about 400 feet wide, and as it flows by the city, its descent is so rapid that a slight damming is sufficient to enable an ample supply of water to be taken off for industrial purposes. The dam is almost directly opposite the city, while the power house is situated on the opposite bank, about half a mile down the stream, thus enabling a fall of about twenty metres (about sixty-six feet) to be obtained. This is about two miles above the falls, so that all the power is obtained from the rapids, and the water is returned to the river again before the falls themselves are reached, at Neuhausen, and thus the demands of industry are met without antagonising the æsthetic interest in the beauty of the cataract.

In this respect, indeed, the use of water power possesses much to commend itself to the lovers of picturesque beauty, for it would be difficult to find a manufacturing city so free from all the repulsive features of a factory town. Smoke there is none and but little noise, while the tower stations along the river front, with their light whirling wheels and flying ropes, add to the surroundings rather than detract from them.

A walk through the streets of the old city reveals nothing of the nature of manufacturing industries, and among the quaint old houses, odd signs and mediæval fountains, and along the old Rheinstrasse there is no indication of the fact that active industrial operations are being carried on within. The houses there overhang the rapids of the Rhine, and from the balconies one can look down into them, and also obtain an excellent view of the wire rope transmission by which all of the earlier portion of the power was transmitted.

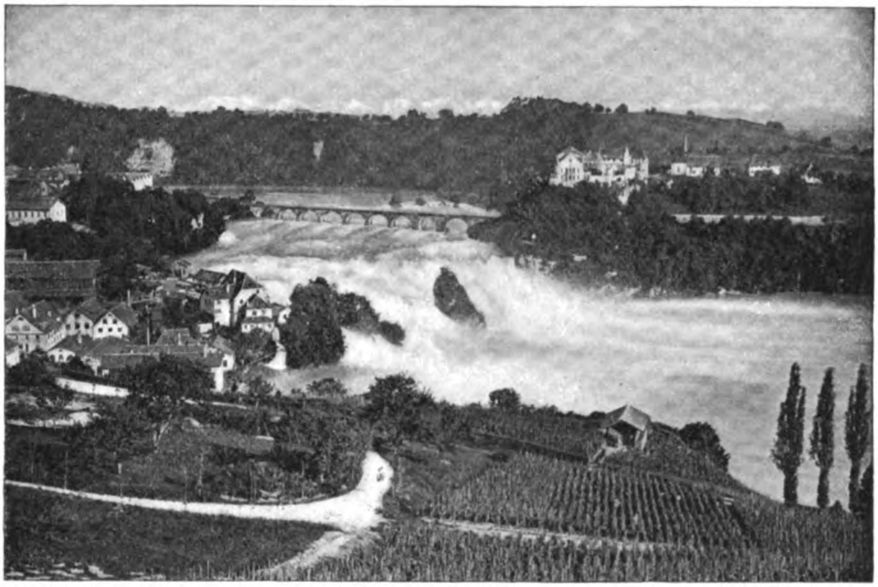
The original plant provided only for about 750 horse-power, and of this about 560 horse-power is transmitted across the river by means of three wire cables, running at a speed of about 4600 feet per minute. The actual span of the greatest of these cables is about 450 feet, the power thus being carried high above the waters of the Rhine to the right bank, where the city is located. A glance at the town will show how essential some such long distance system of transmission was to the development of the power at this point.

The only way in which sufficient head

could be obtained, lay in the utilisation of the rapids by placing the power station below the city at a distance of nearly half a mile. To have done this on the right bank would have required the construction of a canal right through the solidly built-up portion of the old town, a scheme which was a practical impossibility. On the left bank, however, the canal was readily built, although this involved the construction of a short tunnel; but had not the wire rope transmission been available it would have been most difficult to get the power to the points where it could best be utilised.

submerged during the periods of high water and freshets. This required the use of heavier cables and should have been accompanied by pulleys of larger diameter, and, as a consequence, there were many annoying breakages. Ultimately, the towers were raised so as to provide ample clearance at all times.

Many interesting points about the early difficulties of the enterprise were related to the writer by Professor Amsler, by whose engineering skill they were so successfully surmounted, and from the balcony of his establishment on the Rheinstrasse the general view of the whole installation was most effective.



THE RHINE FALLS AT NEUHAUSEN.

It is not surprising that some practical errors were made in this, the first, system of such magnitude, and some of the difficulties which were encountered in this portion of the installation have since been inconsiderately used as arguments against wire rope transmission in general. In order to reduce the sag of the cables which carry the power across the river, they were given an increased tension over that naturally due to the force transmitted, it having been found that the lower portions of the cables were

A walk down the stream and across the narrow foot bridge leads to the power house where, at the present time, about 5000 horse-power is generated, and from which it is distributed over the surrounding country.

Here the electric portion of the plant is more in evidence and three large Oerlikon generators are in use, of 400 horse-power capacity each. One of these is used for lighting the city, and the other two serve for power distribution, while others are to be installed in spaces already provided for them. As in the case of the wire cable transmission, knowledge gained by experience in the first use of electric power there is likely to result in modification in subsequent work. Continuous, low-tension current will probably be superseded by a high-tension polyphase system, and ultimately all the wire cable system will be replaced by electricity.

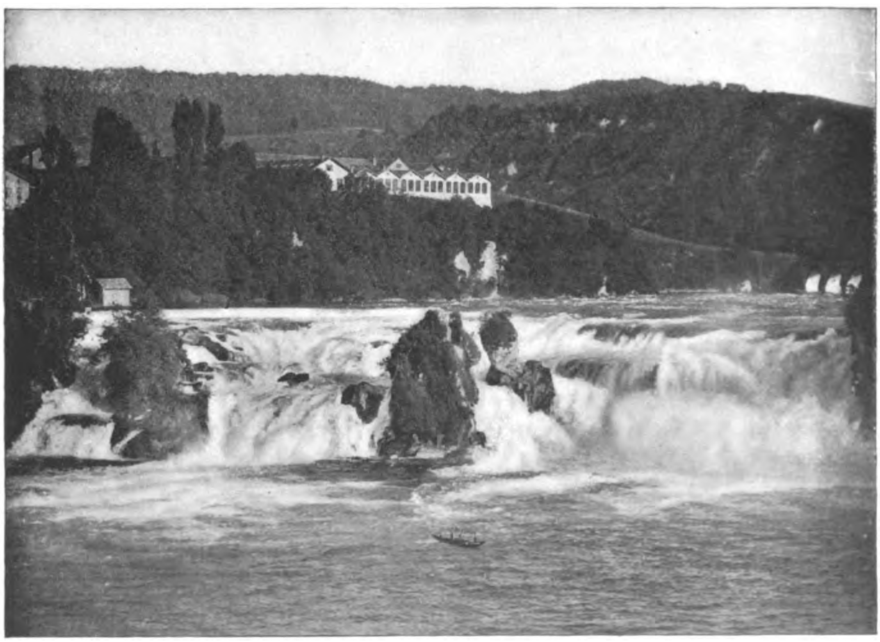
Schaffhausen is now no longer the greatest hydraulic power plant in Europe, being exceeded by the 9000 horse-power of Tivoli, more recently harnessed for transmission to Rome, but it will always be interesting as the pioneer long-distance plant of the world.

The view of the city and river from which the illustration on page 4 has been made, was taken from the villa of Charlottenfels, which lies above the city on the right bank of the river and was the residence of Herr Moser, the leading spirit in the promotion of the enterprise for the utilisation of the power of the river.

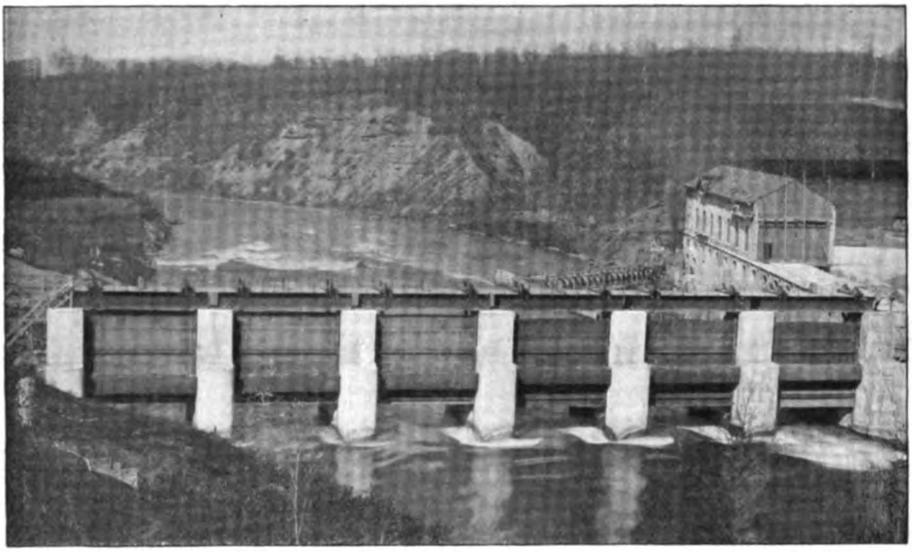
Thus far we have referred only to the plant of the power company at the city of Schaffhausen; but at Neuhausen, about two miles and a half below Schaffhausen, and just above the Falls of the Rhine, there is another large power plant, that of the "Aluminium-Industrie Actien-Gesellschaft." This has been in operation since 1888, and while the power is not distributed, but is used entirely in the one establishment, yet in magnitude it nearly equals that of the Schaffhausen company.

As in the previous case, it is the fall of the rapids which is used, and the descent is so rapid that a fall of twenty metres (sixty-six feet) is obtained, and over 3000 horse-power developed for the production of aluminium by the Heroult process. A view of the buildings of the aluminium company is given in the view of the falls of the Rhine on this page, being the large buildings just above the falls on the right bank.

While the works at Schaffhausen and Neuhausen are among the oldest and most important in Switzerland, yet there are many other installations of magnitude. Among these may be mentioned the hydraulic power distribution



THE FALLS OF THE RHINE FROM THE LEFT BANK. VIEW FROM RAILROAD TRAIN.



THE STONEY DAM NEAR GENEVA, BUILT IN 1895.

at Geneva, where the power of the Rhone will ultimately be utilised to the extent of 6000 horse-power, both for the city water supply and for mechanical motive power as well.

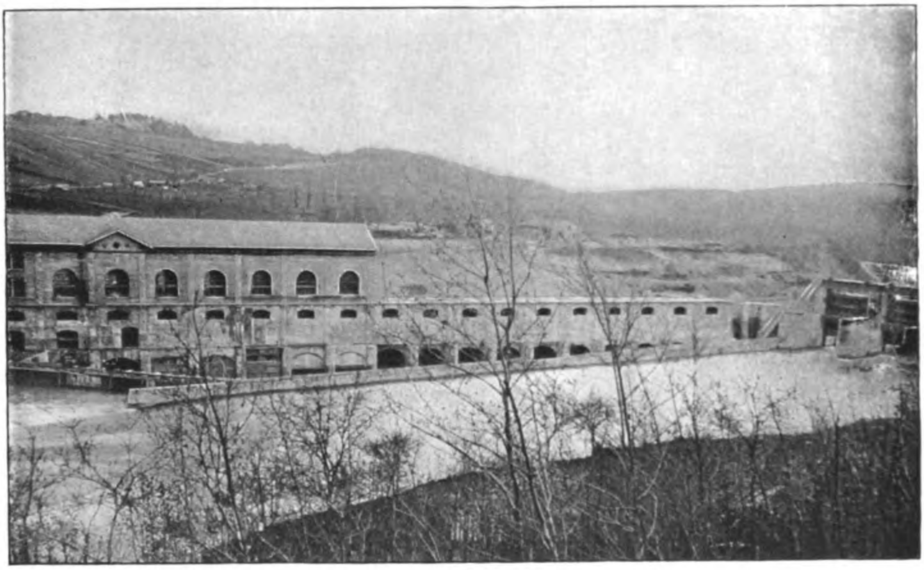
There the head of water is small, varying from six to twelve feet, according to the stage of the river, the flow being controlled by a movable dam composed of rolling curtains and fixed abutments, and the Jonval turbines are composed of annular rings of buckets in order to obtain as high a degree of efficiency as possible when only a partial supply of water is available. No such arrangement is necessary at Schaffhausen, as the supply of water is there ample at all times.

The turbines at Geneva are used to drive the pumps directly, without the intervention of gearing. Two systems are in use,—a high-pressure of 450 feet head, and a low-pressure system of 150 feet head. The former is used for power distribution and the latter for the water supply and for some small motors, each system having its own turbines and pumps.

The investigations which were made as to the efficiency of electrical, hydraulic, pneumatic and wire rope systems, prior to the adoption of the hydraulic system at Geneva may be of interest. For distances under one mile, the wire rope system was the most efficient, ranging from 96 to 60 per cent. Pneumatic transmission showed the best for long distances, ranging from 60 per cent. at 1000 yards to 50 per cent. at 20.000 yards, while electricity began at about 70 per cent. and fell to about 35 per cent. for the same distances. Hydraulic transmission started at 50 per cent. and fell to about 30, but it was adopted because of its safety and convenience, and for the reason that it could at any time readily be used to extend the water supply of the city.

Another interesting installation of hydraulic power is found at Chaux de Fonds, near Neuchatel. There a system of Girard turbines is operated under a head of 170 feet to drive pumping machinery for the water supply of the town. In order to obtain the proper location for the turbines, the plant was placed about 1200 feet below the town, and as the reservoir is 400 feet above, there is a total head of 1600 feet against which the pumps have to act.

The turbines are of the outward flow type, on horizontal axes and are about



THE POWER HOUSE NEAR GENEVA, CONTAINING 15 TURBINES OF 1200 HORSE-POWER EACH.

16 feet in diameter, mounted directly on the pump crank shafts, the whole resembling a double-cylinder horizontal engine, the turbine taking the place of the fly-wheel and the pumps being in the places of the steam cylinders. A test of the system has shown that 67 per cent. of the power delivered to the turbines was returned in water delivered to the reservoir. This is an excellent showing when it is remembered that this includes both the efficiency of the pumps and the turbines, as well as the frictional resistance of the 1600 feet of main.

Among the older hydraulic plants, that at Zurich is of interest as showing the gradual development from the heavy undershot wheels first used, to the modern turbines and impact wheels. The old wheels at Zurich are placed in the arches of bridges across the Limmat and are actuated by the current and the slight head which is produced by the obstruction which the bridge offers to the flow of the river. These old bridges themselves are full of buildings, mostly occupied by printing and book binding establishments, the power thus being utilised at the point where it is generated and no attempt at transmission, even to the banks, being thought of.

The later power plant is situated in an island in the river, some distance below the city, a head of six to eight feet being obtained by damming the stream, and there eight large turbines are developing over a thousand horse-power, part of which is used for the water supply of the city; the balance is transmitted by wire rope systems to both banks and used for many factories. At Zurich the works of Messrs. Escher, Wyss & Co. are situated, where were constructed the turbines for Geneva, Chaux de Fonds, and many other places, this being one of the best known machine shops of Switzerland.

Besides these large installations, Switzerland is full of small power plants, nearly every town in that land of mountains and waterfalls being well supplied with power from the "white coal," as the melting snow on the mountain sides has well been called. When there are no large streams, many small ones are impounded and collected in reservoirs on the hill sides, and it is rare to find a place of any size which is not well lighted by the power of some mountain stream.

At Montreux the electric tramway gets its power in this way, and from the old Roman town of Vevey, to the mediæval castle of Chillon, one may ride in a trolley car, propelled by the power of an insignificant little stream which may or may not be noticed when climbing up the hill sides just above.

The capabilities of this general utilisation of natural power are beginning to be understood everywhere, and with the appreciation of the possibilities of the best methods of long-distance transmission, the development of many mountain streams must surely come. There are innumerable streams which, while very small, are yet very high, and these can, with comparatively little difficulty, be impounded and carried down many hundreds of feet, thus making up for their lack of volume by the great pressure readily obtainable, and, either by the use of electricity, or compressed air, the power may be transmitted to many points of application, with but little loss.

THE FAILURE OF THE MASONRY DAM AT BOUZEY, FRANCE.

By W. C. Unwin, F. R. S.

IN modern times it has become necessary very often to store large quantities of water. For the supply of water to towns, for feeding canals, for moderating river floods, large reservoirs have to be constructed. Generally this is effected by building an embankment, or dam, across a river valley and impounding the water behind the barrier so formed. Such reservoirs were, perhaps, first constructed for irrigation purposes in India, cénturies ago. The earliest embankments were of earth, but in the sixteenth century dams of masonry were built in Spain.

Earthen embankments for reservoirs have been constructed up to as much as 120 feet in height. Under suitable conditions, and with adequate care in construction, they are trustworthy. But some accidents of a terrible kind have happened, and engineers have become less inclined to build earth dams of very great height.

In designing a dam of loose earth, the slopes must be at an angle less than the angle of repose of the earth. In practice, the slopes of earth dams are from 2 to 1 to 3 to 1. The section of the dam is then nearly triangular, and, if of great height, a very large cubic volume of material is required. Their stability is so great with the slopes given that there is no possibility of their being moved or overturned as a whole. If they fail, it is because they are undermined by water leakage, as was probably the case in the disaster at the Dale dyke or Bradfield reservoir at Sheffield, England, in 1864; or else they fail because, from insufficient provision of waste weir, they are overtopped and cut down by the water, as was the case in the disaster at Johnstown, in the United States, in 1890.

In 1858-65, the French engineers had to construct an exceptionally high dam for a reservoir at Furens, and they revived the Spanish practice of building the dam of masonry. Since then many very remarkable dams of this kind have been constructed in France, in England, in India and in the United States.

Earth dams are always straight in plan. Masonry dams have sometimes been built straight, sometimes arched up-stream. In a comparatively narrow valley probably a dam arched up-stream is considerably stronger than a straight dam of the same section. But the problem of determining the condition of stability of a dam, arched in plan, and encastrè in the rock at its bottom edge, has proved intractable. Hence the engineer is forced to treat all dams, whether arched or not, as straight dams.

Further, it is customary to neglect any support which the dam may receive from the fixing of its ends in the sides of the valley. In estimating the stability of the dam, the engineer considers a vertical slice at the deepest part standing independently, and he ignores the possible support which such a slice may receive from the shallower parts of the dam on either side.

It seems pretty certain that the errors thus commited are on the side of safety. But when it is necessary to consider a case of actual failure of a dam, then it must be remembered that any vertical slice does receive lateral support, and that support must be taken into the reckoning amongst the forces acting at the moment of failure.

Theory of Dams.

Some engineers have considered that the safety of a masonry dam was secured if it was safe against sliding on its base and safe against overturning on its down-stream edge. With this conception of the function of the dam in resisting the water pressure, the section was naturally made trapezoidal, or nearly trapezoidal. The up-stream face was, in all early dams, vertical or nearly vertical, and the down-stream face sloped or stepped.

The engineers who designed the Furens dam perceived the necessity of attending also to the stresses in the dam tending to produce crushing. Then it appeared that in a dam of very unsymmetrical section, such as seemed most suitable for resisting on one side a water pressure, it might happen that the crushing stress on the up-stream face when the reservoir was empty and the water pressure absent, might be as great as, or greater than, the crushing stress on the down-stream face with the reservoir full. Two cases, therefore, required consideration,—the case of the reservoir empty and the dam loaded only by its own weight, and the case of the reservoir full, and the weight and water pressure both acting as straining forces. Given, a safe limiting crushing stress, then considerations of economy of masonry impose the condition that the crushing stress on the up-stream face, with the reservoir empty, and that on the down-stream face, with the reservoir full, should each approach, as nearly as practical conditions allow, the given safe limit of stress.

From this way of looking at the problem there was evolved a form of dam section with curved faces which, in the case of a high dam, required less than half as much masonry as a trapezoidal dam with the same stress limit. All masonry dams, built since the Furens dam, have been designed on the French theory, applied with more or less consistency in different cases.

Further, the French theory has only in one respect received any important modification. In 1872 Professor Macquorn Rankine was consulted about a high masonry dam for India. Adopting, generally, the French method of treatment, he pointed out the desirability of fulfilling one other condition. Seeing that a cemented blockwork structure, such as a masonry dam, has little tensile strength, he thought it desirable that there should be no tension in any part of the masonry, at least so far as that could be ascertained by ordinary calculations. This condition was not explicitly considered by the French engineers, but it is nearly, though not quite, satisfied in most existing masonry dams.

The failure of a great masonry dam and the sudden release of an enormous volume of water is a disaster so terrible in its consequences, that no care or caution in the design and construction of the dam to avoid it is superfluous. That such an accident happened in France last year makes it important to re-examine on what conditions the safety of a dam depends.

Estimation of the Stability of a Dam.

According to the older view, which is now generally, though not absolutely, discarded, the dam would be safe if it could neither slide nor overturn. Fig. 1, *A*, shows how a dam might slide on its base under the action of a water pressure, *P*, if the resistance to sliding, or shearing, at *a b* were less than *P*. Such sliding may occur, if the foundation is treacherous, and especially if water under pressure finds its way beneath the base of the dam.

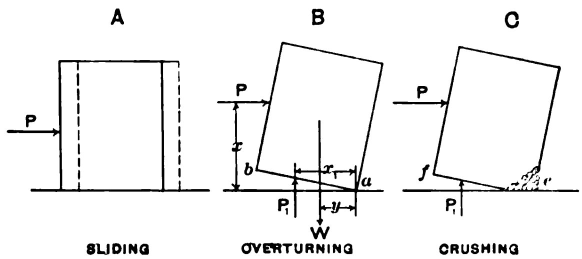


FIG. 1.

Fig. 1, *B*, shows how a dam may overturn under an overturning moment due to the water pressure. If *P* is the water pressure, and *W* the weight of the dam, then, in order that overturning may occur about the down-stream edge, *Px* must be equal to, or greater than, *Wy*.

To put it in another way, overturning cannot occur unless the resultant of *P* and *W* passes through, or outside of, the edge *a*. For safety, it has usually been prescribed that the moment of resistance to overturning, *Wy*, should be two or two and one-half times the overturning moment *Px*, and then the resultant of *P* and *W* is well within the base of the dam.

There is, however, an additional possible force to be considered. If from springs there is water pressure, P_1, below *a b*, then P_1 is an external force which must be taken into the reckoning and the whole overturning moment is $Px + P_1 x_1$.

It is, of course, generally impossible to estimate $P_1 x_1$, and the engineer must, therefore, take precautions, by drains or otherwise, to prevent the possibility of a water pressure existing below the base, or at any horizontal plane in the dam. Some engineers have made allowance for a possible water pressure under their dams, and at least in principle they were right in taking account of such a contingency. It will be seen, later on, that it was probably because the conditions allowed such a water pressure to come into existence that the Bouzey dam failed.

Estimated Strength of a Dam.

Supposing a dam is not of great height, such a sliding or overturning as has just been considered may really occur. But in a very high dam another action enters which profoundly affects the question of safety. Fig. 1, C, shows how, in a very high dam, the edge *e* would crush, or the edge *f* fissure, if any overturning commenced. Further, from the compressibility of all structural materials, a crushing at *e*, or a fissuring at *f*, might occur even while the moment *Wy* was greater than *Px* and no actual overturning had occurred. This would happen if the crushing stress at *e* or the tensile stress at *f* were greater

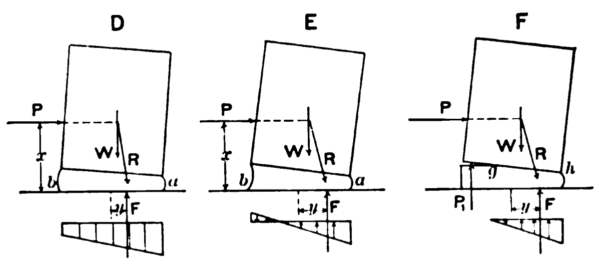


FIG. 2.

than the resistance of the materials of the dam.

Either of these actions may occur independently, and if either occurs, the stability of the dam against overturning is seriously compromised. For if crushing takes place at *e*, the edge on which the dam overturns is moved inwards and the moment of resistance is diminished.

If fissuring takes place at *f*, water pressure is admitted and the overturning moment is increased.

The French engineers abandoned the theory of sliding and overturning, and replaced it by a theory in which the safety of the dam was treated as a question of crushing stress. It will facilitate the explanation of this theory if we consider the condition of a layer of elastic material, say India rubber, supporting a heavy block representing the dam.

Fig. 2, *D*, shows what is the general condition of things. *P* and *W* have a resultant, *R*, acting on the elastic material at a distance *y* on the down-stream side of the centre of the layer. *R* will have a horizontal component, equal to

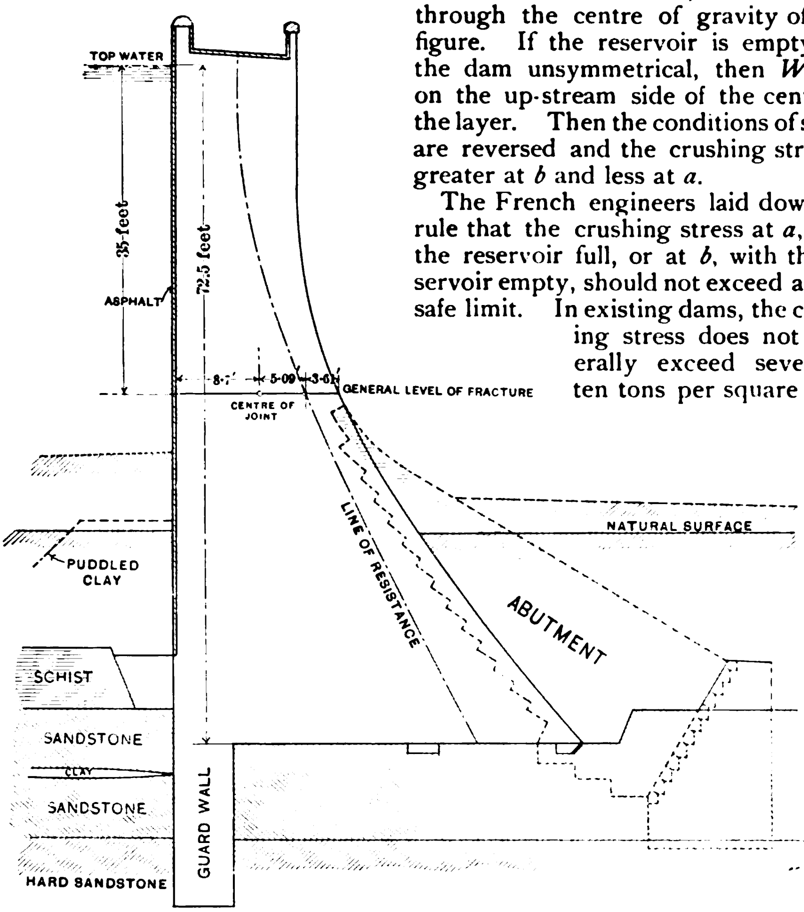


FIG. 3.

P, producing a shearing stress in the layer which is generally unimportant. It will have a vertical component, equal to *W*, acting at *y* from the centre of the layer. This will be balanced by the resultant, *F*, of a uniformly varying crushing stress in the India rubber, greater at *a* and less at *b*.

The smaller figure shows the distribution of the stress, and *F* acts through the centre of gravity of this figure. If the reservoir is empty and the dam unsymmetrical, then *W* acts on the up-stream side of the centre of the layer. Then the conditions of stress are reversed and the crushing stress is greater at *b* and less at *a*.

The French engineers laid down the rule that the crushing stress at *a*, with the reservoir full, or at *b*, with the reservoir empty, should not exceed a very safe limit. In existing dams, the crushing stress does not generally exceed seven to ten tons per square foot, which allows a very large factor of safety against crushing.

Conditions in Which Tension Exists.

If the resultant *R*, of *P* and *W*, acts outside the middle third of the width of the layer, that is, if *y* is greater than one-sixth of *a b*, then the stress at *b* is negative or tensile (Fig. 2, *E*). Now, masonry can, in any case, be little trusted to resist a tension. The cementing mortar has not a large tenacity, and the adhesion of the mortar to stone is less still. Probably under a varying stress any tension is likely to fissure masonry.

If we neglect the tenacity, or treat the mass as incapable of resisting a tension, then the condition in Fig. 2, *E*, is impossible and we get the condition shown in Fig. 2, *F*. A fissure forms on the tension side and extends inwards to g, so that R lies within the middle third of the unfissured part gh, and the tension at g is zero.

Supposing such a fissure formed on the down-stream side of the dam, there would be an end of the action unless the crushing at a became excessive. A new condition of stability would be reached. However objectionable, on practical grounds, it might be that the masonry should be fissured, no specific danger arising out of that condition can be assigned. But if the fissure is on the water side of the dam, then the action is not ended when the fissure extends to g, and a new danger arises to which, so far as the author is aware, no attention has been directed in writings on the subject of dams.

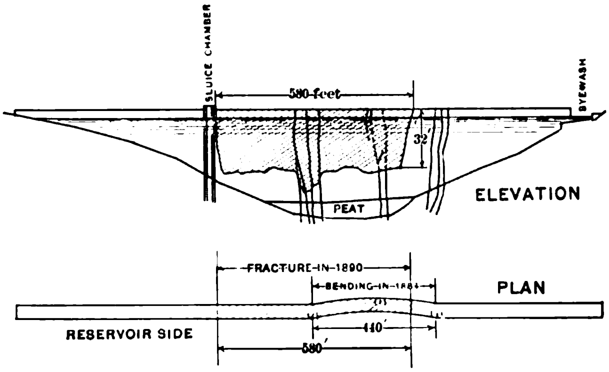


FIG. 4.

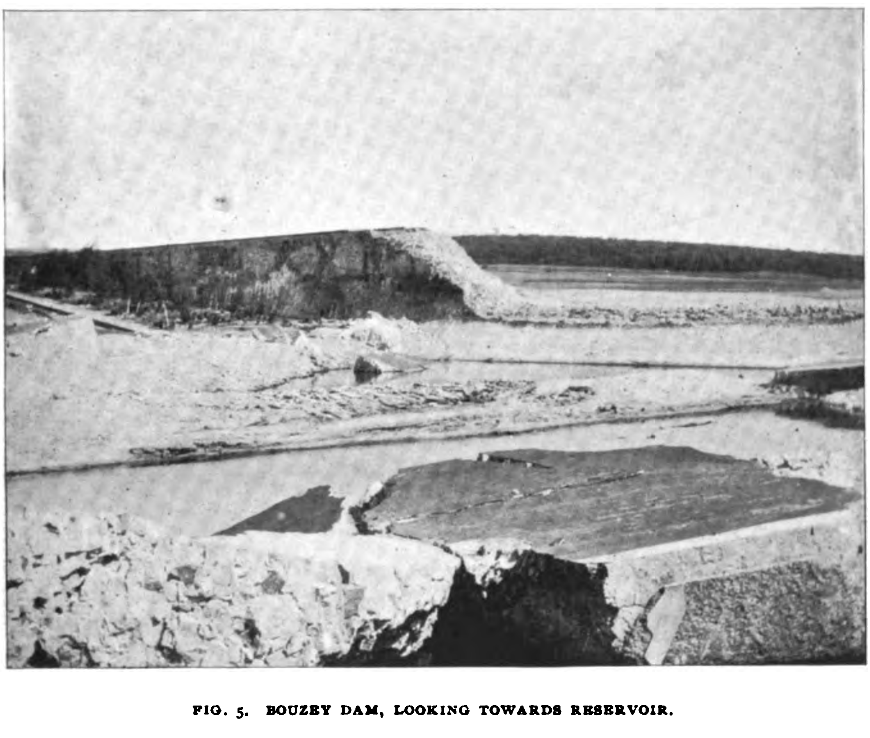


FIG. 5. BOUZEY DAM, LOOKING TOWARDS RESERVOIR.

If a fissure forms on the water face, a new straining force is created, namely the water pressure in the fissure. This new force pushes *R* nearer the downstream edge, there is again tension at *g* and the fissure extends. This fissuring must proceed till the dam is overturned.

So long, therefore, as we consider a vertical slice of the dam, any fissuring, by tension on the water face, must be progressive and must lead to the destruction of the dam.

Rankine perceived the danger of a tensile stress in masonry, but he did not point out the necessarily progressive action of a fissure in consequence of the new overturning force created. He did, however, lay down the rule that in a masonry dam it was advisable that there should be no tension. Consequently, the resultant of the external forces at any joint should be within the middle third of the width, both when the reservoir is empty and when it is full.

Final Statement of Conditions to be Satisfied in Designing a Dam.

The conditions to be satisfied in designing a dam, when its safety is considered as purely a question of stress, are these:— I.—The resultant thrust due to external forces (weight and water pressure) at every horizontal section must be within the middle third of the width.

II.—The crushing stress on the downstream edge with reservoir full, and on the up-stream edge with reservoir empty, must not exceed a safe limit. That that limit should vary with the inclination of the face, as indicated by Rankine and, later, by Bouvier, is a quite secondary matter which need not now be considered.

It may now be pointed out that Condition I secures safety against overturning, or at least secures that the moment of resistance to overturning is considerably greater than the overturning

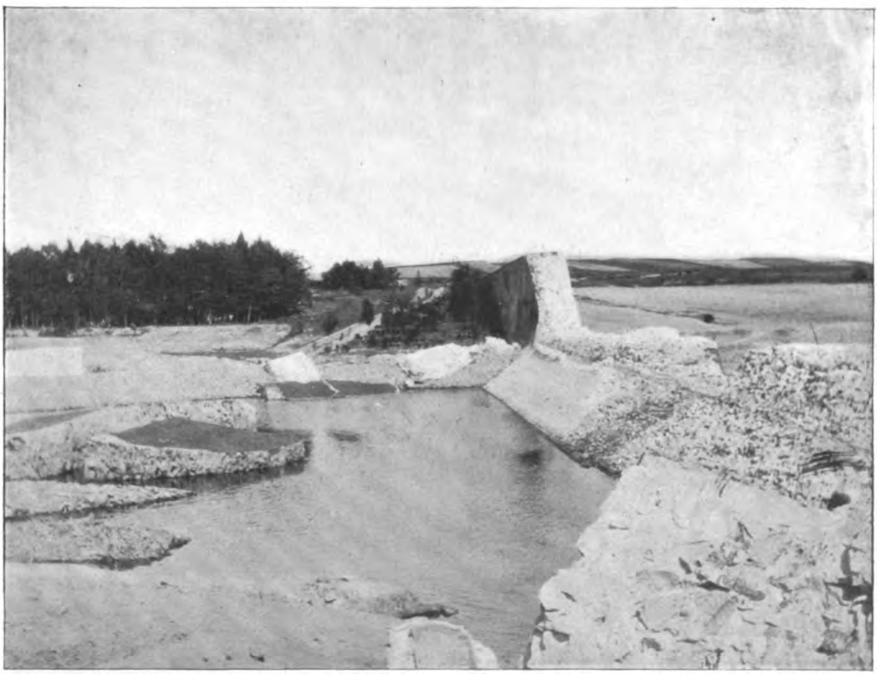


FIG. 6. BOUZEY DAM, LOOKING TOWARDS BYEWASH.

FIG. 7. LOOKING ALONG THE DAM TOWARDS THE SLUICE TOWER.

moment. It primarily secures also that there shall be no tension, so that the creation of a new overturning force in fissures of the masonry is also precluded.

Engineers who perceived that the French theory, with its low limit of crushing stress generally secured ample security against overturning, have ceased to pay special attention to liability to failure in that way. They have overlooked the fact that in the upper portion of a dam, at any rate, failure, if it occurs, is likely to occur by simple overturning. Further, they seem to have forgotten that unless the " no tension " condition is satisfied, a condition of things may arise in a dam, in other respects well designed, in which overturning is certain to occur.

History of the Bouzey Masonry Dam.

The Eastern canal of France is an important channel of communication, joining the Marne-Rhine canal at Toul, on the Moselle with the Saone at Port-sur-Saone. It ascends the valley of the Moselle and descends the valley of the Coney, a tributary of the Saone.* The summit reach on the hills between the Moselle and the Coney is at 1182 feet above sea level.

For feeding this reach of the canal, estimated to require about nine and one-half million gallons daily, a reservoir was constructed at Bouzey, near Epinal, on the Avière, a small tributary of the Moselle. The capacity of the reservoir is 1540 million gallons and it covers an area of 316 acres. To obtain this capacity, a dam, of a height of about fifty-eight feet above the lowest part of the valley, is required.

The rock on the site of the dam is a much-jointed reddish sandstone, and it was ascertained that the rock maintained its fissured character to a considerable depth. It was decided to build the dam of masonry. The sandstone used in its construction had a density of 2 to

* There is a fuller description of these canals in a paper by Mr. W. B. Dawson, Proc. Inst. Civil Engineers, vol. lv, p. 207; also in a paper on the Water Supply of Canals by M. R. Denys, Transactions of Inland Navigation Congress, Paris, 1892.

FIG. 8. BOUZEY DAM, LOOKING DOWN THE VALLEY.

2.2, and, when saturated with water, about 6 or 8 per cent. more. The rock is stated to crush with a pressure of from 288 to 576 tons per square foot.

The mortar, made with hydraulic lime from Thiel, has a little less density than the rock. The average density of the materials of the dam may be taken to be 2, or to weigh 125 pounds per cubic foot. The materials are of rather less strength and heaviness than is usual in structures of this kind, but there is no reason why they should not have made a trustworthy dam. It is stated to have been intended that the limiting stress in the dam should not exceed ten tons per square foot.

It was not thought necessary to carry the foundation of the dam throughout down to impermeable and unfissured rock. It was carried down to rock which appeared solid enough to support the masonry, and for protection against leakage under the dam a guard wall, six and one-half feet thick, was built below the dam and near its inner face. This was carried down to unfissured rock.

Fig. 3, on page 12, shows the section adopted for the dam, with some additions which will be referred to presently. The length of the dam is 1700 feet. The water level, when the reservoir is full, is at 1218.5 feet above datum. The inner face is vertical and is covered with a plaster of cement mortar, one and one-half inches thick. The dam was completed in 1880.

The filling of the reservoir commenced in 1881. When the reservoir was nearly full, springs appeared on the lower side of the dam, having a flow of two cubic feet per second. On March 14, 1884, when the water in the reservoir was at 1210 feet above datum, a length of 444 feet of the dam suddenly assumed a bent form, part of the dam having slid forward, as shown in plan in Fig. 4, on page 13. The flow of the springs increased to 8.1 cubic feet per second. The height of the water in the reservoir was kept up for a year after this.

In 1885, the reservoir was emptied to examine what had happened. It was found that a portion of the dam had slipped forward on its foundation, and had separated from the guard wall below it. The greatest sliding was about one foot. Three groups of vertical cracks in the masonry were discovered (Fig. 4), two on the water face, and one on the down-stream face. These cracks were exactly at the points where, from the horizontal flexure, the masonry would be in tension. These vertical cracks would not necessarily affect the stability of the dam, except so far as they removed from some portions the lateral support of neighbouring portions. built on the water side at the junction of the dam and guard wall, and was covered with a mass of puddled clay. The fissures were filled superficially with cement mortar or cement grout. These works of repair were executed in 1888-9, and the filling of the reservoir was then recommenced. The springs reappeared and the flow was 2.8 cubic feet per second when the level in the reservoir reached 1218 feet above datum. On April 27, 1895, with the water level in the reservoir at 1218.2 feet, a length of 594 feet of the central portion of the dam (shaded in the elevation Fig. 4)

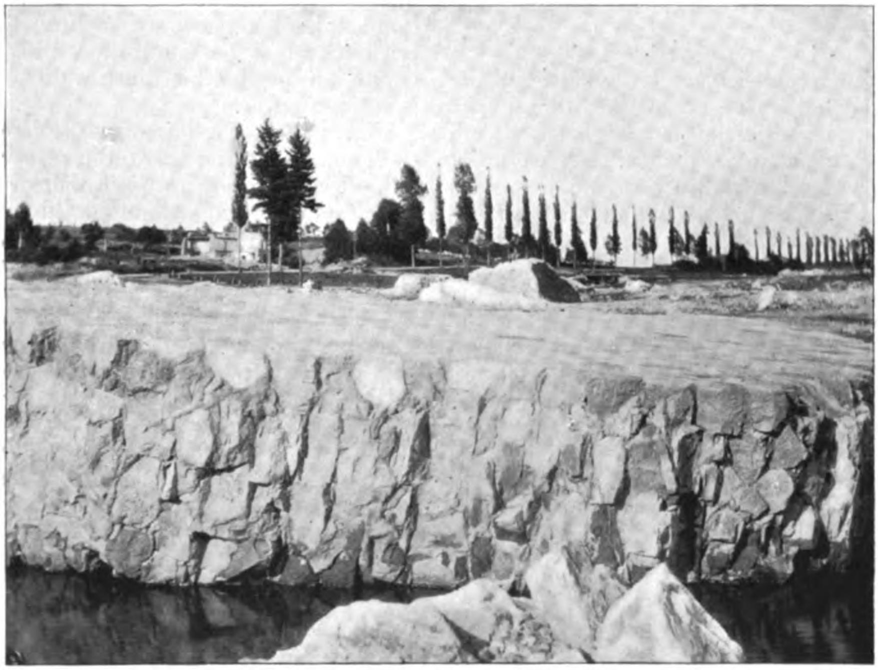


FIG. 9. BLOCKS SHOWING THE CHARACTER OF THE MASONRY.

suddenly broke away at a level 1186 feet above datum. This length includes all but ninety feet of the portion displaced in 1884, but it does not coincide with the displaced part at either end. The bottom of the gap in the dam was nearly level longitudinally. Transversely it was level for twelve feet and then dipped somewhat to the down-stream edge. The foundation appeared not to have moved.

According to ordinary calculations, vertical slices of the dam should be independently stable. In fact, the water pressure was sustained long after these vertical cracks appeared.

Following the recommendations of a special committee of the Ponts et Chaussées, it was resolved to build a strong abutment at the down-stream side of the slipped part of the dam. This is shown dotted in Fig. 3. A portion of wall was

The water released by the failure of the dam rushed down the valley of the Avière, destroying canal works, a railway embankment, bridges, and houses, and causing serious loss of life. The flood only ceased destruction when spreading in the wider valley of the Moselle. The author visited the scene of the catastrophe in company with Mr. G. F. Deacon and M. Denys, Ingénieur des Ponts et Chaussées, the engineer in charge of the Eastern canal. M. Denys courteously gave much information. Figs. 5, 6, 7, 8, and 9, show views of the appearance of the dam, from photographs taken by the author.

Cause of the Failure of the Dam.

As to the cause of the failure of the dam, it may be noted that, though the materials used in its construction were not of first rate quality, they were not so bad as to afford any explanation of the failure, apart from any fault of design in the dam. But possibly their rather low heaviness was not sufficiently considered in settling the section of the dam. There was no evidence in the mass of broken blocks of imperfection of the masonry, or imperfect filling of the spaces between the stones, or of imperfect adhesion of mortar to stone, such as would, in any degree, help to explain a failure.

In the author's view also there was no direct evidence that the slip and fissuring in 1884 contributed to the catastrophe of 1895. The measures taken in 1885-9 appeared to have arrested any further slipping of the lower part of the dam. The fracture of 1895 seemed to avoid, rather than to depend on, the fissures of 1884. The part fissured by vertical cracks in 1884, was left standing, while the rupture of 1895 extended on the other side nearly 250 feet beyond the furthest group of fissures of 1884. Whether the fissures contributed or not to the final disaster, it can be shown that there was an inherent fault of design which seems sufficient to explain the failure without needing to seek another cause of weakness.

In the next place it was striking to notice that at the down-stream edge of the dam there was no evidence of failure by crushing. The mass was torn out along a nearly level plane of fracture, about thirty-five feet below the water level in the reservoir, without any obvious cracking or splintering of the stones along the down-stream edge of the fracture. The mass filling the gap appeared rather to have slid or overturned. Further, on calculating out the crushing stress at the down-stream edge at the moment of fracture, supposing the dam up to that moment intact, it amounts to only about 4.68 tons per square foot,—a stress which the masonry was very well able to resist. A quite different cause of failure than crushing must be sought for, and this is one reason why the failure of this dam is so instructive.

Fig. 3 shows the line of resistance of the dam for the case of the reservoir full,—that is, a line through that point of each horizontal section at which the resultant thrust acts. It will be seen that this line does not comply with the condition of remaining within the middle third of the thickness of the dam. Further, the actual plane of fracture coincides nearly with the greatest deviation of thrust from the centre of the section.

Fig. 10 shows the upper part of the dam and the dimensions at the plane of fracture. Taking the density of the masonry as 2, it is calculable that a slice of the dam, intact, would have a tension of 1.28 tons per square foot at the water face. That is, a tension in excess of the probable resistance of the mortar joints. A slice, therefore, exposed to the pressure of the full reservoir, would fissure.

The progress of the destruction is shown in the stress diagrams given in Fig. 11. *A* shows the condition of stress initially, before fissuring began. There would then be a tension of 1.28 tons per square foot on the water face, and a compression of 4.68 tons on the down-stream face. Assuming that the mortar gave way and a fissure formed, the first effect would be to relieve the tension. The fissure would extend inwards a distance of 5.57 feet. The resultant thrust would then be just within the middle third and there would be no tension if no additional straining action came into play.

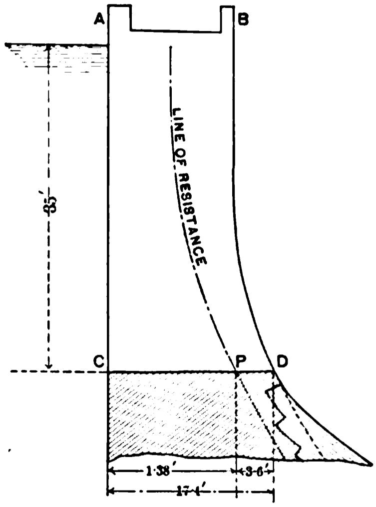


FIG. 10.

The condition of stress is shown in Fig. 11, *B*. The compression would have increased to 5.43 tons per square foot,—a stress in no way dangerous to the masonry. But, unfortunately, the fissure being on the water face, a new straining action would come into play, namely the water pressure in the fissure. This would cause a new deviation of the resultant thrust and there would arise again a tension (Fig. 11, *C*) of 3.47 tons per square foot at *E*. Under the action of this tension the fissure would extend and the destruction of the slice would be inevitable.

It is clear that the design of the dam did not comply with the ordinarily imposed condition that each vertical slice should be independently stable. But that the dam failed by tension seems indicated by the coincidence of the fracture with the plane of greatest tension, and is consistent with all the circumstances observable after the catastrophe.

What remains to be explained is, why the dam for some years supported the water pressure. Probably a fissure in a horizonal plane, such as has been supposed, would be only gradually developed, the variation of the water pressure, as the level in the reservoir changed, being one cause of its gradual extension.

But there is another point. The dam does not consist of independent vertical slices. Any slice in which a fissure existed would be supported by its neighbours on either side. The dam might still stand even when a horizontal fissure existed until the fissure had extended so far that the overturning moment exceeded the moment of resistance plus the resistances at the ends of the piece torn out.

The failure of the Bouzey dam is therefore instructive for these reasons:—

First.—While some engineers have tended to pay almost exclusive attention to limiting the crushing stress on the masonry, this is a case of a dam which failed at a section where the crushing resistance was ample to resist the straining forces, and in the appearance of which no evidence of crushing is seen.

Second.—It did probably fail from neglect of the condition that in a masonry structure of this kind no tension should be permitted. That is a condition which the earlier French writers ignored, and which even more lately has been treated as a superfluous condition.

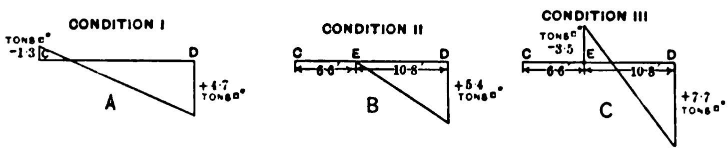


FIG. 11.

The statement of these principles involves nothing novel. But the author believes that the peculiar danger of tension in a masonry structure supporting water, in that if a fissure occurs, a new straining force comes into play at the most dangerous point, has not before been explicitly pointed out.

THE PRESENT STATUS OF ELECTRICITY.

By Wm. Baxter, Jr.

IT is very common to hear men say that we are just beginning to learn the A B C's of electrical science, and that what has been done up to the present time is only a slight indication of what will be accomplished in the future. To such assertions it is very often added that we are actually groping our way in the dark, handling a force that we know nothing about, and that we are not even able to conceive what the developments of the future will bring forth.

The subtle fluid, as the majority of people love to call electricity, has always been regarded by the layman as one of the most incomprehensible of mysteries, but it is such only in his estimation. So far as theoretical knowledge is concerned, we are not so much in the dark as may be supposed. We cannot say that we know all that there is to be known in regard to the subject, but we can say that, as compared with our knowledge of other forces of nature, we are not so far behind as to justify the assertion that we do not yet know the A B C's.

As a matter of fact, we know fully as much about electricity as we do about light or heat. This may be a surprising statement for the laymen to hear, but, for all that, it is perfectly true. As to what has been done in a practical way, it can, without hesitation, be said that if we have not applied it on as extensive a scale as heat and light, we at least have made use of it in as great, if not greater, a number of ways. Heat is used on a far more extensive scale, but the human race has been familiar with it for thousands of years. What has been done in the electrical field, on the other hand, is all the growth of a very short period. In a few years it has developed into an industry that almost rivals one that has been growing from prehistoric times.

These facts, however, fail to impress the average man as they should. When an electrician says that we know as much about electricity as we do about heat, he is at once asked to explain what it is. As he is not able to do this, the conclusion arrived at is that the assertion is only a proof of the exaggerated estimate he has of the extent of his knowledge. Such conclusions are drawn, owing to the fact that it is generally supposed that we know about all that there is to be known about heat and light. It is needless to say, however, that this opinion is very far from correct. We know what heat will do and the conditions under which it will act, and this is nearly all that we know about any of the forces of nature; but if any one should ask, what is heat, light, chemical action, etc., the most learned physicist could not answer the question. If we do not know what heat and the other forces of nature are, we are no better off with respect to our knowledge in this direction than we are as regards electricity. But, although we know nothing of the nature of heat, we have been able to make use of it in many ways, and are finding out new applications every day, and the same is true, within certain limits, with respect to light.

If we can do all this with heat and light, without knowing what they are, there is certainly no reason why we should not be able to accomplish as much with electricity. This is shown to be true by what has been and is being accomplished.

The laws that govern the action of electricity and magnetism in all the various operations in which they are practically applied, are so well understood that the subject may justly be regarded as reduced to one of the most exact of sciences.

We are in the habit of considering as the electrical development that which has taken place within the last fifteen or twenty years, but this, in reality, represents only what has been done in the way of applying the force to certain uses where the transformation of energy on a large scale is desired. To give an accurate exposition of the whole industry, it would be necessary to include all the diverse ramification, and if this were done it would be found that there are very few lines of manufacture into which it has not found its way, and that it is the foundation of a number of the most important enterprises that engage the attention of men.

The telegraph is one of the most important factors in the civilised world; yet we seldom include it in the list of electrical industries, owing, no doubt, to the fact that it has been associated with the affairs of the world so long that it has almost lost its identity. The many modifications of the telegraph, such as fire alarms, hotel annunciators, call bells, etc., are, of themselves, a very extensive branch, not only of the electrical industry, but of the manufacturing interests.

The art of electroplating has been of the greatest value to mankind, and the extent of its application is almost beyond estimation. Not only is it used for covering articles of cheap metal with gold, silver, nickel, etc., but it is also employed to manufacture an infinite variety of articles, useful as well as ornamental. Electrotyping alone, which is one of the branches of this art, is a very important industry, and is so extensively used in every line of business that the world could not very well get along without it. These various applications of electricity in the industrial arts represent, collectively, a large percentage of the activity of the whole civilised world, more than we would imagine at a first glance, for in addition to the capital and men they employ directly, we must add those who are engaged in manufacturing the apparatus and material which they use. All that one needs to do to realise the importance of this industry is to consider the magnitude of some of the establishments engaged in it.

Among the various branches of manufacturing it is exceptional to find one where electricity is not used in some way. Even in the preparation of seal skins it is employed, and it is said that for this purpose it is superior to the older processes, the advantages claimed for it being better quality of work and lower cost of production. Many forms of automatic machines used in manufacturing processes utilise electricity to operate some part. Of late years electric welding and soldering machines have come into very extensive use, specially the former. There are many processes of welding that can be done by electricity that would be practically impossible in any other way.

In large metal working establishments cranes, hoists, pumps, and similar apparatus are operated by electric motors, and in many places it is found advantageous to use separate motors for driving nearly all the large machines.

In chemical processess electricity is of the greatest value. It is due to it that we are now able to use aluminium on a large scale. Although this metal has been known for many years, previous to the introduction of the electrical process, the cost of production was so great that it could not be sold at a price that would permit of its employment except in a very limited way; but now, by means of the electric process, it is obtained at such a low cost that its market price has been very greatly reduced. As a result, it is very extensively used, especially in the form of alloys.

To give a full enumeration of all the ways in which electricity is applied would be, under existing conditions, very difficult, if not impossible here. It is more than probable, however, that if accurate statistics could be obtained as to the amount of capital and number of men employed in all its various applications, the figures would be so large as to prove a revelation, even to those who are actively engaged in the business and believe they know all about it.

In the field of light and power, which is generally regarded as peculiarly that of electricity, statistics are more easily obtained, and the data available show that the amount of business in every department is of a magnitude that is undoubtedly far beyond the estimates of the majority of those who are in a position to judge.

In the electric lighting field, the total capital invested in the United States, for example, is given as over five hundred millions of dollars. The number of plants, public and private, is over ten thousand. The number of motors in use is estimated at about five hundred thousand, and their value at about one hundred millions. The electrical apparatus used in mining is estimated at one hundred millions, and the value of the electric elevator industry will probably not fall short of fifteen millions.

The most important of all the electrical industries, however, is that of electric railways. In this field the investment is very great, and in the United States is represented by a capitalisation of over seven hundred million dollars. The number of trolley cars in use is said to be over twenty-five thousand, and these run on over twelve thousand miles of track. The electric railways represent more than 90 per cent. of all the street and suburban railroads of the country.

The aggregate of all the capital invested in electric lighting, electric railways and electric power is about fifteen hundred millions, and this does not include the value of the establishments that manufacture the machinery and apparatus. As many of these are among the largest industrial enterprises in the world, and as nearly all are concerns of considerable magnitude, it is very evident that their combined capital will run up into large figures.

Inasmuch as the electric light and power industry represents an investment of about fifteen hundred millions, without counting the value of the concerns that manufacture the machinery and supplies, it is evident that to estimate the total investment in every department of the electrical industry at two thousand millions of dollars in the United States alone, is not extravagant, for this would allow only five hundred millions to cover the value of the telegraph, the telephone and the almost unlimited number of electrical manufactories, large and small, that can be found from one end of the land to the other.

It has been estimated that at least 2½ per cent. of the entire population of the United States make their living out of the electric light and power industry and the branches of trade directly dependent upon it. If this be so, there can be very little doubt that if the telegraph and telephone operators and other employees of these companies and the vast army of workers in the countless manufacturing establishments are included in the count, the percentage can be run up to four or five.

From a contemplation of the foregoing brief account of the present status of the electrical industry, it must be evident that the assumption that it is in its infancy is not sustained by the facts. As a science, it is as far advanced as any, and there is no more guesswork in connection with its practical application than there is in any department of engineering.

THE MANUFACTURE OF COMPRESSED FUEL IN THE UNITED STATES.

By John R. Wagner.

THERE are numerous deposits of coal which slacks or decrepitates very much in handling and some of which is even so friable as to cause a large portion of it to be reduced to dust, simply in the process of mining. Material of this quality we would hardly class as commercial fuel at the present time, and yet, if included in the estimate of the world's fuel supply, it would help to give an appreciably higher figure than is generally accepted. There are also numerous deposits of lignites and brown coals which, in their natural state, cannot be successfully used as fuel.

A large part of the small coal produced in England is unsuited for coking. It deteriorates rapidly, losing a large portion of the gases due to "weathering," and this is a strong obstacle to its storage. The property of being a friable and non-caking coal, and the small demand for it, in the raw state, makes the mining of it unprofitable. This small coal may, however, be compressed into rectangular blocks of fuel, called briquettes, possessing greater cohesion than large coal, and being waterproof and not subject to deterioration from exposure. They are also of convenient form for storage, requiring from 10 to 15 per cent. less space than the same weight of large coal.

In America, all the fuel mined, except that developed in recent years, and the anthracite culm, which has lain useless since 1860, was of a character that always found a ready market and stood transportation well. The bituminous coal was of good coking quality, as in the case of some of the Pennsylvania coals, which are dumped direct from the mines into coke ovens, without washing, and produce a coke of good quality.

The briquetting of anthracite culm suggests itself to many who see the vast culm piles throughout the American anthracite region. This is not only true for the anthracite culm of Pennsylvania, but also for the semi-anthracite coals, such as are found in Virginia and Arkansas. In the south of France, where anthracite is found, the fine coal and dust is now briquetted with profit. This coal, while it is fair as to the percentage of ash, is high in sulphur.

In Europe, the desire for the utilisation of the dust fuel was early felt, especially in France, where, in the year 1842, compressed fuel was manufactured on a commercial scale at Bérard, near St. Etienne.

No attempt will be made in this article to describe the various kinds of presses, drying apparatus, or European practice of briquette manufacture, as this can be properly done only in a report of considerable magnitude. The aim here is to give merely the principles governing good practice in the manufacture of briquettes, and to refer the reader for the details of the machinery used and the technology of briquetting to such literature on the subject as will give him the desired information.

A very complete article by William Colquhoun, and discussions thereon, will be found in the proceedings of the Institution of Civil Engineers, London, Vol. 118, Session 1894. A valuable report on German and Austrian practice will be found in the Geological Survey Report of Texas, entitled "Report on the Brown Coals and Lignites of Texas," by E. T. Dumble, State geologist, Austin, Tex., December, 1892. A treatise by Dr. Adolf Gurlt, entitled "Die Bereitung der Steinkohlen Briquettes," 1880, will also be found of value to those studying the technology of briquetting. The French literature on the subject is pretty complete and worthy of careful perusal.

A little history of the briquette and eggette manufacture in the United States will be given, to supplement the American literature on this subject and especially the articles on the Loiseau process and plant at Port Richmond, Philadelphia, as practically nothing has been added to it since 1880. This process and plant will be found described in the transactions of the American Institute of Mining Engineers, Vol. 6 and Vol. 8. There are also articles in the *Journal* of the Franklin Institute, Vol. 74, 1862; Vol. 81, 1866; Vol. 96, 1873, and in the proceedings of the Engineers' club, of Philadelphia, Vol. 3, 1882. The report of the Coal Waste Commission of Pennsylvania, May, 1893, gives a complete list of the various binding materials and combinations of carbonaceous matter used in this industry since its beginning, or about the year 1830.

In America, the manufacture of artificial fuel is limited to that of eggettes, almost exclusively made for domestic use. The question of economic storage has been entirely omitted. In Europe, one of the advantages claimed for briquettes, is that a greater weight can be neatly packed on locomotive tenders and in the holds of vessels and when properly made they produce no smoke in combustion.

Eggette or ovoid fuel, in distinction from briquettes, may be considered somewhat of a luxury for domestic use, similar to that which anthracite coal bears to bituminous. In Europe, the convenience of the fuel for the furnace was not so much considered, as the ability to produce a fuel which was cheapest and best suited for handling, storage and transportation. Much greater stress than in America was laid on the thorough preparation of the coal, on the quality of pitch or binding material used, and on the size of blocks giving the greatest economy in manufacture and handling.

The systems of preparing the coal for coking and briquetting, by washing or jigging, originated in Europe and have there been long practiced to such an extent that almost throughout the whole of the continent, coke can be guaranteed to contain only a certain per cent. of ash. This difference in the art of washing fine coals may, to some extent, account for the slow progress made in the manufacture of briquettes in America.

Statistics show that the production of briquettes in 1893 was as follows:

	Tons.
France	1,750,000
Belgium	1,200,000
England	850,000
Austria	250,000
Germany	1,230,000
Italy	560,000
Spain	100,000
Russia and Sweden	100,000
United States	100,000
China, India and Canada	150,000

The following are some of the qualities of good briquettes:—

First.—They must be homogeneous and hard, so that the breakage in transportation shall be very slight.

Second.—Their combustion must be nearly smokeless.

Third.—Their size and shape should be such as to be most convenient and efficient for the purpose that they are to be used.

Fourth.—They must not be hygroscopic; the moisture contained in them should not exceed 5 per cent.

Fifth.—The proportion of ash should be as low as possible. It should never exceed 10 per cent.

Sixth.—They must be easy to kindle, burn freely, and not crumble in the fire.

Briquettes having these qualities will compete in heating power, as well as in all other points of efficiency, with good coals applicable to the same use.

The proper mechancial preparation of the coal goes far towards making the briquetting, of an otherwise waste coal, successful and profitable. That the thorough washing or freeing from all slate and other impurities is one of the chief factors in determining the value of the product is obvious, since the value of the fuel depends mainly on its freedom from ash, or the amount of available combustible matter it contains. This is especially important where the fuel is to be transported and an extra cost is added for handling and trasportation.

There are two systems of cleaning this fine coal from impurities. First, the more universal or wet process, requiring such apparatus as the "spitzkasten," troughs and jigs as used in ore separation. Of these systems the most extensively used are those of Lührig and of Coppée. Second, the dry separation by means of an air blast. The latter method has the advantage of avoiding the complicated and expensive process of drying before briquetting. This method, however, has been used only to a limited extent. The washing or jigging is even more important in the manufacture of briquettes than it is in the coke industry, on account of the relatively high cost of binding material and manufacture, in consequence of which the percentage of ash which it contains should be as low as possible.

In entering upon the manufacture of briquettes, all the principles and details involved should be as clearly understood as is necessary for success in any other industry, and should be carefully considered before any great expense is incurred. The same preliminary work should be done in this case as is necessary in the manufacture of coke, *i. e.*, experts should be called upon to determine whether the coal is suitable for coking or briquetting, and a trial lot of the coal to be treated should be sent in sufficient quantity to such washing or jigging experts as control the most improved systems, Lührig's or Coppée's, and who will guarantee the washed coal not to contain above a certain percentage of ash, in some cases as low as 6 per cent.

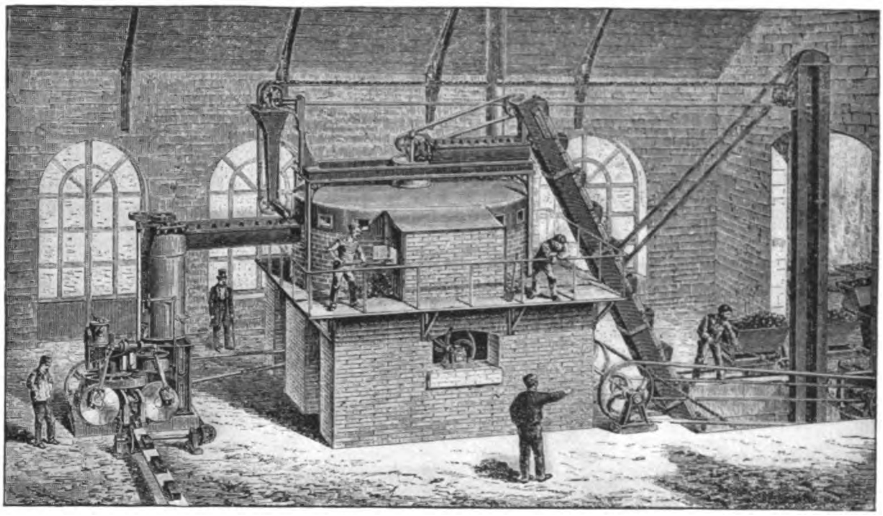
The first questions in briquetting would be, the cost of method and machinery, and whether a briquette of fair quality could be produced from the material that it is desired to utilise. A good idea of the improvement that can be made in the quality of a coal by washing, will be obtained from the following table:—

Locality.	Ash.	
	Raw Coal.	Washed Coal.
	Per Cent.	Per Cent.
Wolfsbank mine, Westphalia.	8.00	2.79
Hörder mine	22.00	3.5 to 5.77
Forst pit, Saxony	22 to 24	5.8 to 6
Brückenberg, Saxony	25.00	5 to 6
Meyram pit, Silesia	17 to 18	4.5 to 6.35

The cost of such washing, including interest, superintendence, etc., was from 5 to 6 cents (2½ to 3d.) per ton of the washed coal at Wolfsbank and Brückenberg. Of course, this is the practice in a country where the separation of ore has developed a very complete system of washing, and where the cost has been reduced to a minimum.

It is only recently that American coke manufacturers have taken up the thorough mechanical preparation of coal by jigging or washing, so as to produce a coke low in ash. This has been done by the introduction of some of the European systems of jigging, such as those above mentioned. In several places in America there are now erected washing plants of this character, and the coke produced from the washed coal runs as low as 5 per cent. in ash, which is equal to the best anthracite lump coal. A washing plant, in connection with a briquette factory, at Couillet, in Belgium, has a capacity of 1000 tons in ten hours.

The size of the coal and the amount of moisture which it contains has an important influence on the amount of bond or pitch required for a firm product in briquetting. All fine dust will not make a good briquette, and it will also require more binding material to thoroughly coat the surfaces, although a certain amount of dust is necessary to fill the interstices between the larger pieces. Thus, the dust collected from the settling ponds cannot be agglomerated with less than 20 per cent. of pitch, while, on the other hand, coal of a uniform size of from 5-16 to ⅜ of an inch in diameter cannot be compressed into a satisfactory state of cohesion without a large amount of pitch. The manu-



A BRIQUETTE PLANT.

facturer has, therefore, to find a mean between the excessive dust in many roughly screened coals and the sized coal from the washery. In England only screened small coal is used, a practice which fully accounts for the fact that more pitch is used in English briquettes than in those of other countries of Europe.

The following table gives the results of a series of experiments made by the writer in jigging Pennsylvania anthracite rice coal (coal passing through a ⅜-inch and over a 3-16-inch round hole):—

	Ash. Coal Before Jigging. Per Cent.	Ash. Coal After Jigging. Per Cent.
Trial A	18.22	12.82
" B	17.60	11.97
" C	16.30	11.55
" D	19.54	14.29
" E	19.10	13.97
" F	18.22	13.02

A feld spar jig of the Lührig type, modified in speed and stroke to be best suited for anthracite, was used in these experiments, and various changes were made from one trial to another, all with the view to further reduce the impurities in the jigged coal without allowing too much coal to go out with the slate. As will be seen, the percentage of ash in the jigged coal is still too high for the manufacture of a good briquette, and it is doubtful whether these results will ever be much improved upon with the quality of the coal as jigged. The coal contained a considerable quantity of material in which the coal and slate were very finely interstratified.

The specific gravity of this material, called "bony coal," is only slightly above that of pure coal and it can, therefore, not be removed by jigging. The pure slate, stones, iron pyrites, etc., were removed very satisfactorily by the jig. This bony coal is found in anthracite quite frequently. In the larger sizes it can be removed by hand picking and recrushing, but in the smaller sizes it often gives considerable trouble. In places where not much bony coal is found in the veins, these feld spar washers, would, no doubt, make a considerably better showing.

A general idea of the arrangement and working of a briquette plant will be obtained by referring to the illustration above, taken from E. T. Dumble's report on "The Brown Coals and Lignites of Texas." The washed fine coal is dumped into a pit near the drying furnace, from which it is elevated by means of a bucket-conveyor and discharged into a trough containing an endless screw-conveyor. The latter carries the coal forward to the centre of the drying furnace.

The heat required for drying is derived from a small furnace shown in front of the drying chamber. As the table in the furnace revolves, rakes move the fuel continually towards the outside at a point where it is discharged into the conveyor-trough connecting the furnace with the agglomerator.

The pitch is pulverised by the crusher shown partly at the extreme right hand of the cut, and is raised by the vertical elevator onto an endless band which conveys it to a hopper at the left of the drying furnace. This hopper contains a feed mechanism which can be accurately adjusted to deliver the exact percentage of pitch required to the dried fuel as it is conveyed to the mixing chamber.

The thorough mixing of the two ingredients is accomplished by suitable mechanical means in the chamber in which it is maintained at the required temperature by means of steam jackets. The tempered mass then falls from the mixing chamber onto the distributing table from which the briquette moulds are filled. In the press shown, the moulding table revolves until the mould comes between the dies or stamps. The pressure exerted on the mass is as high in some machines as three tons per square inch. The finished product, after a fraction of a revolution of the table, falls upon an endless band which delivers it to the loading or storage points.

According to the statements of various briquette manufacturers in Europe, the detailed cost per ton of the product (less cost of raw material) by the latest and most improved machinery, is as follows:—

Wages of workmen	10 to 18 cts.	(5 to 9d.)
Fuel, oil, repairs, etc	7 to 8 cts.	(3½ to 4d.)
Interest and depreciation	6 to 10 cts.	(3 to 5d.)
Pitch for bond	38 to 100 cts.	(1s. 6½d to 4s.)
Cost of washing	6 to 8 cts.	(3 to 4d.)
Total cost per ton of product (less cost of raw fuel used)	$.67 to $1.44	(2s. 8½d. to 5s. 9½d.)

The history of briquette manufacture in the United States seems to show an almost universal failure. In 1874 the manufacture of compressed fuel from anthracite culm was attempted at Mauch Chunk, in Pennsylvania, by the aid of a small moulding machine.

About the year 1876, another attempt was made to utilise the culm banks of the anthracite coal fields, in the manufacture of artificial fuel, by the Delaware and Hudson Canal Company, at Rondout, N. Y. Succeeding this plant came that of Port Richmond, Philadelphia, which produced the so-called "eggettes" from anthracite culm by the Loiseau process.

In the year 1890, a company, called the Anthracite Pressed Fuel Company, was organised for carrying on the manufacture of briquettes from culm, near Mahanoy city, Pa., by which the Philadelphia and Reading Railroad Company expected to effect a saving of from $40,000 to $50,000 (£8000 to £10,000) annually. This plant temporarily suspended operations in 1892, and in 1895 it was totally abandoned and the machinery removed. A description of this plant is given further on.

The Rondout plant was sold to the Anthracite Fuel Company in 1876, the making of briquettes being continued for several years; but it was discontinued in 1880. The fall in the price of coal about that time, and an increased price of the gas coal pitch, due to the greater value of coal tar for chemical purposes, were probably the causes of the stoppage of this plant.

The manufacture of compressed eggette fuel for domestic use seems to have been somewhat more successful. The name "eggette" was given to the ovoids by Mr. Ware B. Gay, who started the eggette plant at Gayton, Va.

It appears that the Loiseau rolls at the Port Richmond works were a success, but other parts of the plant did not work well. The enterprise turned out a financial failure, and the plant, which had been destroyed by fire, was dismantled and the rolls and some other parts of the machinery were purchased and shipped to cement works in the interior of Pennsylvania.

Mr. Gay, after extensive investigations and correspondence with manufacturers of European briquettes and machinery for its production, and a thorough investigation of the Loiseau process, including the manufacture under his process at Port Richmond during 1882, became convinced that the briquette form possessed disadvantages, especially for domestic use, and that the Loiseau egg-shaped product facilitated the combustion and gave a product better adapted for domestic use. In the fall of 1890 he purchased the Loiseau rolls and machinery from the cement manufacturers, and erected a plant for the manufacture of eggettes at Gayton, near Richmond, Va. The plant commenced work, but owing to improper construction, the rolls being in very bad condition from previous use, many changes and repairs were necessary from time to time, resulting in great loss of time and money. The product when properly made was very popular and met with a ready sale. Mr. Gay, after making many experiments and expensive alterations in his plant, gives the following as the result of his experience:—

"The utilisation of culm for the manufacture of artificial fuel depends, in addition to good and economical construction and management, incident to all business, upon the following conditions:—

First.—The quality of culm to be utilised.

Second.—Its location, as regards freight rates, to reach the consumer.

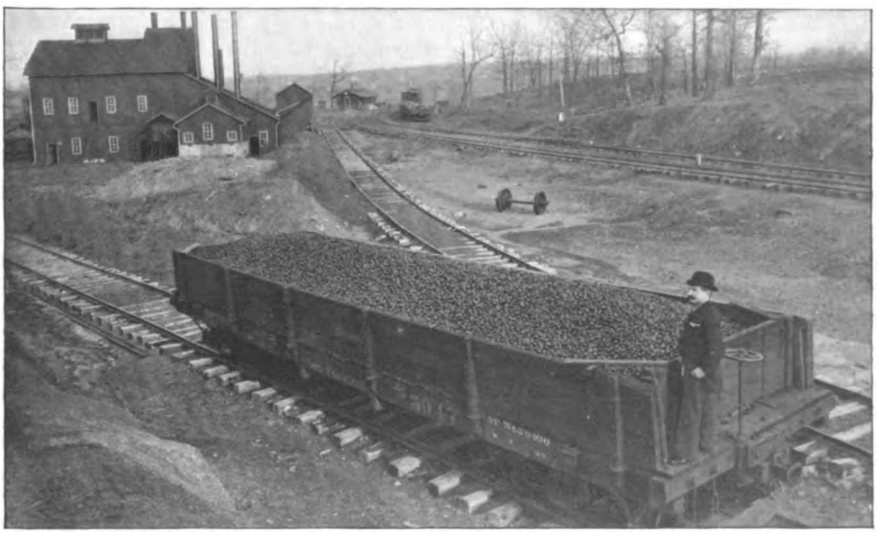
Third.—General market price of other fuels with which the plant would compete.

Fourth.—A less expensive binding material than at present obtainable.

Fifth.—That the prismatic or brick-shaped product is less desirable than one affording better combustion by interstices between the pieces, especially when intended for domestic use."

The Gayton plant was established more particularly for the utilisation of the Gayton semi-anthracite culm. There are four veins in this basin, the upper one of which is about nine feet in thickness and is a very free-burning red ash coal. It is prepared for domestic use with a coal breaker of the Pennsylvania type, equipped with similar rolls, screens, jigs, etc. The eggettes made from the culm of this coal are sold in the city of Richmond, Va. The original capacity of the plant was later doubled.

A plant, similar to the one at Gayton, was subsequently erected at Milwaukee, Wis., for the manufacture of eggettes



EGGETTE PLANT AT HUNTINGTON, ARK.

ANOTHER VIEW OF THE HUNTINGTON PLANT.

from anthracite screenings, made in the shipment of coal from and to lake ports. Eggettes were also made there from soft coal slack. An analysis, made by the writer in 1892, of the two varieties, shows the following composition:—

	Eggettes from Anthracite Slack.	Eggettes from Bituminous Slack.
Moisture	2.05	2 37
Volatile combustible matter	13.85	21.57
Ash	11.57	10.12
Fixed carbon	72.53	65.94
Sulphur	1.272	1.581

These eggettes were very hard and appeared to be able to withstand considerable handling without the production of any appreciable amount of fine material or dust.

A third eggette plant, erected at Huntington, Ark., in 1892, shown on this and the opposite pages, had a capacity of 200 tons per day, the eggettes being made from the semi-bituminous slack from the mines of the Kansas and Texas Coal Company. Many of the Arkansas coals are semi-anthracite, and these are more or less soft and friable and difficult to burn in the fine state, since their combustion is similar to that of anthracite culm. Another plant was subsequently erected for the manufacture of eggettes at Chicago.

All these plants are at present controlled under patents of M. Nirdlinger by the National Eggette Coal Company, of New Jersey. The diagram on the next page shows the general arrangement of these plants, which consist of a raw material conveyor, *A*, the elevator *B*, the screen *C*, the crushers *D*, a second elevator, *E*, the heating and drying apparatus *F*, a third elevator, *G*, with a hopper, *H*, the fuel-measuring wheel *J*, the binder or pitch-melting tank *X*, the mixers *K* and *L*, the tempering chamber *M*, the continuously-acting compressing rolls *N* and the carrier bands *P*. The processes of screening, heating, drying, measuring, melting of pitch and tempering are similar to those described for the plant shown on page 26.

The various patented processes, brought out within the last few years, for the manufacture of compressed fuel, differ only in either the binding material or in the mixture of certain proportions of non-caking with caking coals.

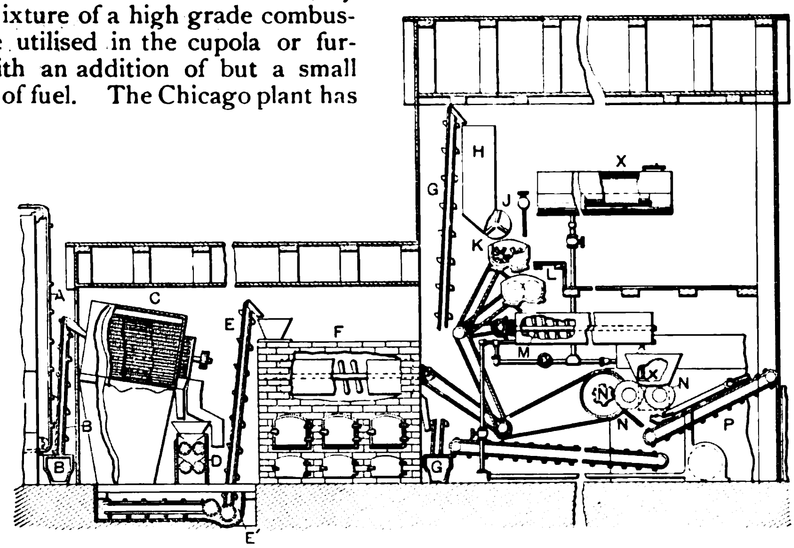
Eggettes manufactured under the patents of M. Nirdlinger are made from a mixture in the proportion of 1800 pounds of anthracite culm, 100 pounds of bituminous slack, 90 pounds of hard coal tar pitch, and 10 pounds of coal tar obtained in the manufacture of said pitch. These substances are thoroughly mixed together and heated to 175 degrees F. before briquetting. Fig. 1, on page 31, gives a view of the face of the rolls showing the egg-shaped depressions; Fig. 2 shows a section on line *ZZ* of Fig. 1; Figs. 3 and 4 are sections on line Z^1 Z^1 and Z^2 Z^2, respectively, to show that the depressions in these rolls are so arranged as to form sharp edges everywhere at their boundaries.

In the slack season for eggettes, these plants are, with slight modifications, adapted for the manufacture of ore nuggets. By this process, it is claimed that all fine ore and flue dust can, by the admixture of a high grade combustible, be utilised in the cupola or furnace, with an addition of but a small amount of fuel. The Chicago plant has been engaged during the slack fuel season in making iron ore nuggets for the Illinois Steel Company.

The last of the briquette (not eggette) plants erected, namely that at Mahanoy City, was of a design and capacity as are built in Europe. Owing to the interest manifested in the utilisation of the anthracite culm banks, a description of this plant is of importance, especially as it represents the latest practice of England in this line. This was the last attempt made to briquette anthracite culm and advocates of this industry should study the causes of the failure of this plant.

The establishment of the plant was the idea of the late Mr. Austin Corbin, who was then president of the Philadelphia and Reading Company, and who felt that the immense quantities of culm lying around his company's collieries ought to be utilised in some way and become a source of profit to the company. A large building, somewhat resembling a coal breaker, was erected for the reception of the machinery.

The erection of the plant was under the supervision of Chief Engineer Charles N. Jacobs and his assistant, J. B. Wimble, both from London, England. The former had been closely connected with the briquette industry in England, and the latter had much experience in briquette fuel works in Ireland and in the North of England, both in construction and operation of the machinery used in these plants. The compressing machinery and disintegrator were made by the Uskside Engineering Company, of Newport, Monmouthshire, England. The process is the patent of A. J. Stevens, of the same city. Twenty-five men and boys were employed to run this plant. It was also run under the direction of a representative of the Uskside Company.



GENERAL ARRANGEMENT OF AN EGGETTE PLANT.

In the manufacture of these briquettes. nothing but perfectly dry coal dirt, then known as culm or roller dirt, was used. This was brought from the various collieries in cars. The latter were run on a siding at the rear of the plant, over a dump hole, connected by means of a chute with a pit located under the rear of the building in which the fuel was compressed. From the pit, the culm was carried, by means of an endless-belt elevator, to the third

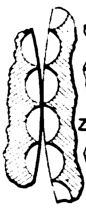


FIG. 3.

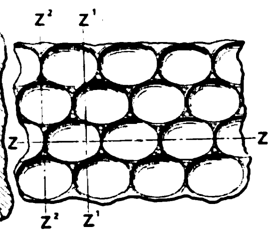


FIG. 1.

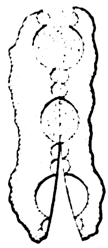


FIG. 4.

floor of the building, where it was screened. From the screen it passed into a hopper which led to the distributor.

On the first floor of the building was located the pitch-mill in which the pitch was ground to the size of pea coal (through ⅞ and over 9-16 inch diameter hole.). An elevator carried the ground pitch to the top floor, where it was deposited in a hopper, which was connected, by means of a chute, with the distributor. This distributor measured the exact proportions of culm and pitch. From the distributor the mixture was dumped into a chute, which led to a disintegrator, consisting of two double-disk wheels, which revolved, one inside of the other, in opposite directions and at a high speed.

This machinery was designed expressly for use in the anthracite coal regions, where the coal is so hard that it was considered necessary almost to pulverise it. The disintegrator answers a two-fold purpose,—that of pulverising the coal and pitch, and at the same time the thorough mixing of the two ingredients. The mixture of culm and pitch, after being elevated into hoppers on the top floor, was run into pug mills, one of these being located directly above the pan of each compressing machine.

Within the pug-mill was a copper pipe, which injected jets of steam into the mixture, the latter being constantly stirred and churned by a system of arms within the mill, which was revolved about a perpendicular shaft. The steam heated the culm and melted the pitch, and the mass then fell into a revolving pan in which it was continually stirred until it reached an opening through which it fell loosely into the dies, of which there were six sets of two each. These dies were located in a revolving iron press table.

The heated mixture of culm and pitch first fell into the two dies which passed under the opening in the pan. The press table revolved a sufficient distance to bring another set of dies under the opening in the pan, and the filled dies were at the same time brought over the hammer, which rose and exerted a pressure of seventy tons on the mixture contained within the dies. This operation required only about 2¼ seconds.

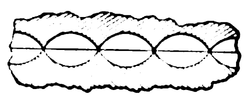


FIG. 2.

The press table again revolved, repeating the first two operations and bringing the plunger of the first two dies onto an inclined plane, causing it to rise and force the blocks of compressed fuel out onto a level of a chute, where an arm quickly pushed the brick off the dies and into the chute. This chute contained an endless belt of steel wire cables, which carried the blocks to the storage yards or to the various sidings where they were loaded into cars for transportation.

Each brick, as originally made, weighed about eighteen pounds and was stamped with the American eagle and the word "Reading." The two machines turned out between forty-six and fifty blocks each per minute, and the capacity of the two in a day of ten hours was about 400 tons. Later on, the dies were arranged for each machine to compress twelve blocks of two pounds each, one machine delivering 300 of these blocks per minute, or giving a capacity, for both, of about 300 tons per ten hours. The briquettes were made of 92 per cent. of clean coal (fine) direct from the colliery rolls, and 8 per cent. of pitch, a residuum from the coking of bituminous coal, and imported from England.

In the beginning, the entire product of the new plant was utilised by the Philadelphia and Reading Railroad Company. The cost of the culm delivered was 30 cents (1 sh. 2½d.) per ton of briquettes, the cost of pitch $1 (4 sh.) per ton of product, and the labour 50 cents (2 sh.), making a total cost of briquettes, at the works, of $1.80 (7 sh. 2½d.) per ton.

On locomotives, these briquettes burned well, did not disintegrate and made steam as rapidly as good anthracite. It was hoped that the briquettes would be valuable for export to South America and the West Indies, which places were then supplied with fuel from England.

Operations were suspended temporarily in 1892, and in 1895 the plant was totally abandoned and the machinery removed. The failure was probably due to the improper facilities for cleaning, or lowering the ash in the culm, and the high price of the English pitch.

The outlook for the extensive manufacture of briquettes in the United States is rather poor at present. The low cost of coal in almost any section of the country, the good coking qualities of most bituminous coals, the scarcity of good pitch or binding material, and the high cost of manufacture will prohibit briquetting. While in Europe locomotives consume a large portion of the briquettes manufactured, in the United States locomotives are rapidly being introduced with fire-boxes and grates of a type capable of burning the cheapest grades of fuel. The fuel requirement for ocean commerce is also not such as to make briquette fuel compare favourably with the many coals of good quality that are available. The manufacturer can generally obtain good coke or anthracite at a price which is in most cases somewhat less than that of the best quality briquette.

With the best anthracite coal, selling at the mines at $3 (12 sh.) per ton, there seems to be only a slight chance for the sale of briquettes, especially when we consider that in 1893 it was not profitable to manufacture eggettes in the city of Milwaukee, where the retail price of anthracite was $7.25 (£1 9sh.) per ton delivered.

From the present requirements in the mining and preparation of anthracite coal, almost invariably a large amount of slate and bone will find its way into the smaller sizes and the culm by crushing in rolls, so that it will contain from 14 to 18 per cent. of ash. For briquette manufacture this would need to be carefully washed so as to reduce the ash about 7 or 8 per cent., in order to convert it into profitable fuel, especially if it had to be transported. Very little has been done throughout the anthracite regions towards reducing the percentage of ash in this grade to anything like these figures, and the cost of so doing would add materially to the price of the manufactured article. Again, if these smaller sizes are well sized and have all the actual dust removed from them, they can be fairly well utilised with the late and more improved firing apparatus, notwithstanding the high percentage of ash they contain. In this state they are, of course, a very low-priced fuel.

While the direct burning of fuel in this condition should not be encouraged (since it is generally very wasteful), but rather that of good preparation, producing an article of superior quality, the fact is, nevertheless, before us that this will not be resorted to until the price of coal is such that the artificial fuel can successfully compete with it.

From the above we see that there are at present only exceptional cases in which the manufacture of artificial fuel in America holds out any promise. These are:—First—The manufacture for local use at shipping ports where the screenings from pure coal can be used without any further preparation, and second, in a vicinity where only non-coking coal is mined and of such quality that it cannot be successfully used in its raw state. Such fuel is well suited for briquette manufacture and the writer's opinion is that in such cases, and under proper management, the manufacture of artificial fuel, especially that of eggettes for domestic use, should be a success.

Improved forms of coke ovens, and methods for operating them, for the saving of bye-products, are, of late, being introduced and from these we may soon be able to obtain enough pitch and of such quality as to admit of its use in briquette making. This would be a great step towards putting this industry, so important in Europe, on a firm footing in the United States.

ROPE DRIVING.*

By Abram Combe.

SO much has been said and written on the advantages and application of rope driving, and so many data and formulæ have been published from time to time, that it is hardly necessary to add to the information already available in these respects; but as rope driving emanated from Belfast, and has now grown to such large proportions in the industrial transmission of mechanical power, a short history of its origin, introduction, and development may prove of interest on the present occasion.

Its introduction is due to the late James Combe, who, in 1856, applied an expanding pulley with V-shaped sides to the differential motion of flax roving frames. The expanding pulley was driven by a round leather rope from a pulley grooved with a V-shaped groove. In the course of his experiments in perfecting this motion he was struck by the large amount of power obtained from round ropes working in V-shaped grooves, and this led him to try their application to the transmission of larger powers. With a view of arriving at the most effective angle for the grooves, a series of experiments were made in the Falls Foundry Works in the following manner:—

A pulley, fixed from revolving, was made with a number of grooves, each having its sides sloping at a slightly different angle from the others; ropes were then laid over these grooves with weights hanging from them at one end and counterbalance weights at the other, and the effect produced on the biting power of the rope in the groove by increasing and diminishing the weights and counterbalance weights was carefully noted. The object was to determine in a practical manner the most suitable angle of groove for a driving rope, so that the rope should neither slip nor yet bite too much into the groove; and the angle chosen after the above simple experiments—namely, 45 degrees—was adopted in the first pulleys set to work, and is at present generally used for rope driving under ordinary conditions.

After several years' use of grooved pulleys and ropes for driving from the main shaft of one of the workshops at the Falls Foundry to that of another, the advantages of rope driving under certain conditions were found to be so great that, on the occasion of replacing one of the main engines in the begin-

* A paper read at the Belfast Meeting of the British Institution of Mechanical Engineers.

ning of 1863, rope driving was adopted for transmitting the entire power of the engine, amounting to over 200 horse-power, from the second motion shaft to the principal shaft. This is the first instance of rope driving being used for a main drive of such importance, and the original pulleys are still in existence and working daily.

About that date round ropes, made of leather strips, were generally used. These, however, were found to have the objection that they were liable to untwist, and the ends of the leather strips were apt to fly out during the working and cause trouble. Moreover, the strips of leather being cut out of the hide in a spiral, were less strong where cut from the smaller diameters, and were liable to break at those parts. Manila ropes were then tried with good results, and leather ropes gradually gave place to them.

It was early recognised by the late James Combe that it is necessary to properly proportion the diameter of the ropes to the diameter of the pulleys on which they work, and he adopted the following minimum diameters of pulleys for the various sizes of ropes:—

1¼ inches diameter rope, 3 feet diameter pulley; ratio 1 to 28.8.
1½ inches diameter rope, 4 feet diameter pulley; ratio 1 to 32.0.
1¾ inches diameter rope, 5 feet diameter pulley; ratio 1 to 34.3.
2 inches diameter rope, 6 feet diameter pulley; ratio 1 to 36.0.

Experience has shown that the results have not been so satisfactory when ropes of the above sizes have been used on pulleys smaller than the above minimum diameters.

When working under ordinary conditions, the following simple bases were taken from which to calculate the power that each of the foregoing sizes of rope would transmit for each 100 revolutions per minute m de by the pulley upon which it is working:—

Rope 1¼ inches diameter on a 3-foot pulley 5 indicated horse-power.
Rope 1½ inches diameter on a 4-foot pulley 8 indicated horse-power.
Rope 1¾ inches diameter on a 5-foot pulley 11 indicated horse-power
Rope 2 inches diameter on a 6-foot pulley 15 indicated horse-power.

For other sizes of pulleys the power transmitted is calculated to be increased in direct proportion to the diameters of the pulleys. When working under the most advantageous conditions—for instance, where the ropes are running horizontally at good speeds, with the pulleys at a proper distance apart, and with the bottom rope acting as the driver—the above bases may be increased by 20 to 25 per cent. with safety. On the other hand, when the ropes are working under less favourable conditions, with centres of pulleys too close together, or ropes running vertically, these bases must be diminished by 20 to 25 per cent. The exact amount of increase or decrease on these standard bases has to be determined in each individual instance, according to the circumstances under which the ropes are working.

The speed originally adopted as being the most advantageous was about 3300 feet per minute. This speed has since been far exceeded in many instances; but it is a question whether advantages have been reaped proportionate to the power gained by the increased speeds. On the contrary, the gain of power by increased speed is largely counteracted by loss of power from atmospheric friction and from centrifugal action; and when this loss is taken into account, along with the increased wear and tear on the ropes and bearings, the speed originally adopted, and speeds within certain limits of it, have been found to give the best results.

The new method of driving soon became known to several English and Scotch engineers, who joined in its further introduction and development. An extended form of main rope driving from the second motion shaft to the various lines of shafts in a flax mill was started in July, 1864, in the Hilden Mills of William Barbour & Sons, Lisburn, and is transmitting 600 indicated horse-power. One of the earliest examples of rope driving from the fly-wheel of the engine itself was completed in 1873, at Owen O'Cork Mills, Belfast. It was designed by Combe and Barbour, by whom also the pulleys were made, the fly-wheel being supplied to their instructions by Hick, Hargreaves & Co.

Later on, in certain districts, especially those in which the cotton industry prevailed, cotton ropes began to be used. These have the advantage of being rather more pliable than manila ropes, especially when the latter are new. The relative merits of ropes made of manila and those made of cotton have frequently been discussed; but experience has shown that, if the pulleys are properly designed and applied, and if the ropes are the proper diameter, good results are obtained, whether the ropes are made of manila or of cotton.

One of the great benefits that was found in rope driving at a comparatively early stage, was that ropes could be applied with advantage to transmit power between shafts that were not parallel. In 1875 a drive was put up in the works of Combe & Barbour to deliver 100 indicated horse-power from one shaft to another which was not quite parallel with it. Here the angle between the shafts is about 3 degrees, and the ropes were applied without making any alteration in the form of the grooves. When, however, it is desired to employ ropes for driving shafts at a greater angle, the grooves in the pulleys are altered to a section which was introduced about 1875, so as to allow the ropes to enter and leave the grooves without greater friction on their sides than when the shafts are parallel.

In 1878 grooved pulleys and rope driving were introduced to replace pairs of large geared wheels, which, from one cause or another, were giving trouble; for example, in places where they were used to combine the power from a steam engine with that from a water wheel, or to combine the power from two engines working under slightly different circumstances. Here the centres of the wheels were so close together that ropes, if applied separately in the ordinary way, would have been too short for effective driving, and there would have been difficulty in putting equal tension upon each of the several ropes. Consequently, in order to secure a proper length of rope and equal tension, a single continuous rope was used, which was laced round and round the pair of pulleys, passing from the first groove of the driving pulley to the first of the driven, thence back to the second groove of the driving pulley, and on again to the second of the driven and so on; and a tension pulley was added for leading the rope back from the last groove into the first.

The continued rapid extension of rope driving, and more especially of driving direct from the fly-wheel of the engine to the various shafts, led to designing fly-wheels to suit the high speeds. A rope fly-wheel was designed by James Barbour in 1879 to meet the special requirements. The peculiar advantage of this method of constructing fly-wheels is that, instead of depending solely on a cast iron arm for connecting each segment to the nave, a strong wrought iron bolt is used, which passes down through the middle of the tubular cast iron arm, and connects each segment directly with the nave; consequently, this bolt not only receives the tensile strain caused by centrifugal force while the wheel is in motion, but it also withstands the driving home of the cotters when the wheel is being put together. When cast iron alone is used for the arms, the driving home of cotters is a frequent source of breakage, which may not be detected until the fly-wheel gives way; whereas by driving the cotters into a long malleable iron bolt there is less danger of fracture. The starting worm or barring engine is made with three pawls for barring round, in order that the motion may be continuous, instead of intermittent, as it is when only one or two pawls are used.

It was about the same date that driving by crossed and half crossed ropes was introduced; also that rope driving was applied to shafts working at right angles to each other, around corners, etc.

A special form of groove is used for cross rope driving. The method of putting on the ropes is such that each rope, though of necessity rubbing on itself, does not rub against its neighbours. Other examples are constructed so that the pitch is greater than twice the diameter of the rope, as a further means of preventing the ropes from rubbing against their neighbours.

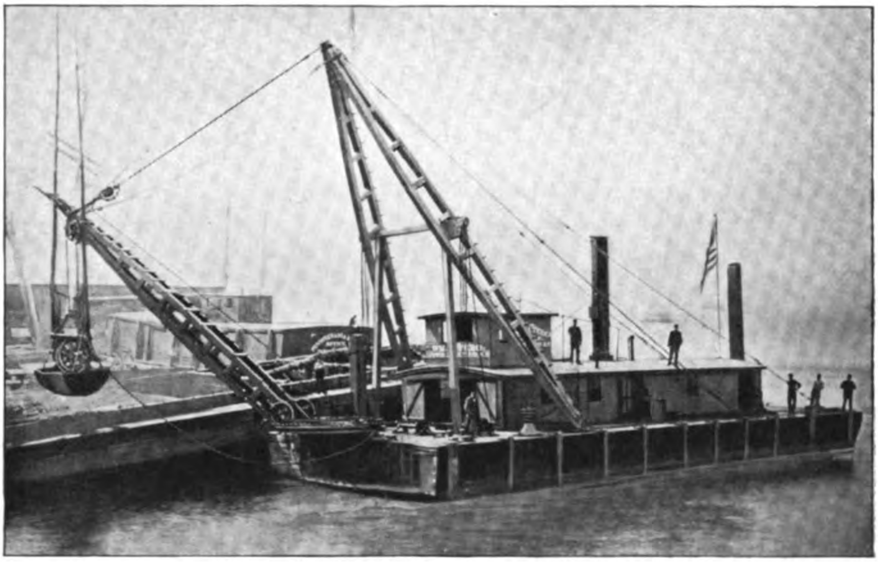
In 1889 another arrangement of rope driving was introduced by James Barbour. Here the driving and the driven shafts were near together, and there was not sufficient space to apply the tension pulley previously described. A single continuous rope was therefore laced round the grooves of the pulleys, and for the purpose of leading the rope back from the last groove of the one pulley into the first groove of the other an additional single grooved pulley was mounted loose on each shaft; these two loose pulleys were made larger in diameter than the fixed pulleys, and the rope was led from one to the other over the top of the ropes working in the grooves of the fixed pulleys. A large number of drives have been erected in this way, and all are working satisfactorily.

About the same date also a drive was erected, in which a single continuous rope was used for driving from one common pulley several shafts running at different speeds.

In 1890 Mr. Barbour further developed the use of the single continuous rope, by applying it to the half-cross drive, in which exists a peculiar method of lacing, whereby a single endless rope is passed round the several grooves in succession, and back from the last groove to the first, without the intervention of a guide or tension pulley.

In many instances existing gearing and upright shafts have been thrown out and replaced by rope driving, and where the rope driving has been properly designed and erected, the total power required for it has, in none of the installations which have come under the writer's observation, exceeded that which was required when driving by wheel gearing; and in many cases the power required to drive the same amount of work by ropes has been less than it was before the change in method of driving took place.

The above examples of the transmission of mechanical power by ropes serve to illustrate the development of this method of driving. Numerous variations have, of course, been made upon each of these plans, which have largely extended the field for the application of rope driving, so that this method of driving, which arose from such a small origin, is now widely adopted for industrial purposes. There is also no doubt that other developments will take place in the future, which will further extend its sphere of usefulness.

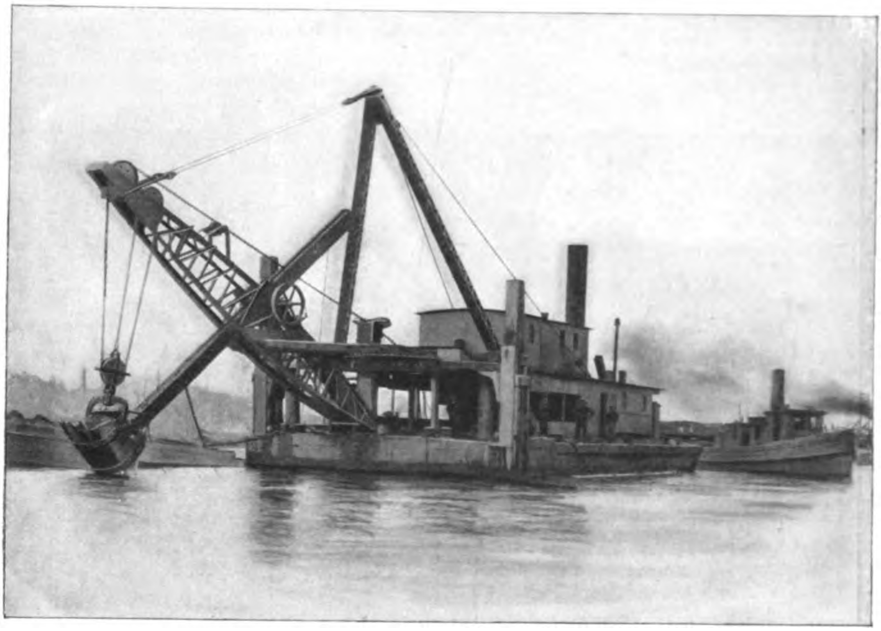


A CLAMSHELL DREDGE.

HYDRAULIC DREDGING.

By A. W. Robinson, M. Am. Soc. C. E., M. Am. Soc. M. E.

WITHIN the last few years the hydraulic system of dredging has undergone a development which has advanced it to a position with an important bearing on the cost and conduct of public works to which it is applicable. The conditions under which dredging is done are, of course, varied, and require different kinds of plants to suit them; but in most cases the disposal of the dredged material is as much or more of a problem than the actual dredging, and forms a large proportion of the cost. For example, when the dredged material has to be deposited into scows and towed a considerable distance, this operation frequently costs more than the dredging. It is in the transportation of the dredged material and spreading it over a large area, as in filling low lands, etc., that the hydraulic method comes into play, and in this class of work its highest economy is reached. In order to fully understand the hydraulic principle and show a comparison of the work that can be done with the different types of dredging machines, let us consider the leading types and their action. These are four in number—first, the dipper; second, clamshell, or grapple; third, ladder, or chain bucket; and fourth, hydraulic or suction.



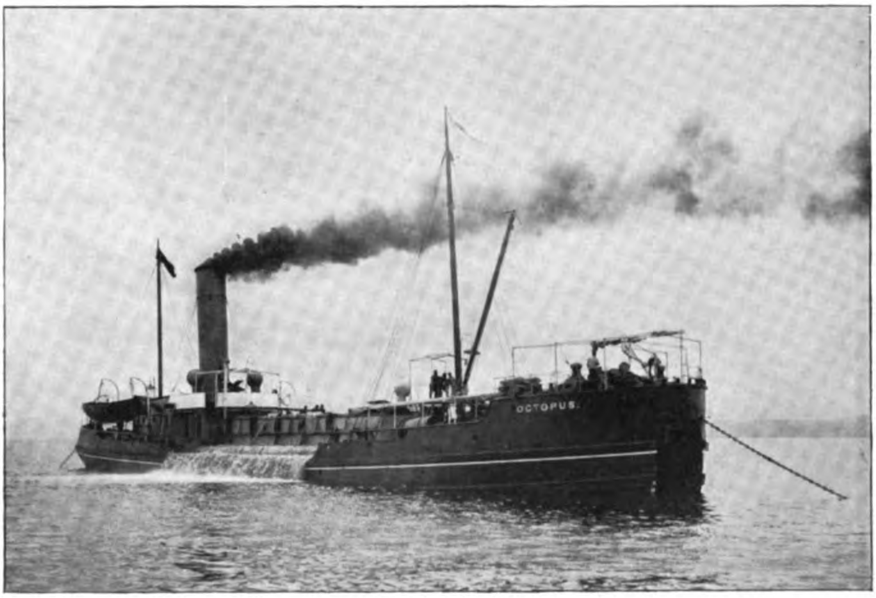
A DIPPER DREDGE.

A LADDER DREDGE.

In the dipper dredge a single dipper or bucket is employed. It is rigidly connected to the end of an arm or dipper-handle and provided with three motions,—hoisting and lowering, swinging, and sliding in or out to vary the radius. This type of dredge is well adapted to dig hard material, as the full force of the engines can be exerted in pulling upon the dipper, while it is being held up to its work by the rigid dipper-handle. Its work is limited to that of depositing the material either into scows or on the bank alongside, within reach of the radius of the boom, which ordinarily is from thirty to fifty feet.

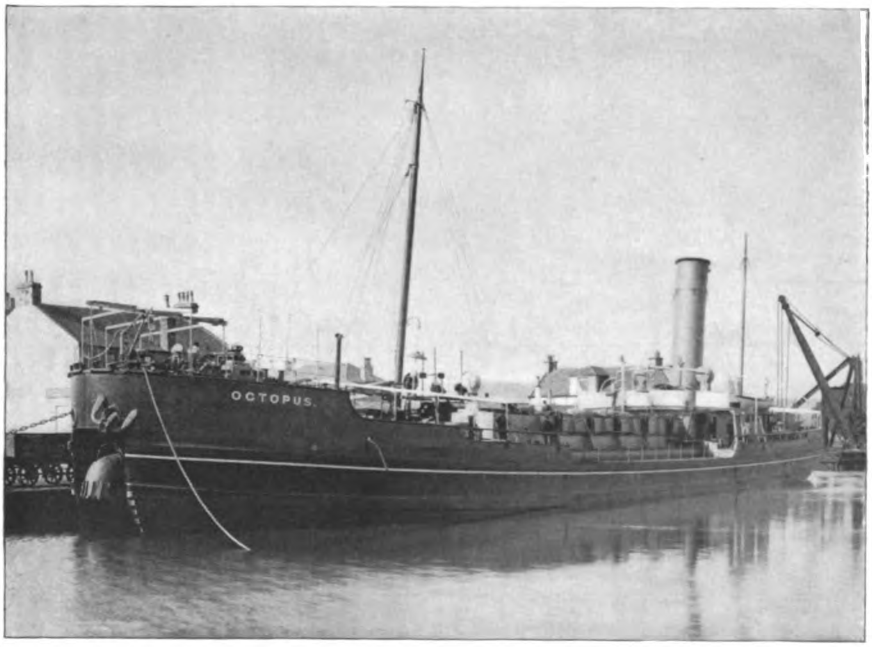
The clamshell or grapple dredge has a boom and hoisting engines similar to the dipper dredge, but the bucket is suspended by hoisting chains from the point of the boom instead of being carried on the end of a rigid arm. The bucket penetrates the ground by its weight alone and is opened and closed by the hoisting chains. The filling of the bucket is aided by closing it while its weight is still on the bottom and before it is raised by the hoisting chains. This type of dredge is used principally for working in soft material and depositing it in scows. The grapple has also been successfully adapted to special purposes, such as sinking bridge piers, taking out blasted rock or boulders, and for handling coal.

The ladder or endless chain dredge is one of the earliest types, and consists essentially of a chain of buckets which run upon a ladder-frame, digging continuously at the bottom and discharging at the top. This type is adapted for homogeneous material, either hard or soft, and for delivering it into scows or upon the bank.



THE TWIN-SCREW SUCTION PUMP DREDGE "OCTOPUS." BUILT BY MESSRS. WM. SIMONS & CO., LTD., RENFREW, ENGLAND.

From the foregoing brief and cursory reference to these types it will be seen that none of them do more than pick the material up and put it down again a few feet distant from the starting point. The disposition of the dredged material is another problem, and in the majority of cases it is the principal problem. In the deepening of many harbours and channels the material is towed out to sea at a cost considerably greater than that of dredging it. Within easy reach of many localities in which dredging is being done, are to be found flats or low lands which are waiting to be filled and reclaimed, and the valuable dredged material, instead of being put upon them, is laboriously taken away a long distance at great expense. Where such conditions exist, the hydraulic dredge now provides the means by which the dredging can be done and the material delivered and spread over the ground at one operation, and at a cost not exceeding the former cost of dredging alone, and, under favourable conditions, at a much less cost.

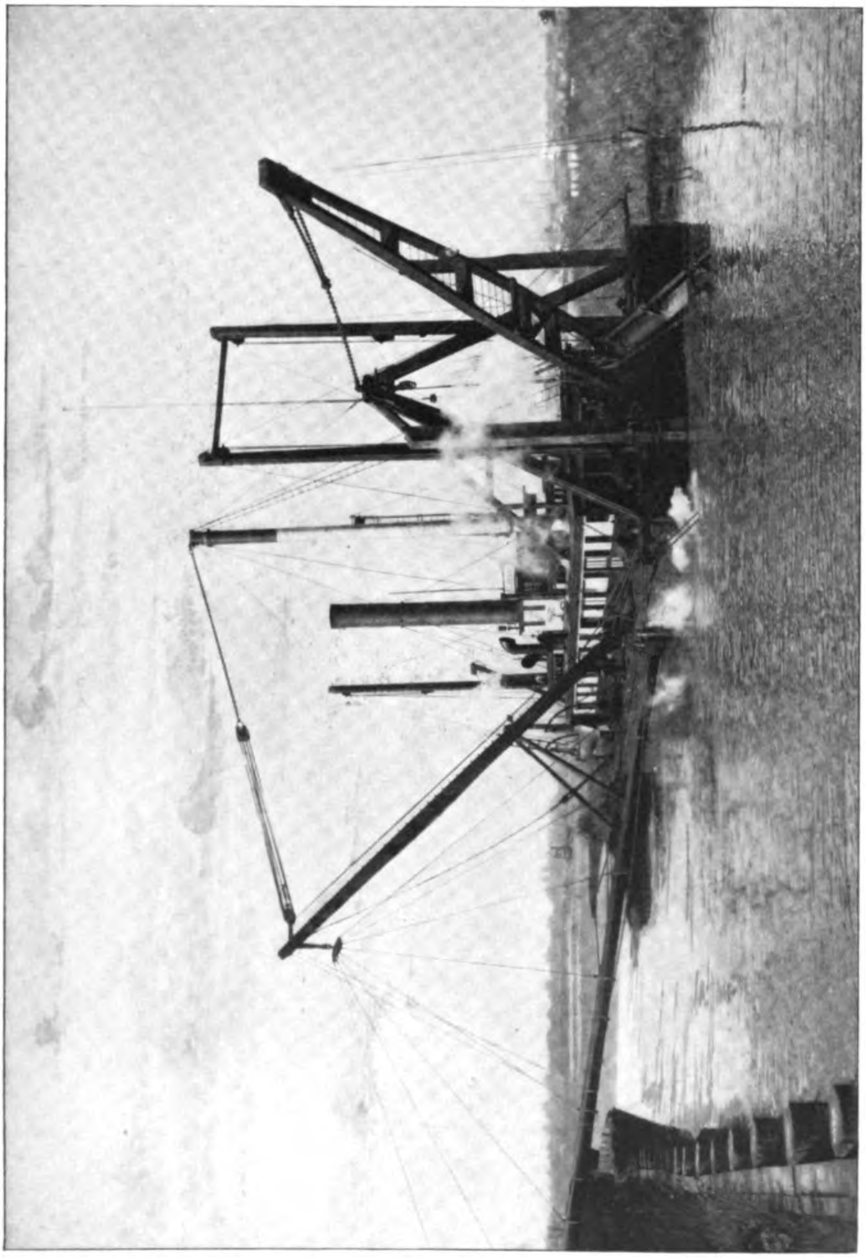


ANOTHER VIEW OF THE "OCTOPUS."

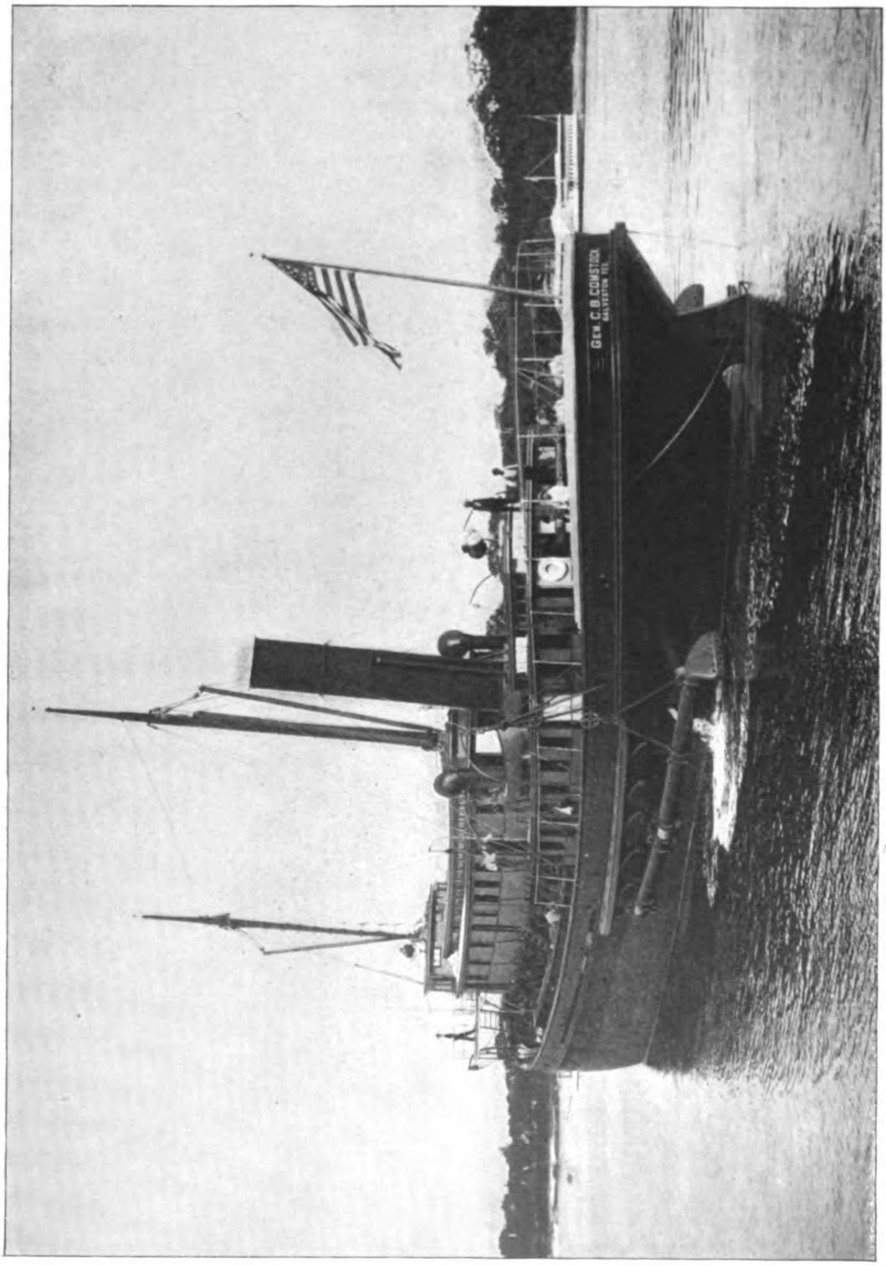
The special advantage, therefore, of the hydraulic dredge is the transportation of the dredged material and its delivery at a considerable distance. It is especially applicable to land reclamation where the material has to be spread over considerable areas of low-lying land. This class of work is performed by the hydraulic dredge at a very low cost, because it combines in one operation the work of dredging, transporting and evenly spreading the material, and the economy with which large reclamation works can be carried on by the hydraulic system must have a marked effect in stimulating such works in the future.

So much more work can now be done for a given sum of money than formerly, that many projects which were before impracticable on account of high cost, can now be executed on a commercially profitable basis. This is such an all important matter to the capitalist or promoter of such improvements that it should receive the closest attention. It is only by keeping informed of the latest development of this class of machinery, and the results obtained, that intelligent estimates can be made of what it will cost to complete any important enterprise involving earth excavation.

Ruling prices per cubic yard at which dredging contracts are let throughout the United States, for example, are now but half or two-thirds of what they were ten years ago. This may be attributed,



THE HYDRAULIC DREDGE "DELAWARE." BUILT BY THE BUCYRUS STEAM SHOVEL & DREDGE CO., SOUTH MILWAUKEE, WIS., U. S. A.



THE SEA-GOING HYDRAULIC DREDGE "GEN. C. B. COMSTOCK." BUILT BY THE BUCYRUS STEAM SHOVEL & DREDGE CO.

in part, to keenness of competition, but in the main it is owing to improved methods of work. The Suez canal could now be duplicated for about one-third of its cost. The Nicaragua canal, although entirely different as to its conditions, can be built for a less sum to-day than was before thought possible. The reclamation of the vast areas of marsh land which are now lying idle in many localities, has become not only a possibility, but commercially profitable, because of the low cost at which they can now be filled in.

In general terms it may be said that the hydraulic dredge is adapted to work under conditions where the material is homogeneous, that is to say, free from large obstructions, and where a fluid or semi-fluid discharge can be provided for. This discharge may be at any distance up to a mile or more. By homogeneous material is meant sand, clay, earth, gravel, alluvial deposit, and, in fact, anything that does not contain large obstructions, such as boulders, roots or stumps, etc., and any material which can be disintegrated by plow or cutter. All such material is capable of being carried through a pipe, when mixed with from 60 to 90 per cent. of water, the amount that can be carried in suspension depending on the distance, velocity of flow and character of material. Stones and other objects of considerable size can be washed through the pipe; in fact, any solids can be carried that will pass through the openings in the pump.

The form of pump commonly employed is the centrifugal. For dredging purposes this is made extra heavy; the internal passages should be large and free, and with curves of large radius. The interior of the pump is sometimes fitted with lining plates to take the wear and abrasion. This wear, however, is not great, and a well-designed dredging pump is about as durable as any other kind of dredging machine.

The centrifugal pump in a hydraulic dredge does not do the dredging, but simply creates a flow through the suction and discharge pipes which will carry the material. Sand or soft mud and the like can be dredged by simply bringing the mouth of the suction pipe into proximity to it, when it will be picked up by the force of the suction, and the amount can be regulated by feeding the suction pipe over the bottom with a gradual movement. In more compact material it is necessary to employ a cutting or excavating device which will dig the material by mechanical means and feed it into the mouth of the suction pipe. By this means the work of the dredge is rendered more certain and the range of work that can be done is increased.

It is usual to make the opening into the suction pipe or cutter head slightly smaller than the passages through the pump. In this way any solid object that once enters will go through without choking. The size and character of some of the solids that will go through a dredging pump are sometimes surprising. Stones and boulders of great size and weight are frequently passed, and in one instance a steel crowbar four feet long went through the pump. The writer has seen solid 6-inch cannon balls that have been dredged up and passed by the pump.

The efficiency of a hydraulic dredge, considered as a machine for raising mud and earth, is very low, but, taking the total result and comparing it with other methods of doing the same work, it presents great advantage. The efficiency of a good centrifugal pump for water is from 55 to 65 per cent. under ordinary conditions; that of a dredging pump is necessarily somewhat less, being from 48 to 55.

Let us take, for an example, the work done in pumping a mixture of 15 per cent. of sand and 85 per cent. of water against a head of forty feet. We will assume, for the sake of calculation, that the pump has an 18-inch discharge and that the velocity of flow is ten feet per second. Now, the weight of such a mixture of mud and water per cubic foot will be 85 per cent. of that of a cubic foot of water at 62½ pounds = 53.12 pounds, plus 15 per cent. of that of a cubic foot of sand at 120 pounds

A STERN VIEW OF THE DREDGE "GEN. C. B. COMSTOCK."

= 18 pounds, or a total of 71 pounds per cubic foot.

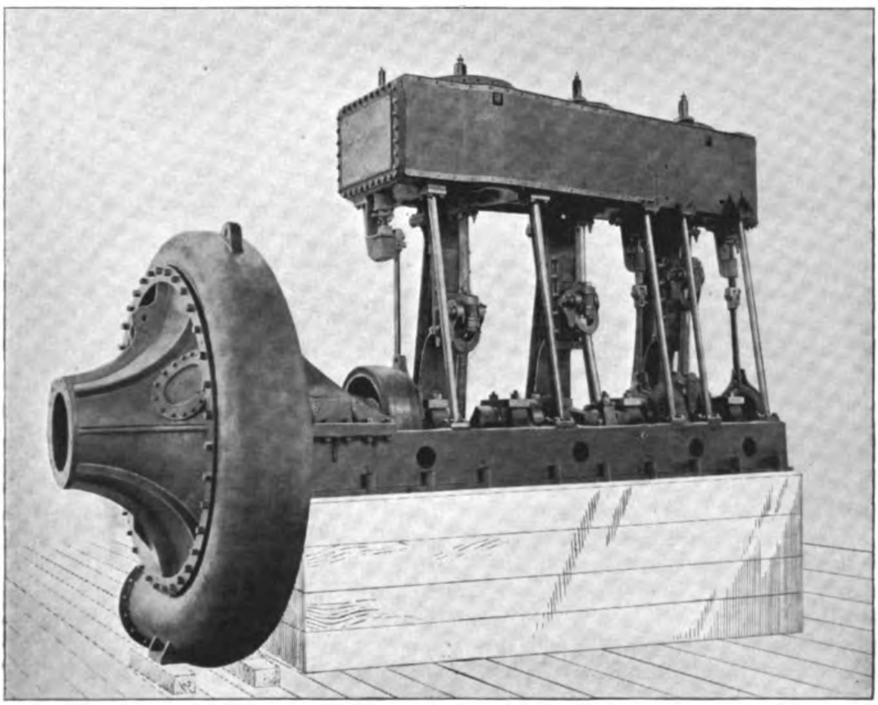
The discharge of the pump will be 1056 cubic feet per minute, and the foot-pounds of work done will be that due to 1056 cubic feet, at 71 pounds per cubic foot, raised to a height of forty feet. This is equal to 2,999,040 foot-pounds per minute, or, say, 90 horse-power. At 50 per cent. efficiency, the horse-power required to drive the pump will be 180. From this it can be deduced that an engine of 180 horse-power, requiring say 3½ tons of coal per ten hours, will dredge and elevate about 350 cubic yards of solid material per hour, forty feet high, or 1000 cubic yards per ton of coal.

Now, a good dipper or grapple dredge, burning 3½ tons of coal per day, will dredge on an average 2000 cubic yards per ten hours, or say 570 cubic yards per ton of coal. The dipper dredge, however, as has before been remarked, simply picks the material up and puts it down again,—either into a scow, or on the bank if it is near enough to reach. The hydraulic dredge, on the other hand, will deliver its output to a considerable distance, and spread it evenly over the surface. It is safe to say that transporting and spreading the material is at least worth as much as dredging it, so that on this basis the work of the hydraulic dredge has double the economic value of other types which do not transport and spread. These figures are, of course, merely approximate and will vary greatly according to circumstances; but they will serve to illustrate the difference between the types.

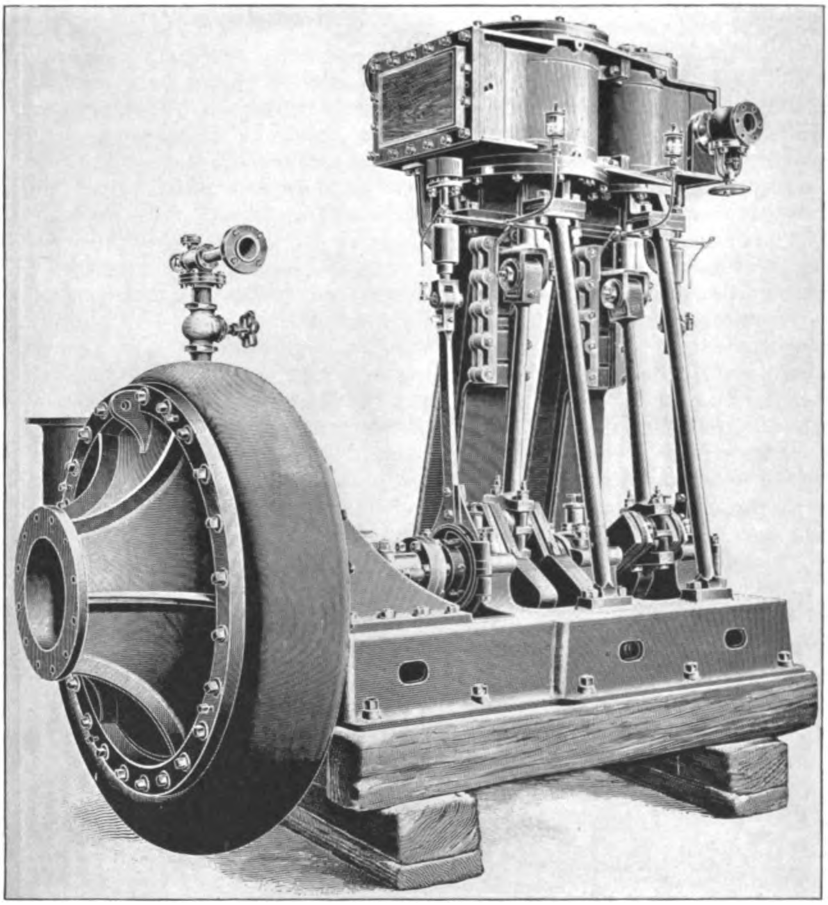
The construction of dredging pumps is a matter of importance, and the chief points to be provided for are durability, non-liability to choke from obstructions, and ease of access for repairs and renewal. It is usually found convenient to build the pumps directly attached to the engines which drive them, especially in the larger sizes. The reason for this is principally on account of space saved by the direct-connected type, and also the avoidance of the belt which is objectionable on account of the heavy side strains upon the shaft, and on account of wear and tear.

The compound and triple expansion engine of the marine type is well adapted for driving centrifugal dredging pumps. The work is analogous to that of driving a screw propeller, and it is practically continuous, or with infrequent stops. Furthermore, high powers at high rotative speeds can be more safely and readily obtained than with a simple or single engine.

On this page and on the one following are given examples of combined dredging pumps and engines from the writer's recent designs. One of the illustrations shows a 15-inch pump with compound engines attached, of 125 horse-power, and the other represents a 20-inch pump, having 450



A 20-INCH DREDGING PUMP, TRIPLE EXPANSION ENGINES, 450 H. P. DESIGNED BY A. W. ROBINSON AND BUILT BY THE BUCYRUS STEAM SHOVEL & DREDGE CO.



COMPOUND 15-INCH PUMPING ENGINE OF THE U. S. DREDGE "GEN. C. B. COMSTOCK." BUILT BY THE BUCYRUS STEAM SHOVEL & DREDGE CO. 125 H. P.

horse-power, triple-expansion engines attached. The latter pump, on being tested, showed an efficiency of 59 per cent. of the power delivered to it by the engines, when delivering against a head of seventy-three feet at a velocity of flow of eleven feet per second. This performance has been rarely if ever equalled in a dredging pump, having large parallel internal passages such as are necessarily used for the unobstructed passage of solids.

The design and arrangement of a hydraulic dredge depends wholly on the character of the work to be done and varies with the requirements. On page 41 is given an illustration of the powerful hydraulic dredge *Delaware*, of Philadelphia. The *Delaware* is designed for general purpose dredging and for delivering the material long distances. This dredge can cut its own channel into solid ground, making a cutting seventy-five feet wide and thirty feet deep at one time, and can deliver the material 4000 feet distant. It is fitted with the pump and engines shown on the preceding page, and its actual measured capacity is 600 cubic yards of solid material per hour.

An example of another type of hydraulic dredge is given in the illustrations on pages 42 and 44, which show the sea-going hopper dredge *General*

C. B. Comstock, of Galveston, Tex. This vessel is a complete sea-going steamer and is designed for dredging ocean bars, or in exposed situations where it is impracticable to anchor the dredge or to work with scows alongside, or a floating pipe line. The dredging machinery is entirely independent of the propelling power and consists of two 15-inch dredging pumps, each with its own suction pipe and drag, which plows and picks up the material as the vessel is slowly steamed over the area to be dredged. The hull of this vessel is 177 feet long, 36 feet beam, and 16 feet depth of hold, and the capacity of the sand hoppers is 560 cubic yards. When at work the hoppers are filled in from forty minutes to an hour, and are emptied in seven minutes through valves in the bottom. This affords a good illustration of what such a dredge will do.

On pages 39 and 40 are shown two views of the hopper dredge *Octopus*, which is a good example of English construction in this line. This vessel has a hull of steel and is of similar character to the *General Comstock*, except that instead of having side suction pipes dragging on the bottom, she is fitted with a telescopic suction pipe at the bow, and the dredge, when in action, is moored by anchor chains.

These examples of hydraulic dredges are only three out of many types that have been successfully used. It will be apparent that as the requirements vary, so the type and design must vary to conform to them. As time goes on, we shall see still further improvements, not only in the hydraulic type, but also in the other recognised types of dredging machines, all of which have their proper field of work.

A TRIBUTE TO J. F. HOLLOWAY.

By Charles H. Loring.

J. F. HOLLOWAY, the well known American mechanical engineer, died at his home in Cuyahoga Falls, O., on September 1.

In what was probably the last product of Mr. Holloway's pen for publication it is written, "Shakespeare's Ophelia, as she mused over her gathered treasures, laid one aside, saying, 'That's rosemary,—that's for remembrance.' It was hoped that some of those into whose hands this leaflet may come, will find in it something for which they will treasure it also—as a remembrance." Though not altogether in the direction in which his thought led him when he wrote these words, how completely his aspiration meets the present sad conditions!

How absolutely those who knew him, and have read this modestly called "leaflet," have found in it that "something" which being, as it were, his last words, is to them the very rosemary of remembrance, full of fragrant memories, to be always treasured!

Mr. Holloway was born in Uniontown, O., January 18, 1825. In his early youth his father took his family to the Cuyahoga river, where afterward grew up the town of Cuyahoga Falls. Here young Holloway came to manhood, having served an apprenticeship with a prominent firm of steam engine builders. Graduating thence he subsequently filled several important positions of responsibility and trust, and about ten years ago came to New York as consulting engineer in the establishment of Henry R. Worthington, with whom he remained seven years. Then he took a similar position with the Snow

Steam Pump Company, in whose service he remained to the time of his death.

In his various occupations Mr. Holloway gained a wide, practical experience in the mechanic and kindred arts, which he supplemented by patient, assiduous, self-guided study of the laws that underlie them. His reading, however, was not confined to technical subjects; it was more comprehensive than this and covered wide areas in the field of ordinary literature. He had especial fondness for modern story books that treat of the characteristics and surroundings of the common people for whom he had a sympathetic and brotherly feeling. Though he had attained a ripe age, he still retained, in his manner of action and habit of thought, the spirit of youth, and this, with a cheerful and kindly disposition, made him always a pleasant companion.

In all the associations social and technical, in which he had membership, his influence was manifest. He devoted himself attentively to their interests and bore a large share of the burdens of their affairs. His calm judgment, even temperament, acute discernment and never-failing good temper, made him a wise and valuable counsellor. He was a fluent speaker, eloquent and graceful, with an overflowing fancy that enriched and adorned his imagery. He was a persuasive debater, clear in statement, logical in deduction, always courteous to those who differed with him, and considerate of their opinions. He had, too, a keen sense of humour, and skill in the use of it, which often gave to his treatment of serious or technical topics an attractiveness peculiar to it, and that without detracting from its impressiveness.

He had pride in his calling and a high estimate of the value of its work, with an eager solicitude that those who follow it should get due recognition and credit for what they accomplish. Some will recall how prettily and inoffensively, yet insistently, he, once on a social occasion, drew from a trans-Atlantic liner's captain the admission that the honours of a record breaking voyage belong to the engineer alone.

Mr. Holloway was one of the founders of the American Society of Mechanical Engineers, was its president in 1884-5, and was, ever since, active in the management of its affairs as an honorary councilor. Of the American Institute of Mining Engineers he was a past vice-president. He was a charter member of the Civil Engineers' club, of Cleveland, O., and its president for three terms. In 1891, he was made an honorary member. He was also a charter member of the Engineers' club, of New York. For two consecutive years he was its president, and at the time of his death he was a member of the board of trustees. Besides his wife, he leaves behind him a daughter, endowed with many graces of mind and person, and a son who, to all seeming, is worthily following the path his father trod.

In a sketch of his on club life, published in this magazine but a short time since, are these pathetic words, made doubly so by this present grief:—" The sad days are those when, bordered in black, there appears on the bulletin board, the announcement of the death of a member and friend. Come when it may, the announcement is sure to bring sadness to those who read it; and as they look upon it, the memory of the friend comes back, his faults forgotten, his virtues cherished, and as they turn away their silent comment is,—' he was a good fellow.' "

In no narrow or restricted sense, but in the broadest, highest, noblest acceptation of the term, he whom we have lost " was a good fellow."

PUMPING WATER FOR IRRIGATION.

By W. G. Starkweather.

THE Pacific side of the great American desert plateau, and particularly California, is exceptionally endowed by nature for the successful pursuit of agriculture. The soil is of a rich brown colour, of the proper weight and depth, and contains the requisite chemical constituents for varied and extensive crops. The physical contour of the country,—long valleys extending northerly and southerly,—is such that the cold winds from either the ocean on one side, or the snow-clad mountains on the other, are excluded in large measure, although occasionally the dreaded "norther" does sweep down on the valley lands, bringing destruction with it. But the temperature throughout the year is fairly equable. This is due, doubtless, to the Japan current, which circles across from the Asiatic side and moves south along the coast.

Another important factor, also, especially in California, is the large percentage, throughout the year, of cloudless days. The sunshine is noted the world over, and can be compared only with that of Southern France and Italy. It has been well said that in California it is "either all clouds or none." Any one who has experienced the rainy season knows the full significance of the "all clouds" portion of the remark. But this peculiar season, remarkable because of the immense amount of rainfall which takes place in a short time, does not last very long, and the dry season is the other extreme. From March until November there is very little rain. That portion of the country not artificially watered then becomes baked and parched in the continual sunshine. If water can be had, however, the above favourable factors ensure one crop at least as an almost certainty, and very often two or three.

Water being, therefore, the lacking element, extreme measures have been taken to gain it. Vast systems of dams and ditches have been built for irrigation purposes. The plan on which these are constructed is almost always the same,—an impounding or diverting dam far enough up the river or mountain side to secure "head" for the lands below; a main canal, or ditch, to those lands, and smaller distributing canals through which the farmer receives water. The dams and reservoirs store up the winter rains, or collect the small continual flow of creeks or rivers, which is thus conserved for summer use.

It is not the intention to develop here the details of this system, which has been ably done by others, and can be found in works on the subject. These systems are all of considerable magnitude, and involve a great expenditure of time and money. They have some inherent defects, apparently unavoidable, and to surmount these recourse has, of late years, been had to independent action on the part of the landholder. In systems already built these defects are (1) the excessive cost of water, due to the large first outlay on the systems, lack of competition, and the usual greed of the water companies; (2) the inability, often, to secure water when needed owing to insufficient capacity of the canals, or because one's neighbour above may be taking all the available supply; and (3) the impossibility of irrigating land higher than the supply ditch. These and other difficulties in the "gravity system," as it is called, have given rise to various systems of pumping direct from wells, sumps, and rivers on to the land. This is only following the example of the ancients, who lifted water from the Nile and the Ganges in the palmy days of the world's youth. For small powers, windmill, man and horse-power are used. For larger duty both steam and gasoline engines have been employed as motive power, either belted, or direct connected to the pumps. The latter are generally of the centrifugal type, as the duty is the raising of large quantities through a comparatively small distance and also because there is considerable solid material in the water which would clog a pump operated by valves.

Concerning the relative cost of the two systems under consideration, considerable data have been collected and condensed into the following comparison. An average of fourteen gravity systems now in operation and ranging from 4000 to 200,000 acres gives a first cost per acre of $11.50. With interest at 7 per cent. and ordinary depreciation and attendance, the yearly running expense per acre approximates $3.

As yet, there are very few large and economical pumping plants in operation, but a conservative estimate, based on those now installed, develops the fact that good plants of large size can be built for about $3.50 per acre, and operated at a yearly expense of probably considerably less than one dollar, interest, depreciation, insurance, etc., included. It is understood that each case would involve special elements that would, doubtless, differentiate these figures, but the same would be true for the gravity system as well. Hence, the estimate may be taken as fairly representing the status of the case.

The capacity of these plants designed for the pumping of water, is of wide range, and at the outset there arises the question of the necessary amount of water for irrigation, or its "duty" as it is called. This varies with the character of the soil and crop, and with the time required for the water's distribution. The time element plays an important part in this distribution. A dry and baked crust in a water conduit will actually shed water for a short time in much the same manner as a dry sponge, and probably because of the particles of air contained in it. Once free this air from the earth, and thereafter saturation soon takes place. This being just what the irrigationist wishes to avoid, the desideratum seems to be the most rapid passage of the water consistent with security of ditch sides and bottom; that is, the largest possible volume of water in the shortest time.

These above uncertain elements render the actual amount of water required a questionable quantity, dependent, in each case, on the relative importance of the different conditions above outlined. The table given on the opposite page shows the necessary number of gallons per minute to cover various acreages twelve inches deep. This is the usual depth for one irrigating, but does not allow for seepage, evaporation, or other wastage. Probably from 25 to 50 per cent. additional, would cover these losses.

The theoretical, or "water horse-power" necessary to lift these volumes of water through different distances is given with sufficient accuracy by the simple formula

$$\text{W. H. P.} = \frac{\text{Gals. per min.} \times \text{ft. lift}}{4000}$$

It is when the matter of efficiencies is considered for the determination of the engine's size that the engineer arrives at still more uncertain data than those already touched upon. The steam engine is a comparatively well known motor, and its performance may be safely predicted, but the gasoline engine is somewhat of a newcomer. The centrifugal pump also, is by no means a machine built on one set of lines, or with one mode of action. As John Richards remarks, it "has more tricks than an army mule."

The gasoline engine acts on a so radically different cycle from the steam engine, that its adaptation to the other's ordinary duty is attended with some

Gallons of Water Required per Minute to Cover Various Acreages 12 Inches Deep.

Hours of Service.	Acres.											
	½	1	2	3	4	5	7	10	15	20	25	30
5	1,087	2,174	4,348	6,522	8,696	10,870	----	----	----	----	----	----
7	776	1,552	3,104	4,656	6,208	7,760	10,864	----	----	----	----	----
10	543	1,086	2,172	3,258	4,344	5,430	7,602	10, 60	----	----		----
12	453	906	1,812	2,718	3,624	4,530	6,342	9,060	13,590	----	----	----
24	226	452	904	1,356	1,808	2,260	3,164	4,520	6,780	9,040	11,300	13,560
48	113	226	452	678	904	1,130	1,582	2,260	3,390	4,520	5,650	6,780
72	75	150	300	450	600	750	1,050	1,500	2,250	3,000	3,750	4,500
96	56	112	224	336	448	560	784	1,120	1,680	2,240	2,800	3,360
120	45	90	181	271	361	452	630	900	1,350	1,800	2,260	2,700

risk. As is well known there is generally one working stroke in every four, the inertia of heavy fly-wheels being depended upon to carry the engine and its load through the other three. Again, in the usual type the explosive mixture must be compressed in the engine cylinder before an impulse can be obtained, and this necessitates the turning of the engine by hand through at least one revolution. If the engine is large, this is a difficult matter, even with patent "self starters," and in any case the engine cannot start with a load, but must be supplied with clutches or double pulleys.

But even with these disadvantages it is, in other respects, the ideal type for small isolated plants. The chief advantage is the compact form of fuel and its automatic supply to the engine, thus avoiding the constant attention of an engineer or fireman, who can, after the plant is started, leave it and look after the irrigating. As one man can often do this latter alone for small systems, the advantage is an important one.

The centrifugal pump is also well adapted to this type of engine, since its work begins only when at the proper speed for the given head. All revolutions less than that simply lift the water up the discharge pipe and maintains it at that level without causing any flow. The work would begin, of course, when water was first discharged.

At the same time, the combination of gasoline engine and centrifugal pump is one which has uncertain elements. The difficulty arises from the uncertainty of the pump's work at various speeds, and also the delivered power of the engine. There is a certain definite number of revolutions for each and every pump which is the best for a given head, but how to find that number is by no means an easy task. A common rule for its determination, when the head pumped against and the diameter of the runner, or impeller are both known, is:

$$\text{Revolutions per minute} = \frac{1900\sqrt{H'} + 2100}{\text{Dia. of Runner.}}$$

This, however, is not very accurate. More than the correct number of revolutions forces the water at too high a velocity through the passages and pipes and by thus engendering useless friction, power is wasted, while too small a peripheral speed will not raise the water in requisite quantity. This efficiency of the centrifugal pump is always a vital part of the computations, but with the gasoline engine it becomes paramount to almost everything else, since this type of motive power is not so flexible as its steam cousin, when changes have to be made. Revolutions are the index of the gas engine's power, and only by varying them can its power be altered. With the steam engine, on the other hand, both revolutions and pressure are components of the power formula, and the engine is easily adapted to irregularities in the pump.

It is apparent, therefore, that the engineer who drives a centrifugal pump with a gasoline engine should be somewhat familiar with the idiosyncracies of the particular types he is employing, or he may be obliged to make some pulley changes, or otherwise experiment. If these points are carefully looked after, it would seem that for small independent plants the gasoline engine and centrifugal pump, in any of the arrangements outlined below, fulfill almost completely every condition.

Some of the plants herein described

were installed by the writer's firm, and the details of such are, therefore, accurate. All are in successful operation, and with others of the same class fully

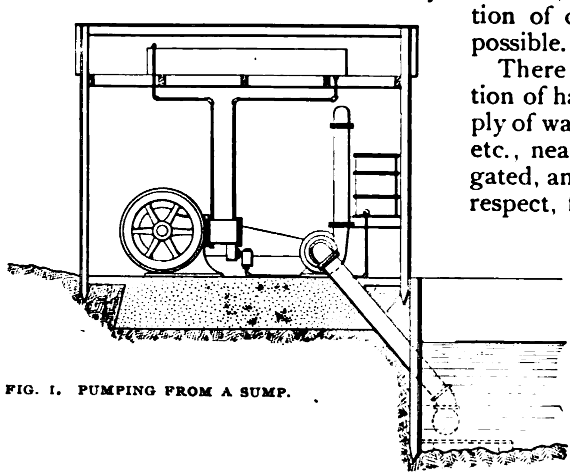


FIG. I. PUMPING FROM A SUMP.

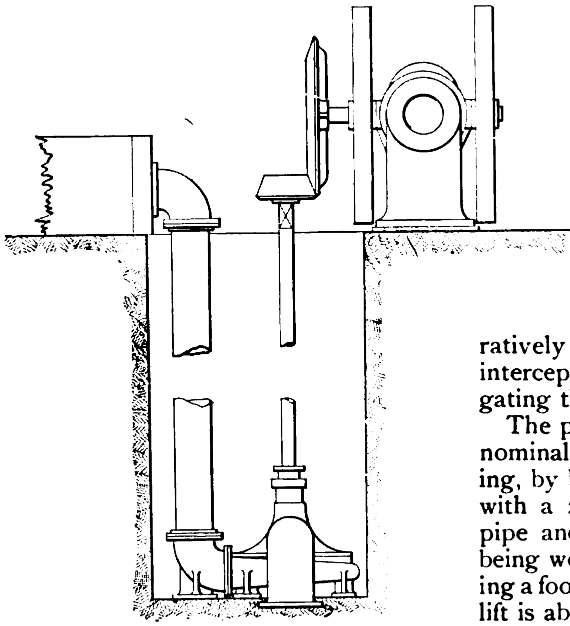


FIG. 2. A GEARED PUMP OUTFIT.

corroborate the proposition that it is generally far cheaper, per cubic foot of water delivered, to pay the interest and depreciation on, and the running expenses of, a pumping plant, furnishing as much water as needed, when required, than the same expense on a dam and long lines of canals. In some cases the plants here described have been estimated as paying for themselves in two seasons, either by increase or duplication of crop, or by making agriculture possible.

There is always the necessary condition of having an available natural supply of water in the shape of rivers, wells, etc., near the land which is to be irrigated, and California is fortunate in that respect, for in almost every one of her numerous valleys water can be found. In some cases it sinks a few feet out of sight in the sand, necessitating the use of intercepting ditches and collecting basins or sumps. This is the case at the plant in Fig. 1, located on the bank of the San Benito, and serving ten or twelve acres. As the river dwindles in summer to almost nothing, two trenches were scooped out of the sand twelve feet wide, eight or ten feet deep and of a total length of three hundred feet. They were planned in the shape of a large T, and the pumping plant was placed at their intersection. The seepage of a comparatively large area is, in this manner, intercepted, and is sufficient for irrigating the acreage above mentioned.

The plant consists of a 9 horse-power nominal 7"x12" gasoline engine, driving, by belt, a 6-inch centrifugal pump, with a 24-inch runner, 10-inch suction pipe and 8-inch discharge, both pipes being well casing, and the suction having a foot-valve and strainer. The total lift is about 10 feet, and the plant delivers approximately 1000 gallons per minute, with an expenditure of one gallon of gasoline every hour. Both engine and pump are mounted on a continuous concrete foundation and are covered by a neat house. The gasoline tank is in one corner, the fuel flowing by gravity to the atomiser of the engine. Overhead, on the timbers, is placed the jacket water tank. Opening from the discharge pipe of the pump, and just outside the house, is a valve which admits water to a wooden box, when the plant is in operation, where it is stored, to be used in priming the pump at the subsequent irrigating, should the foot-valve leak. The machinery of this plant cost about $1300 complete, the proprietor digging the ditches, curbing them and erecting the house.

When the water is taken from wells, and its surface is below the suction limit, a different arrangement is used. Either a pit pump, Fig. 2, is placed close to the water and driven by bevel gearing and a vertical shaft, or, a rope or belt is used, as in Fig. 3, to drive the ordinary pump. The impression amongst many engineers is that centrifugal pumps are not suitable for heads over 25 or 30 feet. Recent experience in California would indicate, however, that even 100 feet is not an uneconomical lift, there being several plants working satisfactorily under this head. Another case is that of several separate wells. If they are close together, the suction from each can be joined in a common suction to the pump.

The conditions are somewhat different, however, when the wells are, as usual, far apart. It then becomes a case of "Mahomet going to the mountain," and a portable plant, Fig. 4, results. It is necessarily a small outfit, capable of being easily transported from place to place. The gasoline engine of the plant now in mind is a 5"x9", 3 horse-power nominal, driving a 3-inch pump.

The machinery is mounted on a stiff timber frame, and is supported by two ordinary wagon trucks with broad tired wheels, which, when the plant is not being moved, can be used for other purposes. The gasoline and jacket water tanks are placed on opposite sides to attain a symmetrical loading. The suction pipe of the pump is detachable to permit its being raised and lowered at the wells, and its foot-valve is small enough to easily go inside the well casing. When the plant is moved to another well, the pipe is hung on hooks under the wagon. The foot-valve used for windmills is a very convenient and compact form for this work. The joint between pump and suction pipe is made with clamp bolts and is packed with a rubber gasket to secure air-tightness. This convenient and handy little outfit weighs, complete, 2000 pounds, and cost, approximately, $600. It will deliver 250 gallons a minute against a 20-foot head. This is sufficient for half an acre per day.

Another form in which the gasoline engine is applied to pumping work is shown in Fig. 6. Here the engine shaft is continued through the pump and the runner is keyed on it. The saving in first cost on both engine and pump is apparent. One fly-wheel (which in a gas engine is exceptionally heavy) is omitted, the pump runner taking its place. On the pump a bearing and pulley are avoided, and the size of the base is much decreased. The cost of the belt is saved, and that of founda-

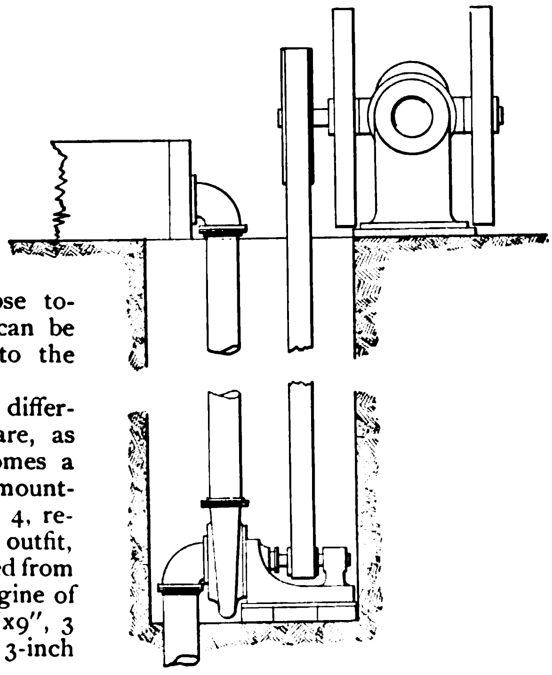


FIG. 3. A BELT-DRIVEN PUMP.

the plant's acceptance. The guaranteed efficiency of the pump was 55 per cent. with the proviso of a bonus in case this figure was exceeded, while the engine was expected to develop an I. H. P. on less than 15 pounds of dry steam per hour. Cottonwood was used for fuel, and the pressure carried throughout the trials was 130 pounds. The vacuum obtained was 26½ inches. Calorimeter tests were made to determine the dryness of the steam. The water discharged from the centrifugal pump was accurately measured over a weir, while that fed to the boiler was weighed in tanks. In every way the test was carefully conducted and to insure certainty it was repeated. It showed that the boiler delivered practically dry steam at the engine, and that the reheating in the receiver produced 10 to 20 degrees superheat, thus avoiding wet steam at the low-pressure cylinder. The I. H. P. of the engine is 82½ at 93 revolutions, while the friction of the entire plant is 11.56 I. H. P.

The piston speed,—560 feet per minute,—is high. The total effective work, as measured by the discharge of 7200 gallons per minute against a head of 24.4 feet, is 44.47 horse-power, thus giving an efficiency of 62.6 per cent. for the pump, and 53.9 per cent. for the complete plant. The steam consumption is 13.19 pounds per I. H. P. per hour, and as a reliable figure, is remarkably good for so small a plant.

The cost of the machinery, ready for steam, but without building, suction, conduit, or discharge pipe, was about $7000. The entire plant, complete, cost in the neighborhoud of $8500, and will probably perform its duty as cheaply if not cheaper, than any other plant on the Pacific coast, every item included.

As was noted at the beginning of this paper, the economical pumping of water is a comparatively new method of irrigating in the far West of the United States, but it may be taken as only a step in the development of the vast and potent possibilities of that great country.

MARINE EVAPORATORS.

By D. B. Morison.

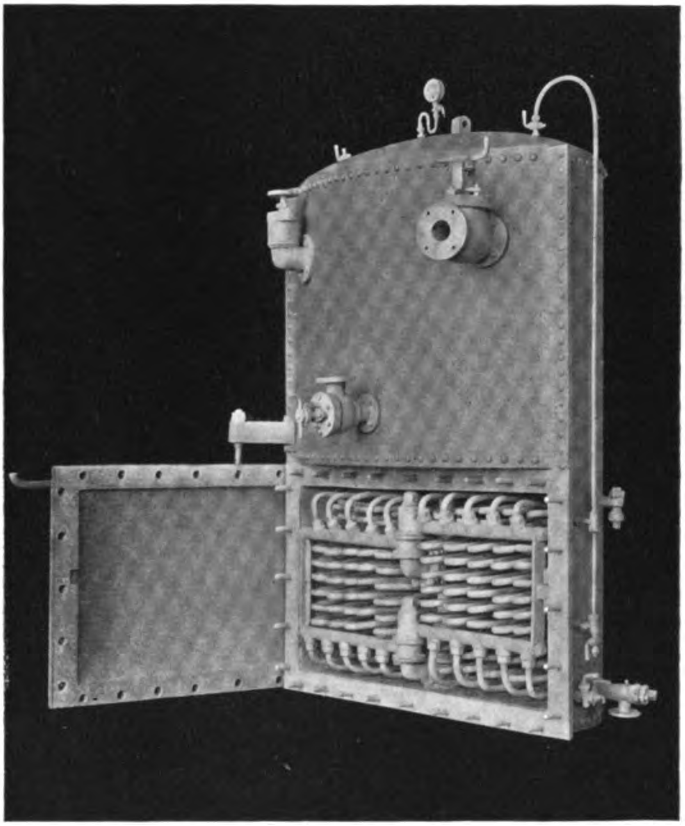
THE universal practice on steamships a few years ago was to supply the loss of water, due to leakage in a condensing engine, from the sea direct to the boilers; but since the introduction of multiple expansion with its higher pressures and temperatures, the necessity for minimising the scale in boilers has resulted in the use of an independent apparatus, in which sea water is evaporated by means of steam, and the generated steam, being condensed, is delivered to the boilers free from all impurities.

Apart from the necessity of such an arrangement from an engineering point of view, there is the commercial consideration of reducing the boiler scaling expenses, minimising the liability to accidents, and prolonging the life of the boiler. Whilst it is possible for careful engineers of long experience to work boilers without an evaporator, there are few superintendents who do not realise the fact that in order to obtain the greatest engineering and commercial efficiency, and as a safeguard against accidents, an evaporator is a necessary auxiliary on board a modern steamship.

The results of an accumulation of scale in boilers, considered briefly, are:—

First.—Decreased efficiency of the heating surface, causing an unnecessary expenditure of fuel.

Second.—Increased temperatures of materials forming the heating surfaces, causing collapse or deformation of furnaces or leakage of tubes and joints.



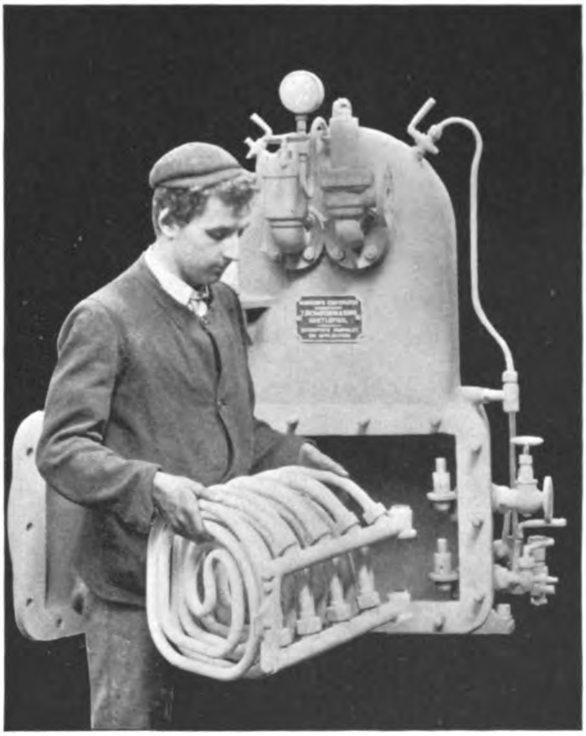
A NAVY TYPE RADIAL EVAPORATOR.

Third.—Increased wear and tear of boilers.

Fourth.—Excessive boiler cleaning expenses.

The chief sources of loss of water in the main engines are from the glands, but these may be minimised by automatic water drainers. Careful attention of those in charge, to all the details of the various steam connections is the chief factor, however, as there is no better index of the efficiency of an engine room staff than the quantity of auxiliary feed water required. The ease with which loss of water in marine machinery can be made up by simply allowing it to flow from the sea to the hot well has often tended to mislead those in charge as to the quantity which should be required and the quantity actually used. The natural result is that there are large numbers of boats in which the loss is most extravagant, the engineers being either unaware of the fact, or accepting the condition as normal.

One of the many examples which have come under notice was a steamer with an evaporator which, even when coated with scale, would have been capable of producing four times the amount of fresh water which should have been necessary. The engineer reported that the evaporator was certainly of assistance, but he had to keep it going continually, clean it every day, and use in addition a large amount from the sea. This is an apt illustration of the unconscious influence that the old auxiliary supply from the sea had over the engineer, as his entire efforts were concentrated in endeavouring to compel the evaporator to produce sufficient



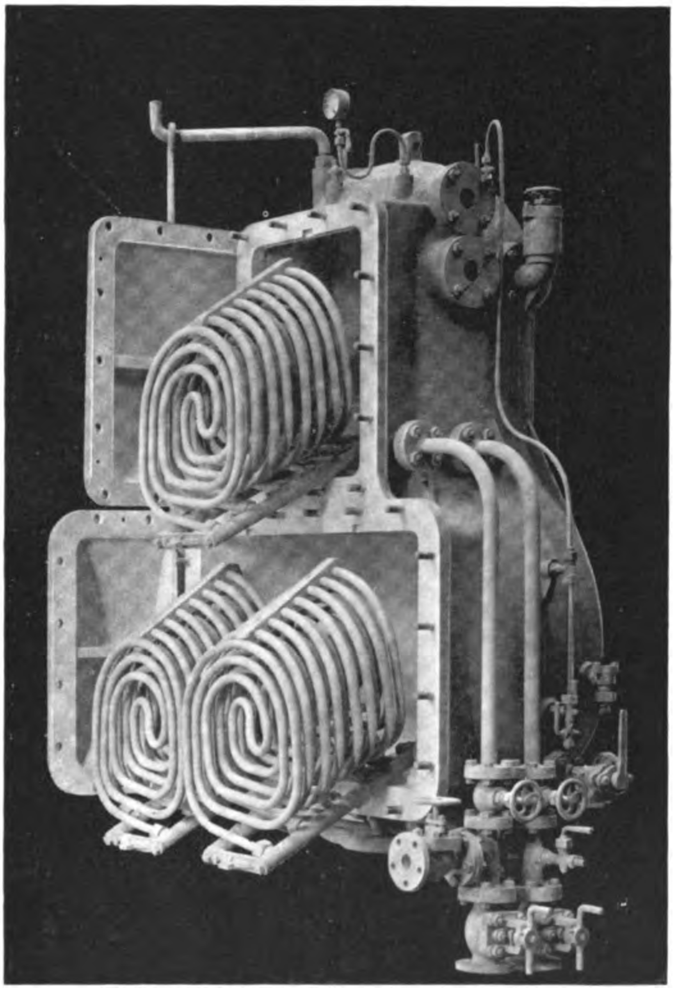
A RADIAL EVAPORATOR FOR STEAM YACHTS.

water to make up the loss, he being totally blind to the fact that the amount of loss was both extravagant and unnecessary. Subsequent investigation showed that the machinery generally had been allowed to get into such a bad condition that the loss of water amounted to fully twenty tons per 1000 I.H.P. per twenty-four hours.

An example of what may be considered an exceptionally high efficiency has been obtained in a steamer belonging to a well-known passenger steamship company, in which facilities were kindly given by the superintendent for obtaining reliable data extending over several voyages. The engines are 28-inch, 46-inch, 77-inch, by 48-inch stroke, with two double-ended boilers of 160 pounds pressure, steam steering gear, electric light, and the usual auxiliary machinery. At sea the average I.H.P. is 2000, and the amount of auxiliary supply, five tons, or two and one-halt tons per 1000 I.H.P. per twenty-four hours, and assuming that the consumption of water is fifteen pounds per I.H.P. per hour, this would be equivalent to 1½ per cent. of the total feed water used.

The foregoing may be considered extreme cases, but the greatest care is necessary in order to obtain maximum efficiency, as a number of very slight leakages, when combined, produce a large quantity at the end of twenty-four hours.

The English Committee on Naval Boilers recommend in their report that not less than six tons of auxiliary feed per 1000 I.H.P. be allowed. This allowance seems very small when the large number of auxiliaries is considered, but probably the estimate is based on the maximum I.H.P. which is, of course, seldom required, and it must also be remembered that the machinery in Her Majesty's navy is kept in the highest possible condition of efficiency. It will be evident, however, that not only does the amount of auxiliary feed vary for different types of engines, but the variation may be very great in ships of the same class, depending entirely on the condition of the main and auxiliary machinery. In passenger boats, where the labour is sufficient to keep everything in good order, a safe allowance is eight tons per 1000 I.H.P. at sea, which, assuming a consumption of fifteen pounds of water per I.H.P. per hour, is 5 per cent. of the total feed; but in cargo boats, where the available labour is much less, and so much attention cannot be given to details, ten tons per 1000 I.H.P. is advisable. In both these cases there is ample margin for contingencies, and if evaporators are fitted of these capacities, but still are not sufficient, then the waste of water is highly extravagant and altogether unnecessary.



A COMBINED EVAPORATOR AND WINCH CONDENSER.

The arrangement of multiple evaporators working in series, so that the generated steam in the first is utilised to generate steam in the second and so on, although being the universal system for sugar refining and distilling, is not in use to any extent on ships in the mercantile navy, as in ordinary cases it involves unnecessary complication and initial cost, besides entailing more attention when working; so that what is generally understood by a marine evaporator for supplying auxiliary feed water is a single vessel in which salt water is boiled away, the heating medium being steam.

From the elementary nature of the apparatus the different designs are exceedingly numerous, as, given a vessel in which water is evaporated by means of steam within a tube, there is ample scope for variation of detail. But simple variation is of no value except accompanied by definite improvement, which results only from development based on the practical requirements of those engaged in the working of the apparatus at sea; and it is becoming more and more recognised by designers that not only must all auxiliaries on shipboard be simple, but that the labour necessary to maintain efficiency whilst at work must be reduced to a minimum.

There is only a certain amount of labour available, and the requirements from that labour are ever increasing; in fact, if engineers at sea are hampered with any detail which requires an undue amount of attention then, as a consequence, something else suffers. It is, therefore, practically imperative for success that such an elementary apparatus as a marine evaporator must not only be efficient, from a scientific point of view, but also from a marine engineer's point of view, which is equivalent to saying that it must be simple in construction, strong, require but little attention when working, and the least possible labour in cleaning.

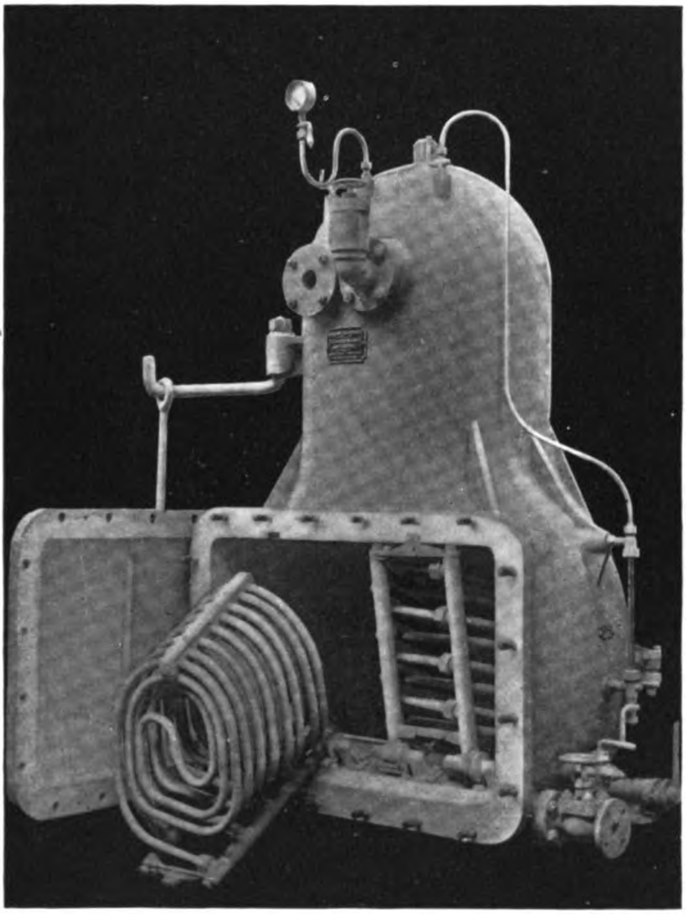
In these times of severe competition, when every detail on shipboard is viewed from a commercial standpoint, the probable cost of obtaining fresh water by means of an evaporator is a most important consideration. There are several arrangements available:—as, steam being taken from the boiler direct, the steam generated in the evaporator may be led to the steam chest of the low pressure cylinder, to the main condenser, or to the hot well. In order to compare the relative economy of these methods, loss by radiation may be neglected, as it is practically a constant quantity; also, for the sake of simplicity, the usual tables on the properties of steam may be taken as applicable to the general conditions.

Steam Supplied to the Evaporator from Boiler, and Steam Generated in Evaporator Discharged to Hot Well.

In considering the method by which steam is supplied to the evaporator direct from the boiler, and the steam generated in the evaporator is discharged to the hot well, or its equivalent, and there condensed amongst the feed water, let it be assumed that the steam pressure in the evaporator is one pound per square inch above the atmosphere, or say sixteen pounds absolute pressure; that the water fed to the evaporator is drawn from the circulating pump discharge at a temperature of 80 degrees F.; and that the temperature of the hot well is 120 degrees F.

Experience has shown that marine evaporators should be worked at a density of from $\frac{3}{32}$ to $\frac{4}{32}$, but for purposes of calculation assume $\frac{3}{32}$; then, in order to maintain that density in the evaporator, one-third of the total amount of sea water fed to the evaporator must be discharged into the bilges or overboard. Consequently, to produce one pound of pure steam, one and one-half pounds of sea water must be supplied to the evaporator, one pound of which is evaporated into steam, and the remaining half pound is discharged as hot brine; therefore, the total heat required to make one pound of pure steam is the sum of the heat in the steam and that in the discharged brine.

Temperature of steam at 16 lbs. abs....	216.3 F.
Heat in one pound of steam at a temperature of 216.3 F. above water at 80 F.	1099.4 TU.
Heat in half pound of brine at a temperature of 216.3 F. above water at 80 F.	68.1 TU.
Therefore the total heat required to produce one pound of pure steam is........ 1099.4 + 68.1 =	1167.5 T.U.



AN EVAPORATOR WITH TWO SETS OF COILS.

If we assume the boiler pressure to be 160 pounds, or say 175 pounds absolute pressure, with a corresponding temperature of 370.8 F., and that the temperature of the discharge from the evaporator coils is 250.4 F., being the temperature corresponding to fifteen pounds, or say thirty pounds absolute pressure, then the heat given up by each pound of boiler steam under these conditions will be 976 thermal units; and as we have already seen that 1167.5 thermal units are required to produce one pound of steam in the evaporator, this is equivalent to $\frac{1167.5}{976} = 1.19$ pounds of steam to be taken from the boiler.

As the pound of generated steam is passed direct to the hot well, and there condensed amongst the feed water, it gives up the whole of its heat above the hot well temperature $= 1099.4 - (120 - 80) = 1059.4$ thermal units; the drain from the evaporator coils is also led to the hot well and gives up $(250.4 - 120) \times 1.19 = 156$ thermal units, so that the

Steam from Boiler, Generated Steam to Hot Well.

Received by Evaporator.	Thermal Units.	Discharged by Evaporator.	Thermal Units.
Heat in 1.19 lbs. of steam at a temperature of 370.8 F. above 120 F. = 1106.4 × 1.19	1323.5	Heat given up to Hot well by Evaporator steam	1059.4
		Heat given up to Hot well by drain from coils	156.0
		Heat given up to Evaporator feed	40.0
		Heat lost in brining	68.1
Total..........	1323.5	Total...........	1323.5

net cost of producing one pound of pure steam, as shown, is that due to brining = 68.1 thermal units.

Perhaps a better idea will be formed of the cost of working the evaporator, under these conditions, if we ascertain the quantity of coal required to produce one ton of evaporator steam, and for this purpose the calorific or heat value of one pound of good coal may be taken at 14,500 thermal units; and assuming the boiler efficiency to be 66.6 per cent., which was about the average result obtained on the trials of the research committee of the British Institution of Mechanical Engineers, we have $\frac{14500 \times .666}{966} =$ 10 pounds of water evaporated from and at 212 F. per pound of coal; and as 9666 thermal units are available by the combustion of one pound of coal, the amount of pure steam generated by one pound of coal with this arrangement will be $\frac{9666}{68.1} = 141.9$ pounds, so that $\frac{2240}{141.9} = 15.7$ pounds of coal is the equivalent of the heat required to make one ton of pure steam under these conditions of working.

Steam Supplied to Evaporator from Boiler, and Steam Generated in Evaporator Discharged to the Receiver of the Low Pressure Engine.

In this case the generated steam from the evaporator is discharged into the steam chest of the low-pressure cylinder, and does work upon the low-pressure piston before it is finally condensed.

Again referring to the data contained in the report of the committee already mentioned it is seen that in economical triple expansion engines, about 17 per cent. of the total heat in the steam is converted into work; for the sake of simplicity, however, we will consider the efficiency as 18 per cent., and assuming that the power developed in each cylinder is equal, one-third of this, *i. e.*, 6 per cent. of the total heat is utilised in each cylinder. It, therefore, follows that (100—18) = 82 per cent. of the total heat is rejected; further, that the amount entering the steam chest of the low-pressure cylinder will be 88 per cent. of the total supplied to the engine, and of the total heat supplied to the low-pressure cylinder $\frac{6 \times 100}{88}$ = 6.82 per cent. is converted into work.

Let the pressure in the steam chest of the low-pressure cylinder be seven pounds per square inch, or, say, twenty-two pounds absolute pressure and the temperature of the evaporator feed, 80 F. as in the previous case:—

Temperature of steam at 22 lbs. abs....	233.1 F.
Heat in one pound of steam at a temperature of 233.1 F. from water at 80 F.	1104.5 TU.
Heat in half pound of brine at a temperature of 233.1 F. from water at 80 F...	76.5 TU.
Heat required to produce one pound of pure steam ....1104.5 + 76.5 =	1181.0 TU.

The equivalent weight of boiler steam necessary to produce the pound of evaporator steam may be found in a similar manner to the first, with this difference, that as the working pressure in the evaporator is higher, the drain from the coils must also be at a higher temperature; this, in practice, is generally about 292.7 F., or the temperature corresponding to a pressure of sixty pounds absolute; then the heat given up per pound of boiler steam at 160 pounds pressure and a temperature of 370.8 F. above 292.7 F. = 933.7 thermal units, so that $\frac{1181}{933.7}$ = 1.26 pounds of boiler steam are necessary to produce one pound of evaporator steam; and taking 120 F. hot well temperature as in the previous case the available heat per pound of boiler steam = 1106.4 thermal units, or 1106.4 × 1.26 = 1398.5 thermal units are passed to the evaporator instead of being employed in the engine in the performance of work, in which case 18 per cent. would have been converted into work as already explained, this amounting to 1398.5 × 0.18 = 251.7 thermal units.

We have also seen that 6.82 per cent. of the heat received by the low-pressure engine is capable of conversion into work therein; it therefore follows that 6.82 per cent. of the heat (above 120 F.) contained in the steam discharged from the evaporator to the low-pressure casing, or (1104.5—40) × 0.0682 = 72.6 thermal units are convertible into work, as compared with 251.7 thermal units if the boiler steam had been passed through the engines direct instead of to the evaporator and thence to the low-pressure engine. In other words as $\frac{306.8}{1064.5} \times 100 = 28.8$ per cent. of the total useful heat can be utilised in the low-pressure engine, the evaporator has practically given up 28.8 per cent. of the total available heat (above 120 F.) contained in the steam generated therein $= (1104.5-40) \times 0.288 = 306.8$ thermal units, the remaining 71.2 per cent. $= 757.5$ thermal units being rejected without useful effect in addition to that lost by brining; whilst on the other hand the heat contained in the water drained from the coils, namely, $(292.7-120) \times 1.26 = 217.5$ thermal units is usefully employed in raising the temperature of the feed as in the former case.

Steam from Boiler, Generated Steam to Steam Chest of Low Pressure Engine.

Received by Evaporator.	Thermal Units.	Discharged by Evaporator.		Thermal Units.
Heat in 1.26 lbs. of steam at a temperature of 370.8 F. above 120 F. = 1106.4 × 1.26	1398.5	Heat given up to	L. P. Casing by Evaporator steam	306.9
			Hot well by drain from coils	217.5
			Evaporator feed	40.0
		Heat lost by	Non-utilised Evaporator steam. ...	757.6
			Brining....	76.5
Total.........	1398.5	Total...........		1398.5

The net cost of producing one pound of pure steam is, therefore, the sum of the two quantities under the heading of the lost heat as shown above $757.6 + 76.5 = 834.1$ thermal units, so that in this case one pound of good coal, under similar working conditions as the first example, would generate $\frac{9666}{834.1} = 11.59$ pounds of pure steam, or $\frac{2240}{11.59} = 193.3$ pounds of coal are necessary to produce one ton of fresh water.

Steam Supplied to Evaporator from Boiler, and Steam Generated in Evaporator Discharged to Condenser.

In this arrangement it is customary to place a vapour or reducing valve between the evaporator and the condenser, so adjusted that evaporation will take place at about atmospheric pressure, the feed being at 80 F. as before.

Temperature of steam at atmospheric pressure	212 F.
Heat in one pound of steam at 212 F. above water at 80 F..................	1098.1 TU.
Heat in half pound of brine at 212 F. above water at 80 F	66 TU.
Heat required to produce one pound of pure steam.................1098.1 + 66 =	1164.1 TU.

which is equivalent to 1.15 lbs. of boiler steam.

As the steam generated in the evaporator is taken to the condenser, it forms one pound of pure water at the hot well temperature of 120 F., the total heat above that temperature (= 1058.1 thermal units) being carried away in the circulating pump discharge without any useful effect; consequently of the heat contained in the evaporator steam only that employed in raising the temperature of the evaporator feed to that of the hot well is retained, the remainder being carried away by the circulating discharge and lost entirely.

Steam from Boiler, Generated Steam to Condenser.

Received by Evaporator.	Thermal Units.	Discharged by Evaporator.		Thermal Units.
Heat in 1.15 lbs. of steam at a temperature of 370.8 F. above 120 F. = 1106.4 × 1.15	1269.0	Heat given up to	Evaporator feed	40.0
			Hot well by drain from coils	104.9
		Heat lost by	Circulating discharge.	1058.1
			Brining ...	66.0
Total.........	1269.0	Total...........		1269.0

The net cost of producing one pound of steam is, therefore, 1124.1 thermal units, whilst the combustion of one pound of coal would produce $\frac{9666}{1124.1} = 8.6$ pounds, and one ton of fresh water would require $\frac{2240}{8.6} = 260$ pounds of coal.

These investigations show that water may be obtained from an evaporator for a nominal expenditure of coal, or very wastefully, depending entirely upon the arrangement adopted, and taking as unity the amount of coal necessary to produce a given quantity of water when the evaporator steam is condensed amongst the feed water, then the relative amount to produce the same quantity when the steam is discharged into the low-pressure casing would be 12.3, and into the condenser 16.5, or, in other words, it takes sixteen and one-half times more coal to produce one ton when discharging into the condenser than when condensing the steam from the evaporator amongst the feed water.

With reference to the steam generated in the evaporator, there is no doubt that discharging direct to the condenser, although a cheap method as regards the cost of fitting up the apparatus on board ship, is distinctly the most uneconomical which could possibly be adopted, and although a connection to the condenser is convenient in port, yet, at sea it should never be used, as it is simply equivalent to a reckless waste of fuel. There is in the hot well a medium, viz., the feed water, which will readily absorb all the heat contained in the steam generated by the evaporator, and in such a manner that none of the heat so absorbed is lost; consequently, to adopt any other method is sacrificing possible economy.

As an example, take a triple expansion engine, indicating 1000 I.H.P., and using, say, fifteen pounds of feed water per I.H.P. per hour. Suppose that the auxiliary feed amounts to 4½ per cent. of the total, and that this is taken from the evaporator in the form of steam at one pound pressure above the atmosphere. Assuming the temprature of the hot well at 120 F. then, if the evaporator steam is condensed amongst the feed water at the hot well temperature, the amount that the temperature of the feed water will be raised can easily be calculated in the following manner:—

Total feed water = 15,000 pounds per hour and 4½ per cent. of this =675 pounds, leaving 14,325 pounds as the amount of water passing through the hot well at 120 degrees. Total heat of steam at sixteen pounds absolute pressure = 1178.4 degrees, and therefore the thermal units in the evaporator steam = $(1178.4 \times 675) = 795{,}420$.

Similarly, the thermal units in feed water from hot well = $(14{,}325 \times 120) = 1{,}719{,}000$, consequently the resulting temperature, after condensation, will be $\frac{795420+1719000}{15000} = 167.62$ degrees F. In the same manner, supposing that the amount of auxiliary feed was 5 per cent., the resulting temperature would be 172.92 degrees, and with 6 per cent. 183.5, and so on, showing that the extent to which this system of feed heating can be carried depends entirely upon the temperature at which the feed pumps will work satisfactorily.

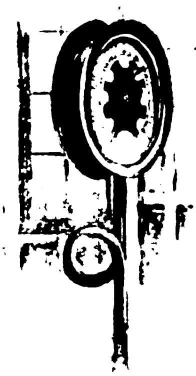
In the above calculations no account is taken of the drain from the coils of the evaporator, which would, of course, somewhat increase the temperatures given, but this increase would probably be counterbalanced by the loss due to radiation and initial condensation in the steam pipe leading from the evaporator.

Evaporators are sometimes used as condensers for winches when in port, and certainly seem well adapted for the purpose. The cooling surface required is usually in excess of what is necessary for evaporating purposes; consequently an increased size of evaporator has to be fitted. In order to minimise this increase in size, a combined apparatus has been designed, the feature of which is the utilisation of the steam space of an evaporator for the reception of a set of condensing coils, such set being a duplicate of the set of evaporating coils in the lower part of the vessel for which they are available when required. In the illustration on page 59 the coils are divided into three similar sets. When evaporating, two sets are in use, and one set is available as spare; when condensing, this spare set is fixed in the steam space so that the available surface when used as a condenser is 50 per cent. greater than the surface when used as an evaporator.

On passenger and better class boats, winch condensers or exhaust tanks are a necessity in order to overcome the delay and inconvenience caused by the escaping steam, but it is the donkey boilers which reap the great benefit as, in cargo boats especially, they never have a large margin in size, and being fed direct from the sea, thereby causing an ever increasing accumulation of scale, they constitute not the least of the worries on board a steamship.

BOILER INSURANCE AND INSPECTION.

By W. A. Carlile.



BOILER insurance differs from life or fire insurance in several ways. It differs from the former in this that life is sure to end some day, and the money will have to be paid; but a boiler is not bound to explode, and no liabilities may ever have to be met. As the Chinese pay their doctors only when they are well, and stop payment when they are ill, so a boiler insurance company is expected to ward off all symptoms of decay, and when it fails to do so, it has to suffer for it.

But as this liability is only from year to year, the company is at liberty to decline insurance at the year's end, if those in charge of the boiler refuse to act on advice which would prolong its life. When this can no longer be lengthened, then the company advise painless extinction to the boiler's existence. No life insurance company would venture to suggest this to those insured.

With fire insurance, if the conditions of the insurance company are violated, the policy is void. With boiler insurance no such conditions are laid down, so that if a boiler owner should, with malice aforethought, blow up his boiler, the insurance company would still have to pay, leaving the culprit to answer for his misdeeds to a legal tribunal, which punishes for culpable ignorance or carelessness. With fire insurance the element of risk is always present; with boiler insurance it is almost eliminated by inspection. During the past eleven years only one insured boiler in every 11,000 in the United Kingdom exploded annually.

With insured boilers, only one death annually to about every 14,000 boilers occurred. With boilers not insured the death rate was nearly three times as high.

This diminution of disaster is wholly due to the watchful care of the insurance companies, including the chief engineer and his staff, as well as the boiler inspectors, who discover and report upon defects.

The work and the responsibility are apportioned as follows:—The inspectors have to report upon defects. If they do not discover them when they should, or if they do not draw special attention to them in their reports, the company holds them accountable. They have also to make drawings of the boilers, showing the thickness of every plate, particulars of rivetting and of staying, and of the setting of the boiler in its brickwork.

These reports and sketches are sent in to headquarters. There the chief engineer and his assistants determine the safe working pressure of the boiler. They note the defects pointed out by the inspector, and his opinion on them. Then they form their own opinion, which usually, though not invariably, coincides with that of the inspector, and they report to the firm accordingly, giving advice as to what repairs, if any, are required. The owner is not obliged to act on their advice, but, as before stated, by such neglect he will be held accountable by the government if any accident should occur.

Insurance agents sometimes turn this fact to their own advantage. One agent asked a firm to insure their boiler. They refused. Then the agent asked if they would allow an inspector to look at their boiler, as it would cost them nothing. Owing to the latter proviso they gladly agreed. An inspector then called, and found the safety valve out of order. This was reported to the firm. The agent again called, and asked them to insure. They refused again, on the ground that they were not going to spend money on what they considered to be a wholly unnecessary repair. Then the agent mildly suggested that if any accident should happen, the government might take an unpleasant view of the case, after they had seen the inspector's report. The result was that insurance was agreed to on the spot.

Though filling different posts, the inspectors and the office staff form one indivisible whole. On any given day hundreds of inspectors are moving here and there over the length and breadth of the land, some speeding along in railway trains, some being borne hither and thither in the heart of busy towns, and some on foot, passing along through flowery lanes, in forest or in field. They are far enough away from their head office, but at the same moment that the connection is apparently severed, hundreds of communications are passing through the post, bearing instructions from the chief engineer to the inspectors, and reports from the latter to the former. Thus the insurance company becomes one organic whole.

But, at the same moment, another host of letters is passing between the company and the insured. In this way the company is merged into a still greater unit, and becomes part of the great world of industry. Thus, from year to year the insurance companies protect the lives of thousands who, perhaps, never heard of a boiler insurance company, or, hearing, heeded not of the work that was being done silently and well.

But now let us look at the work of the inspectors themselves, the men upon whom so much depends, for if they fail in their duty, all must suffer in consequence. Some people imagine that the work of an inspector is dangerous to himself. This is not the case. He goes into an empty boiler, and we have not yet heard of such a boiler exploding while he was inside. He is only to a limited extent exposed to great heat, for if a boiler is too hot for him to inspect, it was too hot for the men to clean, and if it is not cleaned he does not examine it.

As a rule, an inspector suffers more from cold than from heat. In one case, an inspector had to examine a boiler in a field where both boiler and field were covered with snow. Then he had to make his ablutions afterwards in the snow, with an inclement wind blowing.

He has also a disagreeable experience when a boiler is almost too small for him to go through, and yet not small enough to justify him in abstaining from the attempt. Again, he may have to examine a wet boiler, or wet flues, which are much worse.

When he gets to a boiler he has to be keenly on the alert, for the faults which he has to discover,—and he has first to discover if there are any,—do not obtrusively present themselves. They have a faculty of modestly keeping out of sight, and of trying to minimise their own importance. Of this peculiarity he is well aware, but his determination is, that if he can help it, they shall no longer be suffered to "blush unseen."

Three defects which he often finds are corrosion, cracks and grooving. In certain places and positions these are harmless; in others they may be extremely dangerous. Corrosion is usually easily found, but where a boiler has not been properly cleaned, the inspector has to use all the faculties of a trained eye and judgment, so as to discover if it exists beneath the scale that hides the plates. When he suspects its existence, he has to knock away portions of the scale so as to see the bare iron.

It is a curious fact that in a Galloway boiler, if there is any corrosion present, it is almost always greater in the water pockets than anywhere else. In consequence, some inspectors go straight to these pockets, and according to the depth of corrosion there, they can form a fairly accurate estimate of the general condition of the boiler before they go carefully through it.

If corrosion appears to be about half way through a plate, the inspector suggests drilling. From this the exact thickness of the plate is ascertained, and its working strength becomes known. The hole is afterwards closed with a rivet. If the corrosion is nearly through the inspector usually tries to knock a hole right through. This saves a great deal of argument about the condition of the plate, and usually forces necessary repairs upon an unwilling owner.

One inspector knocked a hole through a plate on the shell. The owner was very angry, and told the inspector that his willful stoppage of the boiler had entailed incalculable loss upon him. The inspector suggested that he might have had loss of life instead, and that this would have been worse than loss of money. The owner was not convinced, because, as he seldom came near the boiler, it would have been somebody else's life. Presently the inspector had finished his work, and, quite indifferent to the ravings of the other, was walking away, when he was asked in a more reasonable tone if no temporary repair could be applied. He turned with alacrity. "Certainly, a wooden plug." A gleam of hope illumined the scene.

"A wooden plug, properly driven in, would stop the hole temporarily, but as soon as the pressure comes on,—it will blow out again." The climax was too great, and the owner was at once brought to a more business like state of mind.

The great enemy of the inspector is smooth corrosion. A plate may look perfectly sound and smooth, and only a close examination of its edges, and the laying of a straight-edge along it, will reveal the wasting, which may happen to be very serious.

Another erratic and delusive effect of corrosion is this:—At one inspection a plate is noted as being deeply corroded. At the next inspection the corrosion is apparently much less. The iron cannot have come back in its place again to fill the holes, and the inspector is liable to conclude that he was mistaken at his previous inspection. But he was not mistaken, and if he is not careful he will be mistaken now.

The fact is that the corrosion has ceased to attack the bottom of the pittings, but is taking a turn at the surface of the plate. Thus, though the corrosion is really greater than before, it appears less, for the pittings are not so deep as they were. These are a few of the almost innumerable vagaries of corrosion in boilers.

Cracks have also to be looked for. In the shell of a boiler these may be a serious matter. In a tube they are, as a rule, of less importance. The worst cracks are seam-rips. These run from one rivet hole to another, and unless there be a leak, it is usually almost impossible to discover them. Fortunately, however, there is usually a leak, even though slight, and the vigilant inspector is warned in time. Cracks from rivet holes to the edges of plates are, unless numerous, of little importance. Cracks that run through the rivet hole for a couple of inches into the plate are common. If few in number they are not serious; but a hole should be drilled at the end and a rivet inserted. This prevents the crack extending.

As the tube in a Lancashire or Cornish boiler is in compression when under steam, cracks, as a rule, are not likely to lead to explosion. In one boiler there was a transverse seam-rip on the tube. It ran from one rivet hole to another for a length of fourteen inches. There was no leak. The inspector told the owner that there was no danger, and the boiler was worked for three or four years afterwards without any farther development of the defect.

With grooving, everything depends on its position. On a front end plate it is extremely common, and is usually quite harmless. Even if a crack appears at the bottom of the grooving and goes right through the plate, it is still not of urgent importance. In one case a boiler was deeply grooved on the end plate. At the bottom of the grooving was a crack, and through this crack was a leak on the front of the boiler. The crack was six inches long. The firm studied economy, and because the inspector could not say that the crack was dangerous, they would not stop the leak, which went on for several years without getting any worse.

When grooving is on the shell of a boiler then the crack which usually accompanies deep grooving may develop suddenly and disastrously to life and property. Longitudinal grooving on a shell is the most insidious and dangerous form of grooving known, and on account of scale it is usually very difficult to discover. Fortunately, however, it is rare. Transverse grooving on the shell is also rare. But it is more common than longitudinal grooving, though of less importance. Grooving on a tube is more common, but of even less importance, though, if it is deep, repair is advisable, as cracks and leaks might appear as well, necessitating the stoppage of the boiler at an inconvenient time.

Of these three defects,—grooving, cracks, and corrosion,—cracks are chiefly due to strains of expansion and contraction. Where corrosive action is present, the cracks develop into grooving. Surface cracks lead to groovings, which, when deep enough, encourage the cracks to go quite through the remainder of the plate, thus causing leaks. The three defects named are closely related. The bright surface of a crack tends to corrosion, and where corrosion is present, the thinning of the plate tends to its cracking. Grooving and corrosion are also closely inter-related.

But the search for these defects in boilers, though an important part of an inspector's work, is still only a part. He has to examine the staying of each boiler, and take note of all particulars connected with the gussets and other stays. The strengthening of tubes must also be noted, whether these be Adamson's joints or other means.

Boiler fittings have also to be looked to, and the brickwork setting of the boiler must be examined, generally and in detail. This may be considered as of secondary importance by the uninitiated, but some of the most disastrous explosions have occurred through brickwork hiding defects on the shell.

The reason why rupture of the shell is so disastrous, is because of the reaction from the outrushing steam. If tubes give way, a boiler practically retains its position. If the shell gives way, the boiler usually soars into the air, wrecking not only the premises that it leaves, but those on which it alights. Thus, as a departing or a coming guest, it is equally unwelcome. A rocket is lit at its lower end, and as the flame rushes down, the rocket rushes up. It is the same with boilers, and according to the place of initial rupture, is their first movement determined, though what their subsequent movements may be, as they are torn and riven into a hundred fragments, no mortal man can predict.

The one part that has been overlooked is always the part that goes wrong. Hence, an inspector has to do his utmost to see all parts, though he has to contend with scale within, and brickwork without. He has to suspect every part of the boiler to be wrong, unless he has proved it right, and rarely is it that fault has to be found with him for not discovering what, to the untrained eye, would be absolutely undiscoverable.

The conditions thus far considered are related to the boiler itself and its surroundings. But there are also human conditions to be taken into account. We have already glanced at some of the peculiarities of boiler owners and attendants. Let us look a little more closely at these!

It may be said, once for all, that, as a rule, an inspector meets with courtesy and kindness wherever he goes, provided that he display the same qualities himself, as he almost always does.

We have the parsimonious owner. Of course, some men who are on the verge of bankruptcy must try and economise to the uttermost. As a rule, however, the most greedy to save are those who have plenty. They will use all kinds of pressure to get an insurance company to tell them that their boiler is not in immediate danger. To attain this end,—which would clear them in case of a government inquiry,—they try to "talk over" the inspector, while they send to his company threats of transference of the insurance to some rival company.

But a boiler gets too bad to be run longer with safety, and repair is ordered. In such repair it is usually quite impossible to remove only the defective part. The whole plate has often to come out. When this happens, the inspector has to meet bitter reproaches as to the needless expense that he has brought upon the firm, in having a plate removed which was "as good as new," this being the stock phrase.

When the parsimonious man is a bully in addition, then the scene is more lively; but if the inspector keeps his temper, he is completely master of the situation, and can meet all bluster with calm indifference.

Then, again, we have the smooth spoken and apparently friendly owner. He sometimes happens to be the bully with a sheepskin drawn over his more alarming and wolfish proportions. His gentleness and affection are usually prompted by the fact that he desires to sell one of his old boilers. The boiler is probably so bad that it will hardly hold bricks, much less water, but the worse it is, the more do his amiable virtues blossom forth. He wants to get the inspector to give the most favourable report possible, and there are usually veiled hints about the inspector sharing in the profits. As, however, such profit sharing is never hinted at with passable boilers, the inspector has to be, if possible, more strict in his inspection and uncompromising in his report than he usually is.

Then we have the owner or manager who indulges in lies. One inspector went to see a boiler at Christmas time. This had been arranged beforehand with the owner. The inspector found the works closed. He went to the caretaker, who, having received no orders, would not admit him. He reported accordingly. To his amazement the owner denied that the works were shut up, denied that any one had been to the caretaker, and affirmed that the inspector had never come near the place. He, himself, as a matter of fact, had forgotten all about the arrangement, but would not admit it, for fear the insurance company would ask him to pay for the wasted time of the inspector.

At another place an inspector found the flues not half cleaned. The men said they had not been allowed time enough for the cleaning. The report came round in due course. Then the manager declared that the boiler was thoroughly cleaned, and that he had asked the men personally, and they confirmed this. The inspector went back, saw the men, and learned from them that the manager had never been near them.

Then the inspector went to see the manager. He was busy. Next day he was out, and so on for every day for a week, till the inspector gave up in despair his search for the vanishing gentleman.

Among attendants, the most aggravating is the man who says his boiler is all right, but who, as soon as the inspector emerges from the caverned gloom, proceeds to ask him, in a mysterious and tragic way, if he has noticed this and that. In not one case in a thousand is there anything wrong which has been missed by the inspector, but the annoyance is none the less on that account, and may lead to the greater part of an inspection having to be made over again.

One man told an inspector, who had just completed his inspection, that there was a dangerous defect in the boiler, but that as he was only an attendant, it was not his business to say anything about it. After about an hour's questioning, he relaxed so far as to state that it was under the bottom of the shell. In went the inspector again to the flue, but he came out without finding anything. Then the attendant's report grew still more alarming, and at last he permitted himself to state that there was a dangerous seam-rip under the bottom. Another search by the inspector failed to find it. At last the man was persuaded to go in and show the place, but he could not find it himself.

Then we have the friendly, but garrulous, attendant. If he is asked whether he feeds with town water or canal water, he will give a long and irrelevant dissertation on feed waters when he was a boy, or relate the history of the whole country side, in order to explain why the canal water was used once, but is not used now, though in the end he quite forgets to say what is used.

We have also the attendant who knows everything and who instructs the inspector upon engineering in general, and upon boilers in particular, till the inspector dives out of his sight through the manhole opening.

But the different types of men met with lead to the different types of works to which inspectors go. These cannot be specified, for they range over an immeasurable area. Inspectors go to boilers that are helping to make pins and needles, and to others that are used for forging chains and anchors. Cotton spinning, and iron making, bicycle works and sewage works alternate in bewildering profusion with a thousand other industries. In these different kinds of works we usually find different kinds of boilers, though there is no accurate rule why one kind of boiler should be used in any works in preference to some other kind.

If, however, the works are very small, a vertical boiler is generally employed. If the works are larger we may find a Cornish, or one-flued boiler. If still larger, we may have a Lancashire or two-flued one, or, in its place, a Galloway boiler. In rolling mills and iron works we have the Rastrick or up ended boiler, which utilises heat that would otherwise be wasted. Where fuel is cheap, long cylindrical, egg-ended or dish-ended boilers may be found, while for agricultural work the portable locomotive type is common.

Where pressure, and not size, is to be the dominant factor, we have, at the lower end of the scale, the vertical, the plain cylindrical (whether egg-ended, flat-ended or dish-ended), the Rastrick and the Cornish. The Cornish, or one-flued boiler, could as easily be made into a high-pressure boiler as a Lancashire, or two-flued one, but it is usually smaller than the Lancashire, and, as a matter of fact, high-pressure and low horse-power seldom go together. Therefore, the Cornish remains among the low-pressure boilers, or those up to say sixty pounds per square inch, and the higher pressure ones are the Lancashire, the water tube boiler and those of the locomotive type. The two latter, at least, may be found to range as high as 200 pounds per square inch.

We have already glanced at different types of men and their peculiarities. We shall now look at the different types of boilers. "Like master like man," holds true with boilers, and whether we regard the boiler as the servant of the man, or the man as the servant of the boiler (and a good deal can be advanced for both views), we shall find that iron and steel, like men, have special and definite ways of going wrong, just as much as mind and muscle.

Look, first, at the vertical boiler! Its advantages are these:—It requires no setting, is easily portable, and does not readily go wrong. When, however, it fails, it is usually owing to grooving in the furnace, just above the bars, and sometimes to corrosion there, as well as higher up in the firebox. In one case, where two cross tubes were so made as to touch each other, a hole was fretted through them after a few years wear. On the water side, corrosion usually attacks the uptake about the water level. External corrosion also frequently sets in below the mud-holes owing to joints not being made tight.

Then we have the Cornish, or one-flued, boiler. This, in many cases, is found grooved on the front end plate, and sometimes on the back end plate. When the grooving gets about half way through, a cover patch is usually rivetted on externally. Internal corrosion, when present, is usually along the upper half of the tube, and all round the shell at the water level, for about a foot in vertical width. Edge cracks are sometimes found on the tube above the fire, and occasional distortion of the tube is not unusual. If the distortion is barely perceptible, it is left alone. If greater, the plate is heated and put back with a jack, or, still better, renewed. If still greater, the plate has to be cut out. The chief fault of the Cornish boiler is the difficulty in cleaning it. As a rule, the lower part of the tube and shell is never properly cleaned.

In the Lancashire, or two-flued, boiler, we have grooving similar to that found in the Cornish. The other defects also of the Cornish boiler are reproduced in the Lancashire. Though the bottom of the shell and tubes are accessible for cleaning, yet the water spaces all along the boiler, at each side, between the tubes and shell, are rarely or never properly cleaned.

Galloway boilers (or those in which the two furnaces run into one large kidney-shaped tube in which are many cross tubes) are, as a rule, less liable to grooving on the end plates than the Lancashire or Cornish type. The cross tubes, however, are difficult to clean. The large heating surface of these tubes promotes circulation, but their liability to scale largely discounts this advantage. This type of boiler meets, more nearly than any other, the conditions required by a Lancashire boiler, and hence these two may be considered as rivals for public favour.

The water tube and the locomotive types of boiler are usually employed for the highest steam pressures; the former for higher horse-power, the latter for lower. Also, where horizontal space is limited, the water tube boiler is often the best. Its practical non-liability to disastrous explosion makes it also one of the best types for the basement of a valuable or a crowded building. The removal of scale from the tubes is, however, not always easy. Bulging of the tubes over the fire is of comparatively frequent occurrence, but if this gets very serious, leakage usually gives warning of danger, and the defective tubes can be renewed in time.

As the Lancashire and Galloway boilers are akin, so the water tube and the locomotive types are each prepared to do the work of the other. The larger boilers of the locomotive type run their rivals closely, for their advantage is that they require no special brickwork setting, and are more compact. The firebox of the locomotive is, however, liable to many defects, such as leaks, bulges, cracks and corrosion. With care, these can be minimised, but they stand to its disadvantage when the locomotive type is compared with the water tube variety.

All the above boilers claim to be fuel saving. But there are cases where fuel is abundant, and its economy in use, therefore, a secondary matter. The cost of the boiler has then become of more importance than the cost of its coal. As a result, we have the plain cylindrical boiler, leaving the town for the country where coal is cheaper. It is well that it should pass from the more crowded centres of industry, for these boilers are far more liable to explosion than any other kind. They are, it is true, easily kept clean, but they are not easily kept tight. Being more susceptible to the varying strains of expansion and contraction, edge cracks, and seam-rips in their plates, are often found. In all probability this type of boiler will, in a few years, have followed to the silent tomb, the old wagon boiler, the rectangular flat sided boiler, and that curious boiler entirely of brick, which was made and worked successfully in the early and low-pressure days of steam power.

The Rastrick, or up-ended, cylindrical boiler, aims at economy of ground space, at cheapness of first cost, and at the utilisation of waste heat. But,—as in the case of the plain cylindrical horizontal boiler, which pairs with it,—the cost of frequent repair becomes a heavy item. The heat that acts upon it is so intense that its plates bulge and buckle, and its seams crack. For various reasons this boiler is not usually well cleaned, and the heavy scale which is allowed to accumulate within it, tends to aggravate and accentuate the above defects.

Corrosion also is frequently found within such boilers.

These, then, are the main types of land boilers, and the principal defects which are peculiar to each. Other defects are common to many, or all of them, such as damage caused by external damp. The water which causes external corrosion, wherever there is a leak, may not itself be naturally corrosive, but good water outside a boiler causes more corrosion than bad water inside of it. The effect appears to be due to the alternations of wetting and drying.

If we look at a telegraph pole we may sometimes see the wood deeply eaten into, just above the ground. Below and above this the wood is sound, but between earth and air, or wind and water, the wasting appears. In the interior of a boiler we may trace the same action. Along the line of water level, when the water is sometimes high and sometimes low, corrosion is frequent, and it is still more frequent at the water level around the uptake of a vertical boiler.

Dampness under brickwork is a common cause of external corrosion. The brickwork both hides the dampness and retains it in its place. Composition covering on the top of a boiler, usually peels off when there is dampness below, but when there is a thick coating of gas tar over all the softening of the composition is not seen, and the leak is not easy to discover.

Again, composition upon vertical boilers, or upon the domes of horizontal boilers, is rarely held close up to the plate. It falls back and leaves a clear space, in which the corrosive effect of damp may have free play, while the composition itself remains dry. Iron sheeting or wooden lagging is about as bad as brickwork, and few would suspect how serious may be the mischief going on beneath the gaily painted covering which brightens the boiler room.

As opposed to this, a curious case may be cited. For two or three years, water from condensed steam had been running down under the covering of a multitubular boiler. The danger was repeatedly pointed out to the owner. He, however, objected to the cost of removing the lagging, but at last the insurance company got so pressing that he had it removed. The inspector called, and was met with a storm of reproaches from the owner because no corrosion was visible.

"What, then, do you want?" queried the inspector. "If there had been corrosion you would have been angry at the cost of the repairs, but now, when you have no repairs, instead of being pleased, you are very much dissatisfied." The owner, upon this, moderated his transports, and then the inspector proceeded to show that the other could take no credit to himself for the satisfactory result, which was due to the following cause.

The water, before running under the lagging, had trickled along the lower guide of the crosshead of the engine mounted on the boiler. This surface was, of course, always lubricated, and the water carried some of the oil with it. The latter, on reaching the boiler plate, had hardened into a protective covering for the shell, and over this the water had passed harmlessly, leaving the plates intact.

As an instance of the occasional difficulty of detecting external dampness, even when the manager has the plates bared of brickwork when requested, the following case is instructive. At a certain gasworks there was an egg-ended boiler. The manager, being a careful man, had the flue covers removed for inspection, and as much of the seating as was possible. Everything appeared in good order to the inspector, and the boiler was restarted.

A few days afterwards, the inspector was summoned back by telegram, for the boiler had begun to leak badly at the back end. This back end abutted into the base of the chimney, and to get at it the chimney, which was about thirty feet high, had to be pulled down. The back end of the boiler was then found to be deeply corroded all over.

The inspector had sounded those plates on the inside, but owing to the brickwork on the outside resting upon the boiler, the sound of the hammer was deadened, and no suspicious ring could be heard. Outside the roof of the boiler house, and close to it, a small exhaust pipe opened into the chimney. The draught had not been sufficient to carry up the chimney all the exhaust steam, and, as a result, there had been a constant fine rain falling down the chimney, soaking through the brickwork at the back of the boiler. This was responsible for all the damage.

Whenever grease gets into a boiler the evil effects that follow are common to every type. In the old days, grease used to be purposely introduced in order to prevent scale and most of us have heard of the man who was sent to clean a boiler, and who made himself so comfortable that he fell asleep inside. He was forgotten, and the boiler closed up and set to work. After the usual lapse of time, boiler cleaning day again came round, and to the astonishment of every one the boiler was found to be free from scale. The mystery was, however, explained, when the bones of the missing man were found at the bottom. It is, however, more than doubtful if any other kind of animal or vegetable fat would have produced such surprising results, and boiler scalers are not available every day for such a purpose.

As illustrating the effect of grease, the experience may be cited of one manufacturer in the earlier days of boiler insurance. The fusible plug over the fire one day melted out. The attendant insisted that he had plenty of water in the boiler at the time. A new plug was put in, but it blew out as the other had done. A third was tried, but with the same result. Then the fusible plug was verbally consigned to a remote region, and the hole was filled with an iron plug. After that, when the boiler was at work, the furnace crown bulged down in several places.

The cause was then traced to the exhaust injector, which had been putting greasy matter into the boiler. This was discontinued, the fusible plug,—which in its dumb way had been trying to explain matters,—was reinstated, and no further trouble was experienced. One strange part of the whole affair was that no trace of grease was ever discoverable on the boiler plates.

It will, as a rule, be found that when bulging is due to shortness of water, the bulge is on the top of the tube, but when due to grease bulges are found to the right and left of the furnace crown.

Scale also is common to all types of boiler, and many are the attempts made to get rid of it. These would require a special article to themselves, but one attempt, striking in more ways than one, may be noted in passing. A boiler owner in Birmingham had heard that petroleum would remove scale. He considered that, if mixed with the feed water, a large part of the costly fluid would be wasted, and so, being of a frugal mind, he decided to have the interior of the boiler painted with it.

A man was set to the work. After he had applied the petroleum over a considerable part of the surface, he left the boiler at the dinner hour. Then he came back, and with his light attempted to enter. It was simply an attempt, for before he had got half way through the manhole there was an explosion of the petroleum vapour and he was blown out of the boiler several feet into the air.

But time fails to tell of other defects, such as sprung seams of the shell, due to accumulations of scale, and consequent overheating, of expansion joints that don't expand, of safety valves sticking, and of feed valves causing boiling water to feed the wrong way. Enough, however, has been said to show, in outline, the working of boiler insurance companies.

We have glanced at the responsibilities resting upon these companies, and at the skillful organisation by which inspection is made possible. We have considered the difficulties to be met and the obstacles to be overcome, if explosion is to be prevented, and though we know that such accidents can never be wholly got rid of, yet we also know that a long step has been made in that direction by boiler insurance companies and their inspectors.

Current Topics.

MANY years ago an engine, built by Corliss, was set up in a rolling mill in one of the Western American cities. It was, in several respects, an exceptional engine, different in a number of particulars from the regular Corliss design, and has only once or twice been duplicated. After running for four or five years, it was taken down and erected in another city, and the engineer in charge found that one of the dashpots needed renewing. An order was at once sent to Mr. Corliss for the dashpot castings in order to fit up a new set. In due time there arrived by express a box, and the engineer, on opening it, found, much to his indignation, instead of the castings, a dashpot, bored out, bolt holes drilled, seat faced off, and everything finished, ready for putting on to the engine. His first impulse was to consign the thing to the scrap heap and order another casting for, as he remarked, "any fool should have known better than to send a finished pot 1500 miles with the expectation of its fitting an old engine." However, the thought occurred that there might possibly be metal enough in the flanges to enable new holes to be bored, and he, therefore, concluded to try the thing in its place, and was much astonished to find that it went on just where it belonged, with bore and bolt holes coming exactly in line. That was at a time when interchangeability of parts in machinery was not so common as it is now and when its existence in connection with small details might well have been a matter of wondering comment.

WE are often wont to think that in these days of scientifically trained designers there is less of the cut-and-try in constructive mechanics and more of scientific proportioning; but there are some glaring examples of the very opposite. Every one can remember the fearfully and wonderfully distorted shapes of the earlier bicycles and one has only to pick up an old catalogue or glance through the advertising pages of any of the leading magazines of a few years ago to be reminded of the outrageous defiance of all rules, mechanical and artistic, which those vehicles exhibited. One can scarcely believe that any attempt whatever was made to ascertain the forces or analyse the strains upon either frame or driving gear, and the present light and stiff frames and carefully proportioned propelling gear are the result of many trials and failures,—a "survival of the fittest" rather than an "evidence of design." It is difficult to avoid the conclusion that a large sum of money and a vast amount of human energy might have been saved had just a little knowledge of mechanical design been infused into those early efforts, and, indeed, there are wheels now on the market making claims for superiority upon points which, to the engineer, are obvious mechanical defects, so that the cut-and-try stage cannot yet be considered as altogether past.

ONE of the most annoying things about many of the handbooks and "pocket books" of engineering information is the lack of definiteness in the original data of the formulæ and rules which they employ. Having recently had occasion to look up some information concerning the performance and efficiency of hydraulic rams, it was found that in nearly every instance the authority consulted referred to the height to which the water was forced, without stating from what point this height was measured. In some instances it appeared that the height was taken from the level of the ram itself; in others from the level of the original water supply; but in every case the seeker after information was left to hunt this out for himself, and in no case was the information given so clearly as to make him feel that he had it right after all. That there is ample room for improvement in such points nearly every one will admit, and those who are not yet of that way of thinking will soon become so after a few bits of such experience.

Two articles in an issue of the *Army and Navy Journal* of several months ago shed light in a most amazing and contradictory manner upon some of the features of the line and staff contention that is now progressing in the United States Navy. One of the articles is an account of a convention of naval militia officers, held in the city of Baltimore; the other deals with the position of the naval engineer corps, being a review of some essays published in the *North American Review*. From the reported proceedings of the militia convention it appears that the United States Navy Department and the line officers of the navy are labouring with great zeal to build up the naval militia and make of it a reserve from which officers may be drawn in time of war or emergency. From the *North American Review* papers it is learned that the same navy department and the same line officers are putting forth their best endeavours to prevent the engineers and other staff branches of the regular navy from taking any part in the management or control of the navy in either peace or war. Civilians who may get three or four days of drill upon a man-of-war each year are thus pronounced eligible for all the degrees of rank and command in the service, but officers of the service itself, many of whom have been trained to the naval life and discipline from youth, are not eligible!

OFFICERS of the naval militia are good average representatives of American professional and business life; they are lawyers, mill owners, bank clerks, engineers of different specialties, merchants, etc., sufficiently prosperous to afford a fad, and patriotic enough to direct that fad into the naval militia channel. The list of the militia membership shows that the lieutenant-commander of one of the battalions is a physician of the city in which the battalion is located. The officer concerned is, doubtless, as well prepared for naval administration as any other officer of his command, while his knowledge of medicine and surgery would stand him in good stead on a war vessel, where, other things being equal, he would be the more useful and desirable officer of the two. When war occurs and he takes his place as commander of a gun vessel, which is what he is in training for, he will find under his command a veteran naval surgeon who, for twelve or fifteen years or more, has been in daily contact with the regulations and discipline of the service, but who is declared by the Navy Department and the line officers incompetent to exercise command, even over the nurses who attend his sick. Which of the two doctors in the nature of things is more apt to be the better naval officer when they meet, and why should line officers, while striving so bravely to make a commander of the civilian, strive equally hard to prevent his naval confrère, under far better opportunities, from developing in the same direction?

PAYMASTERS and their clerks are appointed in the navy from civil life and come from professional business classes that very largely predominate among the officers of the naval reserve. They are, therefore, quite as competent as the latter to acquire the military drills of the navy and the habit of directing men and guns; but, as a plain fact, they are not permitted to learn either, and, incredible as it appears, they are actually without duties or stations in the organisation of ships' crews for battle! Here we have two educated men, wearing officers' uniforms and filling officers' positions year after year on board armed ships, who are denied the right to add to the fighting qualities of those ships by contributing their abilities, and who, in battle, must hide somewhere out of the way like non-combatant women and children. And this while the Navy Department is annually expending many thousands of dollars to make combatant officers of similar gentlemen by giving them a few days' drill and a chance to see a war vessel once a year.

WHEN we come to the naval engineers the situation is even more contradictory and absurd. For thirty years United States officers of the engineer corps have been educated at the Naval Academy under the same system and by the same methods that are used for training officers for the line. They are subjected for four years to a code of discipline and military ethics equalled in rigour nowhere in the United States, except, possibly, at West Point; they begin the acquirement of habits of command from the day of their admission to the Academy by being obliged to act as squad and section leaders; many of them have been company commanders in the cadet battalion; many others have been junior line officers, for one cruise at least, and have exercised all the so-called military functions of that branch. It would appear, then, that the charge of being unqualified for command from lack of early training cannot be directed against this corps; but it seems to be made nevertheless. One of the *North American Review* essayists says that there has always been "a steady determination that the engineer should have no part in the military organisation." The opposition appears to have no logic behind it, and exists only because one part of one branch of the naval service proposes to reserve for itself all the honours of the service, no matter what talent the service may lose in consequence.

UNLIKE the unfortunate paymaster, the engineer does have a station in action, and an important one at that, for no objector in the ranks of the line has yet gone so far as to propose dispensing with the use of machinery and hiding the engineers away in battle for fear they will contribute in some way to the success of the fight. In the daily exercise of his duties the engineer does command men, and many of them, though the navy regulations solemnly declare that he cannot and must not do this. In fact, he appears to practice by the exigencies of his position all the functions that the line officers claim belong solely to themselves, and why, in common sense and in the interest of naval efficiency, the regulations do not give him the authority to do what he actually does do every day, instead of denying that authority, is quite incomprehensible. All this present fuss between the line and engineer officers of the United States Navy seems to hinge right on this point. The engineers are striving to get from Congress the legal right to perform duties which their commissions require of them, and the line officers, without arguments to support their position, simply say that they do not want this done.

THE young line officers these days have a great deal to say about the "efficiency" and the "best interests of the service," which they promote according to their lights by aiding the development of the naval reserves on the one hand and by trying to strangle the development of the real navy on the other. In one case they select a civilian engaged in the peaceful pursuit of commerce or a profession, give him a week's drill on an antique monitor, put a commander's uniform on him, and pronounce him qualified for the command of a national vessel in time of war. In the other case they complacently rest upon the bald assertion that the engineer, trained in their own school, is unfitted by his training for any part in the military organisation of the service and must not be allowed rank, title, or authority as a naval officer. The public is certainly entitled to an explanation by the Navy Department why the naval officers of the staff corps cannot learn in, say, ten years some of the professional mysteries that the gentlemen of the naval reserve absorb satisfactorily in as many days. Also, whether it really advances "the best interests of the service" to deny to nearly one-half of its commissioned officers all part in its military organisation, and at the same time to depend upon very superficially drilled citizens for the supply of officers that a war might make needful.

THE most notable power transmission plant yet attempted, both from point of view of amount of power and the distance of transmission, is under way in Utah, in the United States. The Pioneer Electric Power Company, of Ogden, Utah, recently placed a contract with the General Electric Company for a complete 5000 horse-power three-phase plant, covering a transmission of thirty-six miles from Ogden to Salt Lake City. The power will be obtained from the fall in the cañon of the Ogden river, at a point almost within the limits of the city of Ogden. Across the head of the Ogden cañon a dam is to be thrown, and an immense storage reservoir formed, which will cover fifteen or twenty square miles of a valley in the mountains. From this dam to the power house is a distance of nearly six miles. The water will be carried through a six-foot pipe of wood for about five miles, while for the rest of the way it will pass through a six-foot pipe of rivetted steel. The effective head of water at the power house will vary from 400 to 450 feet and the full capacity of the pipe line will be 10,000 horse-power. Two duplicate receivers will be used, one at each side of the power house, so that either can be shut down without stopping the plant. To these the pipes running to the water wheel nozzles will be connected. The water from the wheels on each side of the power house will pass into a central tail race under the floor between the two lines of generators and will be conveyed into canals for land irrigation in the vicinity of Ogden.

THE electric plant at first will consist of five 1000 horse-power 24-pole three-phase generators, driven by Knight water wheels, running at 300 revolutions per minute. The wheels and fitting will be furnished by the Risdon Iron and Locomotive Works, of San Francisco. Water wheel and armature are mounted on the same shaft, and are supported by the same base frame and bearings. The periodicity of the current will be sixty cycles per second and the generators will be wound for 2300 volts. Two exciters, each of 100 kilowatt capacity, direct connected to their own water wheels, will be provided, either of which will suffice to excite the fields of all the generators in the completed station. Transformers, nine in number, each of 250 kilowatt capacity, will raise the generator potential from 2300 volts to 15,000 volts, at which pressure 2000 horse-power will be transmitted to Salt Lake City. The local distribution of the balance, at Ogden, will be made at 2300 volts. The transmission line and transformers will be arranged to allow of the use of a potential of 25,000 volts. This will permit of the efficient transmission of current to the mining camps from thirty to thirty-five miles beyond Salt Lake City.

ANENT the remarkable 35 mile electric transmission plant at Fresno, in California, of which mention was made in the August number of this magazine, a correspondent points out that at Virginia City, in Nevada, in the water power plant of the Nevada mill, a still higher head of water is used, amounting to 1630 feet, or 220 feet more than that at Fresno, and that this, therefore, should be credited, instead, with being the highest known in connection with power transmission purposes. The Nevada mill plant, moreover, like several others now in existence, is one that effectually disproves the old saying that "the mill will never grind with the water that has passed," inasmuch as the water is used twice over, first driving a 11-foot Pelton wheel under a head of 460 feet, and then being conveyed to the main shaft of the Chollar mine through two iron pipes of 8 and 10-inch diameters. These pipes descend the shaft to a subterranean chamber on the famous Sutro tunnel level, 1630 feet vertically below the surface, in which are six Brush generators, each driven by a phosphor-bronze Pelton wheel, 40 inches in diameter, making 900 revolutions a minute, and capable of developing 125 horse-power each. After passing the wheels the water is discharged through the Sutro tunnel. The current from the generators is conducted 2800 feet to six 75-horse-power Brush motors in the mill. The object of the plant is to save water, which is both scarce and dear in that locality, all the water used being brought from the Sierra Nevada mountains,—a distance of thirty miles. At one point it is carried through a valley by means of one 10-inch and two 12-inch pipes, the pressure at the lowest point being 900 pounds to the square inch. As an economiser of water the plant has accomplished all that was expected of it.

THE question of economy in the use of steam pumps involves several considerations, such as the particular kind of work to be done, the first cost of the pump, cost of running and maintenance, the length of time for which the pump is to be used, and several others. It is not steam or coal consumption alone that is to be taken as the measure of economy of a pump, but the result of a careful comparison of the relative values of steam and of simplicity of construction, and it thus frequently becomes an interesting problem to determine which of these two values is properly entitled to the greater share of attention. If we take the comparatively simple case of flooded excavations to be pumped dry, the choice of a pump to do the work is easily governed. A cheap pump, even though comparatively wasteful in the use of steam, will generally be selected and will successfully meet the requirements of the service.

IT is natural that under these circumstances the different forms of vacuum pumps such as the pulsometer, the pulsator, the aqua-thruster and others are coming into more and more prominence. All these pumps have the obvious advantages of simplicity and low cost. Of course, as compared with some other forms of pumps, their figures for steam consumption are often, in fact, generally, pretty high. Still, the demand for simple pumping machinery, capable of handling large quantities of water will keep them in favor, and as, in the course of time, means will probably be found to make them more economical without sacrificing their simplicity, better performances may be expected.

It has been well suggested that a partial remedy for the great waste of steam in these pumps may be found in the adoption of a lining for their steam and water chambers, to consist of a metal having a comparatively low specific heat, as, for example, lead, or of some good non-conducting substance. Taking, say, lead as the lining material, the following figures show very strikingly what degree of saving may be effected by it. It may be assumed that the pump chambers are alternately heated and cooled through a range of temperature of 200 degrees Fahr., and also that sufficient time is allowed to elapse between each stroke or discharge for the whole of the metal to pass through this range of temperature. The specific heat of lead may be taken as 0.0314, that of water being 1, while that of iron is about 0.12. These figures represent the respective losses, caused by condensation, proper to lead and cast iron. For every 314 pounds of steam condensed by the lead, 1200 pounds will be condensed by the iron, showing that by the use of the former instead of the latter metal about 74 per cent. of the steam wasted could be saved. Here, then, is an item worth studying. Nothing has yet been done in this direction, so far as can be learned, though the promise of gain seems to be quite decided.

Speaking, recently, before the American Association for the Advancement of Science, on the artistic element in engineering, Mr. Frank O. Marvin pointed out, among other things, that in many large cities there are engine rooms fitted up in elegance, with marble floors and wainscot, decorated walls and ceilings, brilliantly lighted and with all the appliances of the plant, engines, dynamos, switchboards, and even the smaller accessories in keeping with the surroundings. These plants are used as drawing cards or advertisements. But there are other plants, not so used, where there is displayed less elegance, but fully as much artistic sense in adapting the room and its treatment to its purposes. In many of these places only the enclosed type of engine can be employed. In all of them the standard of maintenance must have its influence on the matter of design, which will, in turn, react on the former. An engine might pound itself to death in a dark basement, but would have its slightest vagary looked after in one of these better planned housings. This result cannot be entirely accounted for by the larger room, the better light, the rules and regulations. There is a refining, educating influence in these artistically planned constructions that makes better men and more efficient workmen of the attendants. Whatever they may cost, there is a credit side to the balance sheet.

A recently published item relative to the comparative cost of the world's four great tunnels, places the cost of the Hoosac tunnel in the United States, the oldest one of the lot, at £76 or about $380 a foot. The Mont Ceris tunnel, the next in date, cost, according to the same item, £71, or about $355 a foot; the St. Gothard cost £46, or $230 a foot; and the Arlberg, the latest in date, cost only £31, or $155 a foot. This rapid decrease in cost, within comparatively few years, is cited as a marked indication of the great progress in mechanical methods and improvement in rock excavating tools. A still more striking result exists in the case of a tunnel through the Cascade mountains, on the line of the Northern Pacific railroad, in the United States. This, unlike those named, which were excavated in old, settled countries, with the terminal easy of access, was in a peculiarly difficult location, so much so that it took months to convey the machinery to the spot. Rivers had to be turned aside, bridges built, and material transported over improvised roads through nearly 100 miles of forest, mud, and snow fields, yet the tunnel, which is 16½ feet wide, 22 feet high, and 8950 feet long, was bored through the mountain in twenty-two months, at the rate of 413 feet a month, and at a cost for the completed tunnel of only £24, or about $120 a foot.

A CORRESPONDENT of the *Iron Trade Review*,—a salesman of improved machinery,—makes a very effective point in machinery buying. He tells of his efforts to induce the proprietor of a small shop to purchase one of his machines, and the latter, getting interested, finally agreed to call on him and see the machine in operation. When he came, after looking the machine over, he opened his grip and pulled out a pair of overalls and a jumper, and wanted to know if he might run the machine himself a while, and upon receiving permission took hold and ran the machine for a whole day, remarking that he wasn't going to have any machine around his shop that he couldn't handle himself.

"Now," writes the *Iron Trade Review's* correspondent, "here is a man after my own heart. If he buys my machine it will be because he wants it, and not because I have hypnotised him into buying it. He will always be satisfied with the machine, and be glad he has it, because he will feel that it is a good investment. He will look upon me as a person who has helped him to economise in his shop, instead of as some one who has buncoed him out of the price of the machine; and the whole thing is exceedingly satisfactory from my standpoint. Now from his standpoint:—The man said nothing whatever to me of his thoughts, but in addition to the general principle that he wouldn't have any machine around that he couldn't run himself, I can easily imagine that the details of the mental operation were something as follows:—There is always more or less jealousy in a shop, and there is often some person of more or less influence who will oppose any improvement that is proposed by some one else There is also much opposition in certain quarters to all improved machinery *per se*, and even in this small shop there might be both of these things to bother the proprietor if he didn't know all about the machine before it came to his shop. He may even need to show some one how to run the machine, and this he can now do."

"I KNOW of one large concern," the same writer goes on to say, "that has a machine trial department, where every machine that comes into the shop goes first, and is worked in that department until the master mechanic says whether the machine is to be accepted or rejected, and what he says goes. Sometimes a machine is kept in this department six months, and at the end of that time, or before, if the master mechanic is satisfied that the machine is all right, it goes to its regular place in the shop, and what is more, it stays there. And no claim of any person who for any reason has a grudge against the machine, that the machine is no good, is considered. The point has already been settled and there is nothing more to be said. This large shop therefore accomplishes by its system and horse sense, just what the proprietor of the small shop first mentioned accomplished by his personal attention."

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CASSIER'S MAGAZINE

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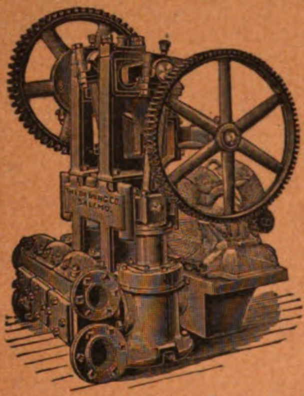

Fig. 55. Electric Pump.

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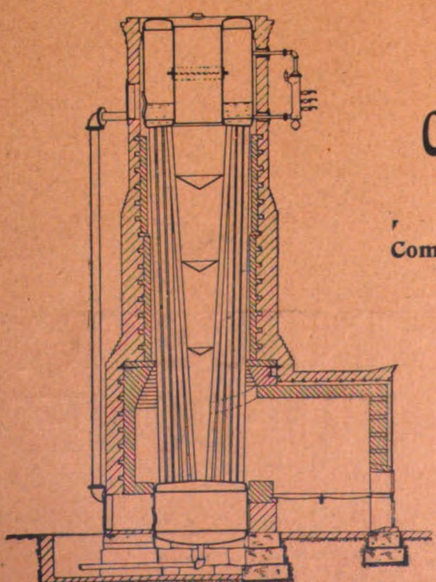

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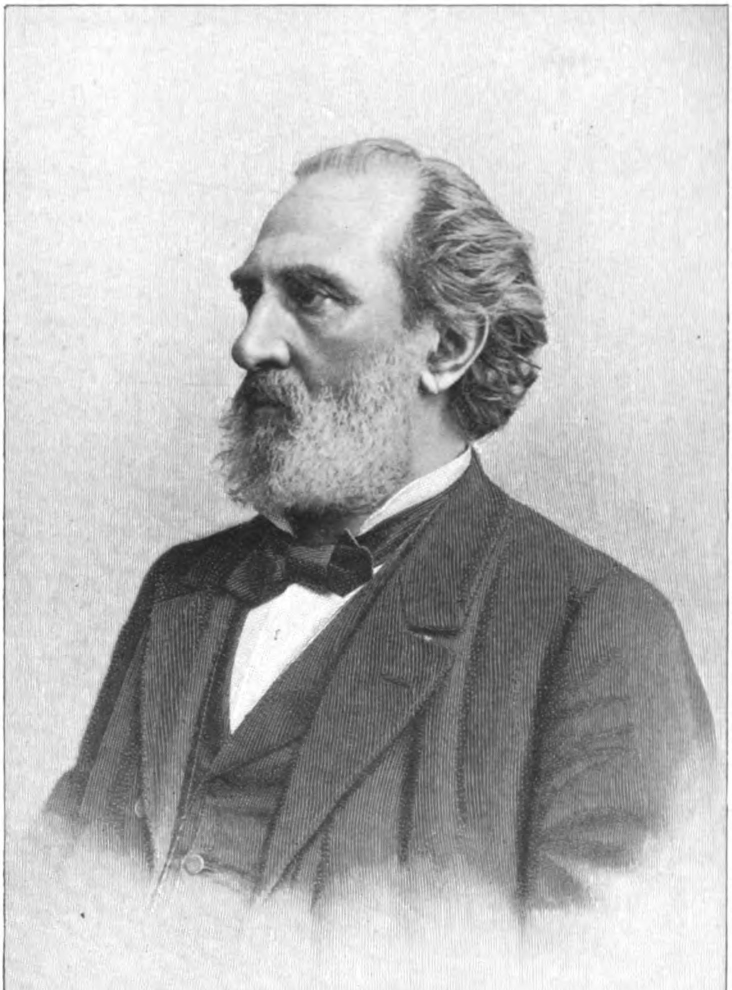

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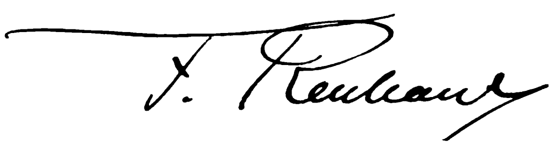


CASSIER'S MAGAZINE.

VOL. XI. DECEMBER, 1896. No. 2.

GRIST FOR THE MILL.

THE MODERN SAW MILL.

By W. H. Trout.

IT requires only the most superficial consideration of the great extent of building and manufacturing investments to see that somewhere there must be an immense amount of lumber and timber sawn. The products are in evidence all the time, but where are the mills?

There are lumber yards in every town, and immense yards in the great cities. These we see. We also see and hear the carpenters' clatter which is continually going on. Where does all this nicely prepared material come from? Where is the home of the saw log and the place of its transformation? The general public knows as little about this as it knows where its coffee is grown, or its rubber shoes are made. The modern saw-mill has undoubtedly reached its highest development in North America; it might be regarded

THE FIRST STEP.

as an almost distinctively American institution. The general European market for standard boards, planks and timber generally, is supplied from American ports, as North America is practically the only lumber exporting country of the world.

The European make of lumber is more of a special character for small and special orders. Economic treatment of the material is there of the first consequence. Time spent in the work, or labour saved by machinery, is of far less account, as labour is comparatively cheap and there is not so much work to be done. The logs also being smaller, the capacity of the machines is much less, and the first cost of the mill is much decreased.

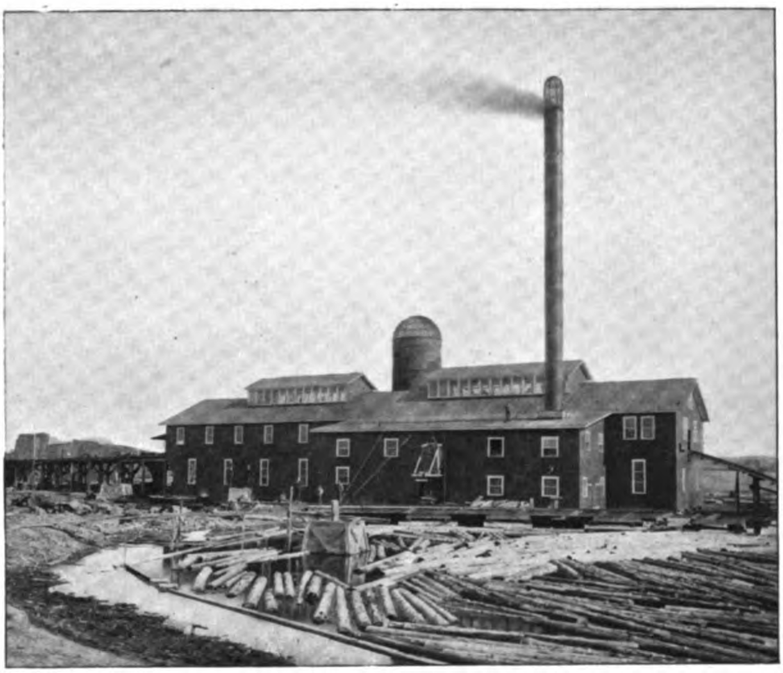
Less than a hundred years ago Norway and Sweden were about the only lumber exporting countries of the world. There is still quite a large but straggling business done, in which the American style of band mills and other improved saw-mill machinery have been introduced.

In Germany, where there is almost a model system of forestry cultivation and protection, there are some excellent mills, Kirchener of Leipsic being the principal manufacturer of the machinery. In connection with the large timber yards of Great Britain there are some superior mills, mostly for the purpose of resawing and supplying special orders. Messrs. Ransome & Co., of London, are leading manufacturers, making a full line of woodworking machinery, principally for export; Australia, South America, New Zealand and Africa are the principal receiving countries.

In considering the particular subject of this article, it may be well to first in-

A LOG POND.

quire what a modern saw-mill does. A very general reply would be that it saws lumber. By lumber is meant boards, planks, scantling, joists and bill stuff generally. But timber also of all sizes is sawn. The broad axe for hewing timber is known only by the old men of the present time and is not used by any.



A TYPICAL SAW MILL.

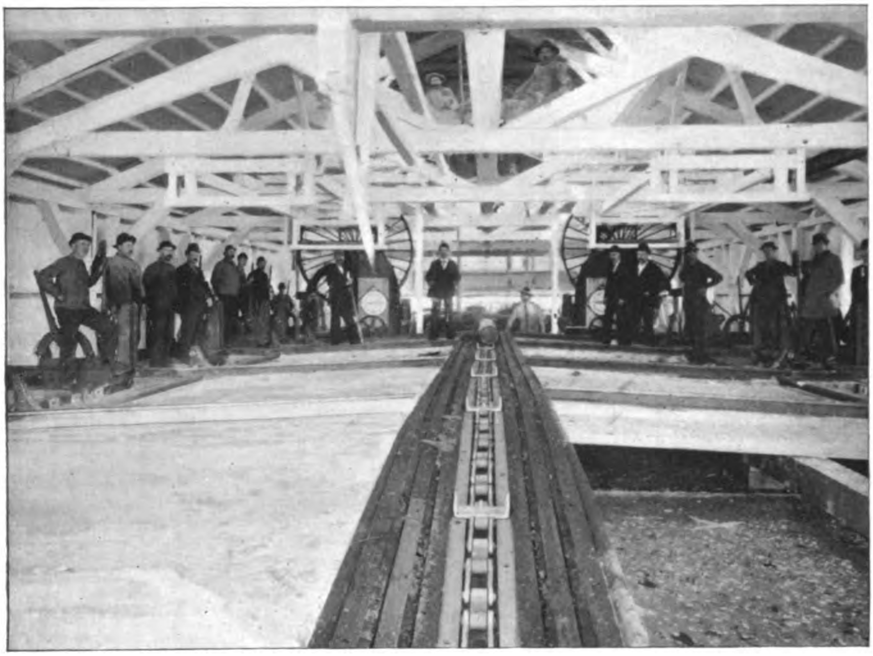
The circular and band mills have made it an antiquated tool.

But lumber and timber are only the principal products of the mill. Besides these it utilises a great part of its own waste, from which box boards, barrel heading, shingles, laths and pickets are made. If the mill is situated in or near a town, kindling wood is about the last of its economic products, while the saw-dust is the main dependence for fuel to furnish motive power for the mill. The nameless material that is finally left goes to the great burner, or "hell," as it is sometimes called, where scarcely ashes even are left.

If the mill makes hardwood lumber, the box, shingle and lath machinery will be left out, and instead there may be machinery for quarter sawing oak or ash, and the refuse will be worked over and cut up into special sizes for the turning shops, the final residue going all into stove wood.

The regularly built modern mill is always a two-story structure, built at the most convenient locality for receiving the logs from the "limits," meaning the portion of country over which the firm holds ownership or the right for cutting logs, and also convenient for shipping the products of the mill. If the logs come in by water, as is most common, a portion of the lake or river is separated by booms, enclosing space for storing different kinds of logs, with a space in front of the mill from which the logs for daily sawing are taken. They are drawn up on a slide or slip by means of an endless chain, provided with saddles or spurs, upon which the logs rest and thus ride up into the mill.

If logs come in from the woods on a logging railroad they are, by preference,



READY FOR THE LOGS.

rolled off into a pond, and then handled as just stated. But in many mills where the pond is not available, the logs are rolled off on to skids in a great yard from which they are rolled again on to a car which is drawn up into the mill by an endless wire rope. This does not run continuously in one direction, like the chain, but reverses, to return the car for a following load.

After the logs have entered the mill, they first undergo an inspection to see that no stones are lodged in the bark, or spikes left by the river men. Each log's diameter is then measured at the small end, by a scale which is graduated to give the quantity of lumber in feet that a perfect log will make. By his judgment the scaler makes such deductions as may be necessary on account of imperfections and records the number.

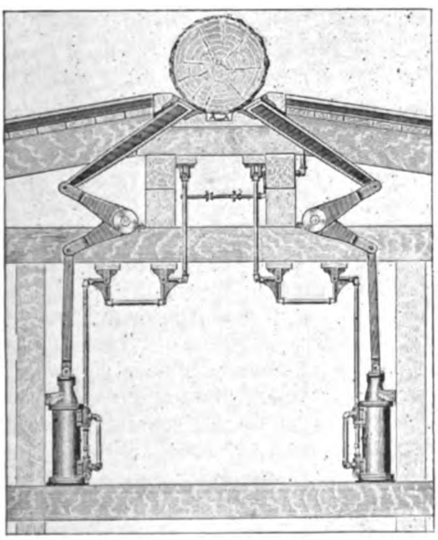
The scaler, or his assistant, next operates a steam machine, usually called the log "flipper" or "kicker." This is located under the log slip. A movement of a valve lever causes two pushers to come up through the slip and send out the log to either side of the mill as chosen, or as certain conditions determine; long logs, for instance, must go to the long carriage.

The log is now lying on what is called the log deck, which is an inclined floor of heavy plank, on which are the skids, inclining with the floor toward the carriage, so that the logs readily roll down. About three feet from the carriage is placed a log stop, which consists simply of two or more double arms, with one end of each projecting above the deck to prevent the logs rolling on to the carriage until required. These arms are usually on a shaft and are kept in position or released, as required, by a steam cylinder connected to the opposite end of one of them.

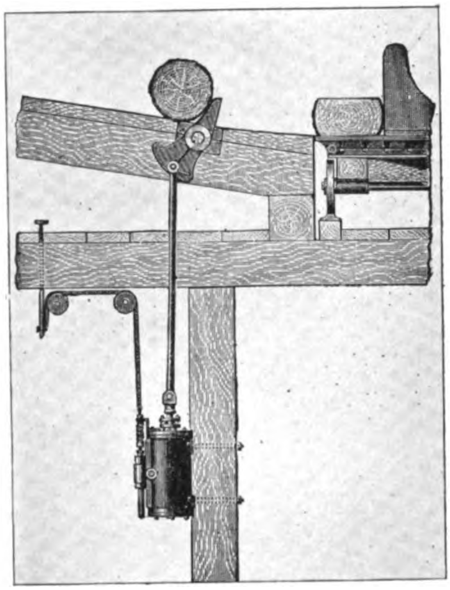
In order to place a log on the carriage the sawyer turns steam into the lower end of the cylinder which revolves the stop, carries the log with it, and rolls, or, rather, throws, the log on the carriage. Then the setter or his assistant instantly dogs it. The sawyer then moves the carriage toward the saw; the setter, at the same time, sets the log forward to the saw line for the first slab, and in a few seconds this is taken off.

The carriage is then reversed or gigged. The first effect of this motion is, by means of the offsetting mechanism, to move the carriage away from the saw about 5/8-inch, so that it returns entirely clear of the band saw, thus avoiding the liability of splinters or shakes that may project from the log catching the back of the saw and carrying it off the wheels on which it runs. At the best such accidents sometimes occur, but they are not usually serious, as the saw becomes suspended on a form which is left close in front of upper wheel for that purpose of safety. The principal use for this form, however, is to assist in taking off and placing on the saws when changing them for filing.

A band saw, 12 inches wide and 50 feet long, with an initial speed of 10,000 feet per minute, running amuck among a lot of workmen, would not be pleasant to contemplate. An experience like this was not uncommon ten years ago. But nowadays a band saw rarely breaks. When it does, it is so well safeguarded



A STEAM LOG KICKER. MADE BY MESSRS. WM. E. HILL & CO., KALAMAZOO, MICH.

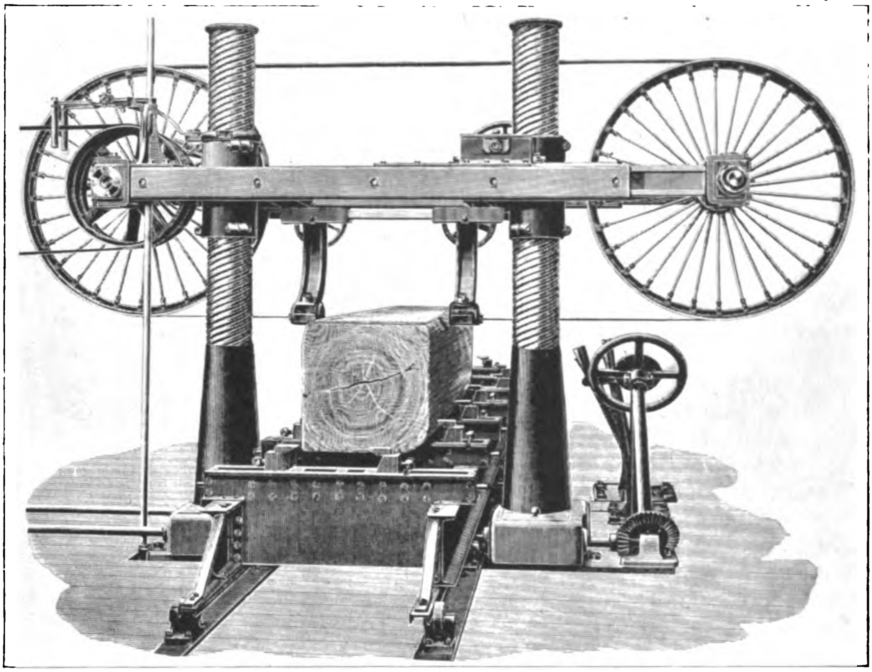


A LOG ROLLER, MADE BY THE M. GARLAND CO., BAY CITY, MICH., U. S. A.

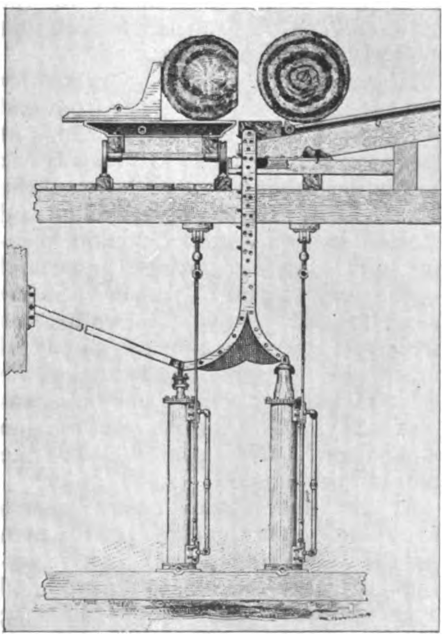
that it usually lands in a tangled heap in the saw dust pit. Sometimes, however, it gets away and performs curious antics. A millwright known to the writer relates such an occurrence that took place some time ago.

He entered the mill in the lower story and ascended the stairs at the front end of the log deck. With his first look at the band mill he beheld the saw break on the descending upper quarter of the wheel. The free oncoming broken end shot off in a tangential direction, passing high over the carriage track, and went through a pane of glass in a window about ten feet away. The entire saw preserved the same line till all passed outside of the mill and landed in the water of the bay. Only one pane was broken. It was all done in a fraction of a second. No one saw it but the man in question.

At the time of the break a log was being loaded on the carriage, the men saw the millwright, bowed their recognition, dogged the log, and proceeded to move the carriage up to the saw; but, greatly to their surprise, no saw was there. They looked confused and



A HORIZONTAL BAND SAW, MADE BY MESSRS. ALLEN RANSOME & CO., LTD., LONDON.



A STEAM NIGGER, MADE BY MESSRS. HILL & CO.

stared around for it. No saw below, above nor anywhere,—not a trace.

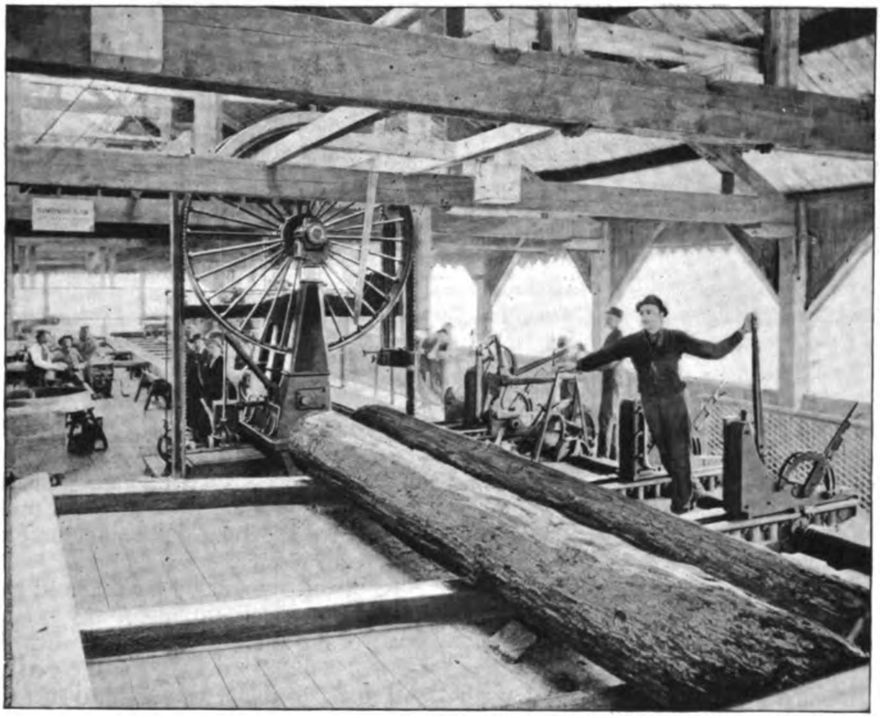
When they could no longer stand being laughed at by the millwright who enjoyed the situation, they charged on him,—declared that he was a witch; that the saw was all right till he came; that he must have made away with it in some way. The puzzle continued till the men who were working outside on the boom timbers, and who alone heard the glass break and beheld the saw coming down into the water, fished it up and dragged it in. Of course, there was another saw ready to replace the broken one, and the work proceeded, as we shall now, with our description of the mill work.

The first slab was taken off, and the log gigged back, when we digressed for the story. The setter on the carriage looks to the sawyer for orders, and these are given by a sign with the fingers, one, two or three signifying so many inches.

Two or three-inch boards are usually taken off at first. The log is then turned over. This brings into play another steam machine, the log canter, or, more commonly, the "nigger," which is a long perpendicular toothed bar that comes up through the floor, and catches the under side of the log, gives it a rolling motion and, with a half revolution, brings the sawn side of the log up against the knees; then it is again dogged, the log is again set forward and the second slab is taken off. This is followed by a number of boards.

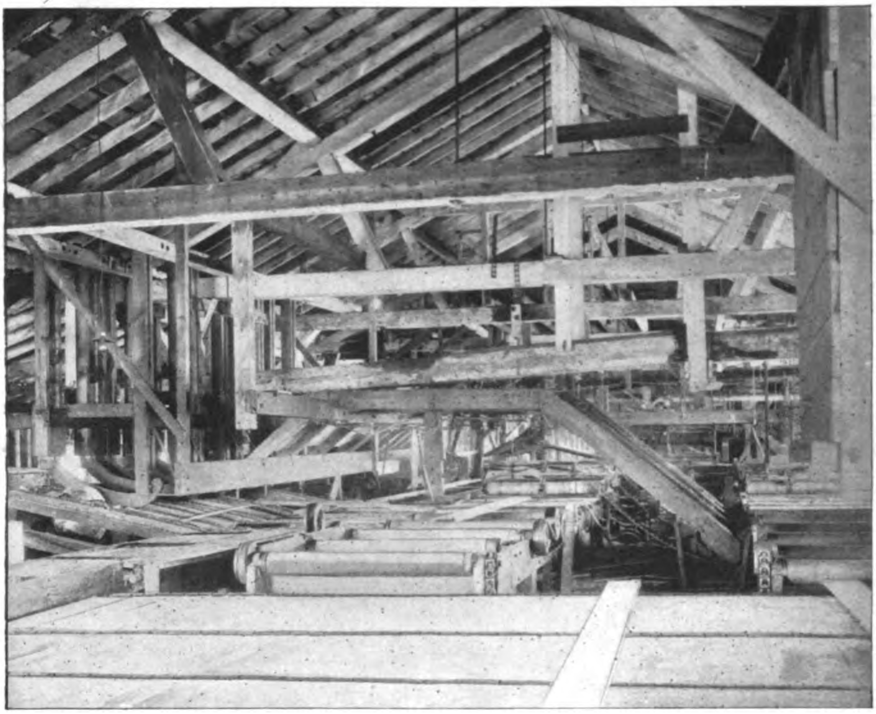
The log, or, rather, the stock, as it is now called, measures one of certain standard widths, say 10, 12, 14 or 16 inches, when the "nigger" gives it a quarter turn, leaving it on the flat. After the third slab, stock boards or plank are sawn, as may be determined, until there are only two or three boards in the last piece.

The "nigger" again comes into play for its final service to this particular log. It gives this last piece a final half-turn, leaving the sawn side against the knees. It is again dogged, set forward, the last slab is taken off, and two or three boards, leaving a final board or plank to be discharged on to live rolls, along with the last sawn board. The entire operation has been performed much quicker than the reader peruses this brief description. The empty carriage is now returned to take on another log, and to repeat the same or somewhat similar operation.



A BAND MILL AT THE CHICAGO WORLD'S FAIR IN 1893, MADE BY THE STEARNS MFG. CO., ERIE, PA., U. S. A.

The "nigger" deserves more than passing notice. In regard to the origin of its name there is a story that a certain lumberman had several coloured men employed to do his log rolling. Having acquired some expertness, they frequently struck for higher pay, which was given without much protest. But one Monday morning when the crew came they saw the toothed bar come up



THE BACK END OF A MILL.

through the floor and turn the logs while they looked on with the whites of their eyes at their utmost expansion. At last the boss ordered them home as he had a "nigger" now that never would strike.

The machine possesses virtues both positive and negative, of a more decided character than are usually credited to its namesake. As a waiter it is a perfect success,—comes without ringing, does its duty instantly, and very modestly and promptly retires. It appears to act wholly on its own account.

The sawyer quietly moves a lever, but there is no apparent connection between lever and "nigger." The latter pops up like Jack-in-the-box and performing its duty in a "now-you-see-me, now-you-don't" fashion. It acts like a thing alive and is always ready.

The original construction of the log canter, by John Torrent, its inventor, comprised a perpendicular wooden bar, faced with iron, and having teeth on the side toward the log. It ran in guides at its lower end, and was raised with a chain, wound by frictional gearing. This style still is used in water mills, but nearly all steam mills now employ the steam nigger.

In the movements of feeding and gigging the carriage no mention has been made of the agent that accomplishes the work. The steam feed was the earliest and most useful of the many direct applications of steam in saw-mill work. It consists of a long steam cylinder, about 10 or 12 feet longer than the longest log sawn, and from 7 to 10 inches in diameter, according to the weight of carriage and the work to be done. It has a piston with a long rod connecting by a swinging bracket to the carriage. There are valves at each end for admitting and releasing steam. The sawyer's lever and connections to the valves complete the machine.

When skillfully handled, its effectiveness equals its simplicity and no single improvement in modern saw-mill machinery has done more than this to increase the regular daily output of a mill. With the high-pressure steam so commonly used, it requires a steady nerve and a cool head to handle it safely and quickly. With such it may run for years with scarcely any repairs, but one or two wrong moves of the lever will effect a prodigious amount of ruin in a few seconds, and, maybe, loss of life or limb to some one.

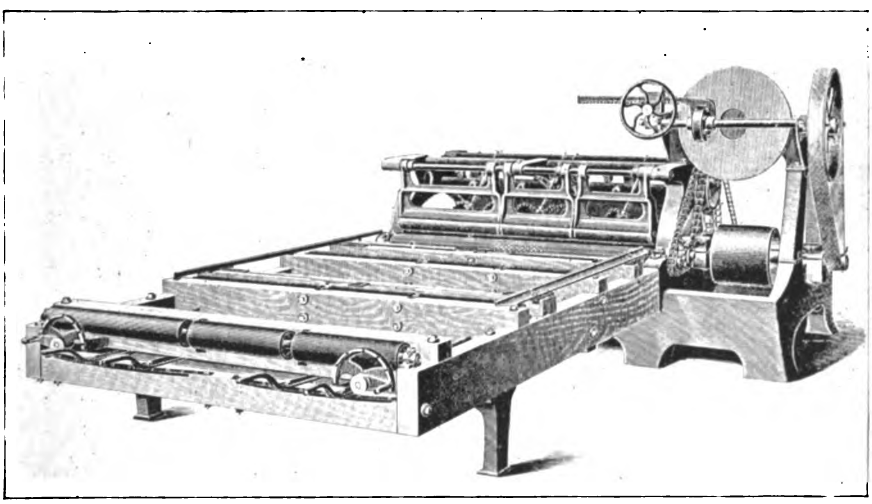
The sawn lumber, as discharged from the carriage, is landed upon a system of live or running rolls, which transport slabs or lumber toward the back end of the mill. These rolls are of cast iron, ordinarily 10 by 24 inches, with a mitre wheel on the end of the shaft, and are placed in a frame, or roller case as it is called, about 4 feet apart. A long shaft extends along the frame, and, with mitres corresponding, connects all together, and keeps them running.

Lumber, timber, or slabs, placed upon the rolls, travels along at their surface speed, which is usually from 200 to 250 feet per minute. Stops are provided in this roller case to arrest the onward movement of boards to the edger, or slabs to the slasher. The edger stops must be depressed to allow slabs to pass over, and both must be depressed to allow timber to pass over, or stock boards if that is the plan.

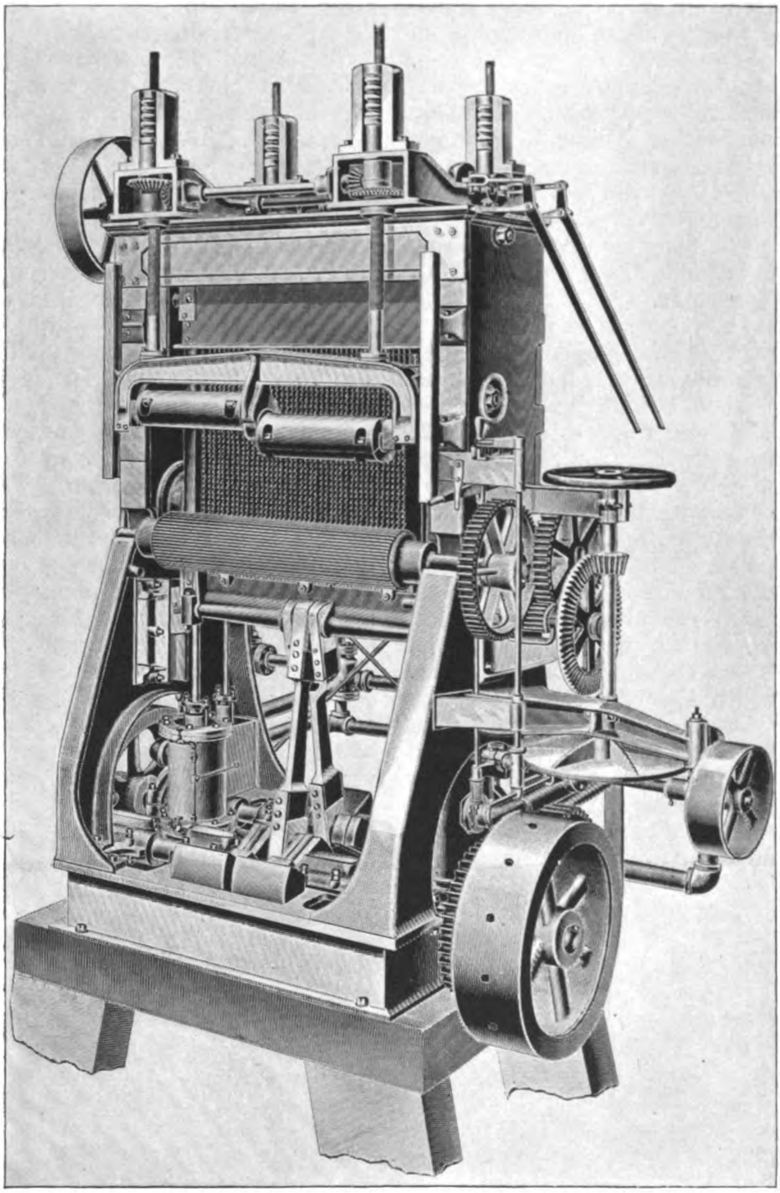
The band mill saws the log into boards, or plank, or stock for resawing, such as is done on a gang of saws, if the mill contains one. Certain kinds of light stock go to the edger, which is the machine next to be considered.

About one-third of the boards in a log have rough edges. These, with other faulty boards, must pass through the edger, which sizes them down to their greatest standard parallel widths. This gives the machine its name. There is also in connection with some edgers what is called a flooring gang, which is a number of saws placed one inch apart. These saw small stock 4 or 6 inches thick into ordinary flooring. The centre of the edger is usually placed about 10 feet farther behind the band mill than the length of the longest board.

If any considerable percentage of the lumber is exceptionally long, say 24 feet or over, there will usually be provided in the roller case a circular crosscut saw, mounted on the upper end of a sliding frame. Beneath the lower end of this is an upright steam cylinder which can be made to quickly raise the saw to cut off any board or slab that may be lying on the rolls. This machine is called the jump saw.



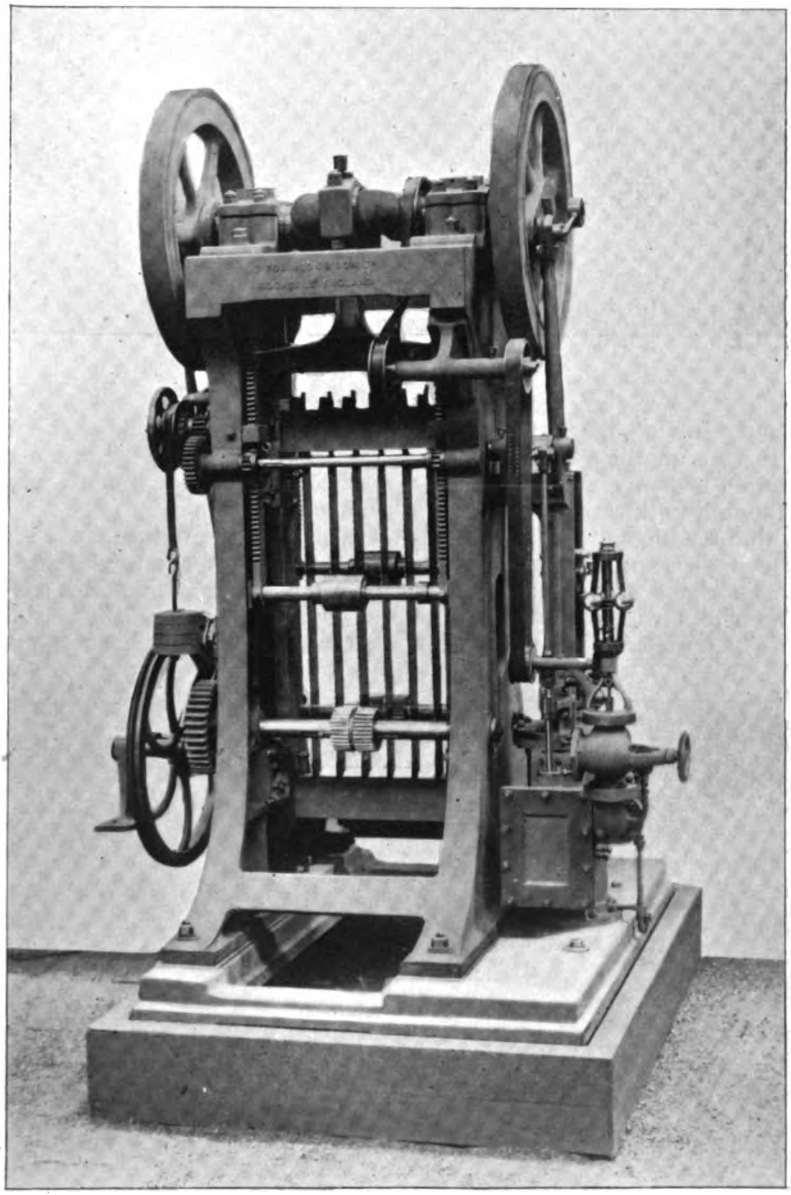
AN EDGING MACHINE, BUILT BY THE E. P. ALLIS CO., MILWAUKEE, WIS., U. S. A.



A GANG MILL, BUILT BY MESSRS. CLARK BROS., BELMONT, N. Y., U. S. A.

In small mills, where first cost is often a great consideration, the edger is placed close to the roller case, so that the edger man can lift the boards off the rollers on to the edger front table. It is generally regarded as a better plan to place the edger a few feet at least from the live rolls, and use a chain transfer to bring the boards. The edger man then has better command of his time, and can allow the boards to pile up for a few moments if necessary. This transfer may be automatic, or it may be a steam transfer.

This edger man's position is one of the important places in the mill. He sees instantly all that can be made out of a board, places the saws in position, gives the board its direction, lets go and the machine does the rest. In a second or two it is at the other end, straight and parallel. It then passes on with accelerated speed over the back end of the back table, and is fired out on a smooth platform in which are embedded special transfer chains. The inclined side surfaces of these present no hindrance to the end motion of the board



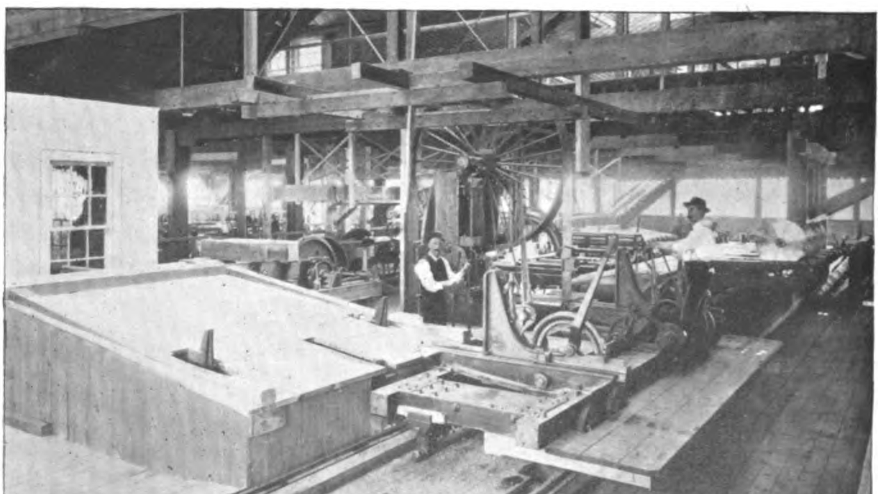
A GANG MILL, BUILT BY MESSRS. THOMAS ROBINSON & SON, LTD., ROCHDALE, ENGLAND.

AWAITING SHIPMENT.

which, after leaving the last live roll, comes to rest on the platform and is then carried sideways on the chains across the mill to the trimmer.

Length, breadth, and thickness comprise the dimensions of all rectangular forms. The band saw determines the thickness of all boards and the width of some. The question of width is finally settled by the edger, and at the trimmer the length is finally determined. In carpentry there is a rule to cut so that you can cut again.

This rule is followed by the lumberman. His 16-foot logs measure 16 feet 6 inches. In the woods the ends cannot be squarely sawn, and they are liable to get battered badly against the rocks in



AN ALLIS BAND MILL AT THE CHICAGO WORLD'S FAIR.

their passage down the river. The boards, therefore, must have their bad ends trimmed squarely, and in order to be able to cut again, the 16-foot board is 16 feet 1 inch. So it is with all lengths from 10 feet to 12, 14 and up, usually to 20 or 24 feet, but the trimmer may be made to trim any ultimate length desired. The operator of this machine must use his judgment, similar to the edger man. He frequently cuts the faulty end of a board and thereby raises the grade.

After the lumber is passed over the trimmer, it is graded and marked with reference to quality. It is then carried on by chains to an assorting platform, or it may be automatically assorted with regard to lengths, by a series of chains leading from the trimmer. It is then loaded on tram cars, according to grade and dimensions, and is drawn out by a horse some distance to the yards or piling ground.

Timber goes directly from the saw on the rolls to the back end of the mill, where the first end is trimmed by a circular saw, called the butting saw, mounted and operated like the jump saw before mentioned. This line of rolls is extended outside of the mill, but the extension is made up of dead rolls, over which the timber is shoved by hand. When the last end of timber is about passing the butting saw, it is stopped and trimmed to definite length, as specified in the bill. After trimming, it is run on the rolls a short distance from mill, and is shoved down sideways on to skids awaiting shipment.

(To be Concluded.)

HYDRAULIC POWER IN LONDON.

By E. B. Ellington, M. Inst. C. E.

THE distribution of power over extended areas has, of late years, been greatly developed, and is recognised as being one of the most important engineering problems of the present time. A great deal has been done in many parts of the world to utilise and distribute the great natural sources of power as at Holyoke and Niagara in the United States and at Schaffhausen and Geneva in Europe. Still, at the present time the great centres of industry depend for power for their manufactures, not upon any general system of distribution, but on isolated power-generating plants at each of the numerous factories which, however large they may be individually, require only a small fraction of the total power demand of the district. That such a system, or want of system, is wasteful and extravagant must be admitted, but the causes which have produced it are obvious and imperative.

So long as water power from natural falls was practically the only available source, factories naturally congregated in the neighbourhood of the falls. Each took its share of the general supply, and co-operation existed, as it were, ready-made. The era of coal and steam changed all that, and it was naturally more convenient to carry power in the shape of coal to the factory in trucks, than to establish a more comprehensive system of distribution.

At the time no other method of utilising the great coal reserves was possible, but to-day we stand on a different platform altogether, and it is only custom and the rigid grooves of trade which prevent more scientific and economical methods of distribution from being established. There are great possibilities in the future in this direction, and any one who reads the signs of the times must believe that the day is not far distant when the coal fields will become great sources of power distribution in some other shape than that of coal.

In towns this system of the co-operative use of coal supplies has become so general that its significance is overlooked. Every gas works is a case in point. In so far as gas is used for working gas engines, a gas supply throughout a town is a case of power distribution in that town, the source of power being the coal.

It is the same with electrical supplies in most cities, and in that particular form of water supply which is generally understood under the term "hydraulic power." Gas, electricity, steam, hydraulic, and one should add compressed air power, are only then particular methods of distributing the power inherent in the coal where the coal consumed is the primary source.

All this seems elementary, but from the way in which even well-informed and trained engineers often speak on the subject of the relative economy of gas, electricity, steam, air, or hydraulic power, it is difficult to understand that they fully realise that they are, one and all, but methods of distribution of a single source of power, and that *prima facie* one would not expect to find any great difference between them, unless, indeed, in the case of compressed air in which the generation of heat in the work of compression is an initial difficulty which can only be overcome by the somewhat cumbrous method of subsequently reheating the air, so that it ceases to be a self-contained system.

The distribution of hydraulic power in London is the biggest thing of its kind in existence. It is not only unique in the sense of being the largest distribution of power from central stations in any city in the world, but it is, excluding smaller installations in other cities, the only instance of a power distribution which furnishes exclusively a power supply. In other systems, viz., gas, electricity, and steam, the main intention is to supply light and heat, the supply of power being only subsidiary. Even the compressed air supply in Paris, which is the nearest in idea to the hydraulic supply in London, is dependent largely upon its lighting business.

Hydraulic power in London and other cities is also interesting in another way, in so much that it depends not only exclusively or mainly on the supply of power alone, but that the supply was originally intended to serve, and is in fact almost entirely used for, one special class of business, viz., that of lifting. It is a most remarkable instance of the specialisation of modern industry and is perhaps the most conclusive illustration that can be given of the fact that practical considerations have an altogether preponderating influence in determining the kind of power to be used.

In any system of power distribution, all that is, in fact, supplied is a certain amount of energy. A given quantity of gas, electricity, air and water, under the given conditions, is furnished to the consumer, containing so much energy, which he can utilise as he pleases, say, for lighting or power. In all these different systems energy alone is supplied and on the current rates of charge a scale of the relative cost of energy can be made, irrespective of how it is going to be used.

If, however, one system is generally used by preference for one purpose, and another system is very generally used for another purpose, it is quite clear that the relative economy of the supply of energy cannot be the dominant factor governing the choice of system.

It will be found that the main factor which governs the choice of method is the relative directness of application. The success of the hydraulic power supply as a commercial undertaking in London and other towns has been due to the fact that for lifting purposes, generally, hydraulic power is unrivalled in the facility with which it can be directly applied to the work to be done. Professor Unwin, F. R. S., in his recent book on the "Development and Transmission of Power," went fully into the question of the relative cost of power under different systems, and his conclusions were not altogether favourable to the economy of hydraulic power distribution for general purposes.

For reasons to be given presently, I think that hydraulic power can be distributed at a rate which will not exceed the cost of any other method, but taking the scale of charges for hydraulic power in London, it will be found that even the lowest rates exceed the cost of an equivalent amount of energy supplied from the gas mains in the shape of gas. But a consumer can no more use the gas, when he has got it, for working his lift direct than he could use the hydraulic power, when he has got it, for the direct lighting of his office or warehouse.

In both cases he must convert it and redistribute it on his own premises, and the apparently cheaper energy, in the long run, may be the most expensive. Electricity can no more be used direct for lifting purposes than gas. The only difference between using the gas or electricity is that a dynamo is less of a nuisance than a gas engine.

It has always seemed to me that the question of the supremacy of hydraulic power for lifting purposes may be vividly presented by considering what a well-trained mechanical engineer would think of a proposal to run a dynamo to turn a wormwheel to work a screw press, as an improvement on Bramah's beautifully simple hydraulic press. In any case it would seem a retrograde step, but if, as is the case, both forms of energy are equally available from the street mains at about the same cost per unit, the proposal to use electricity as being the best would be scouted as absurd.

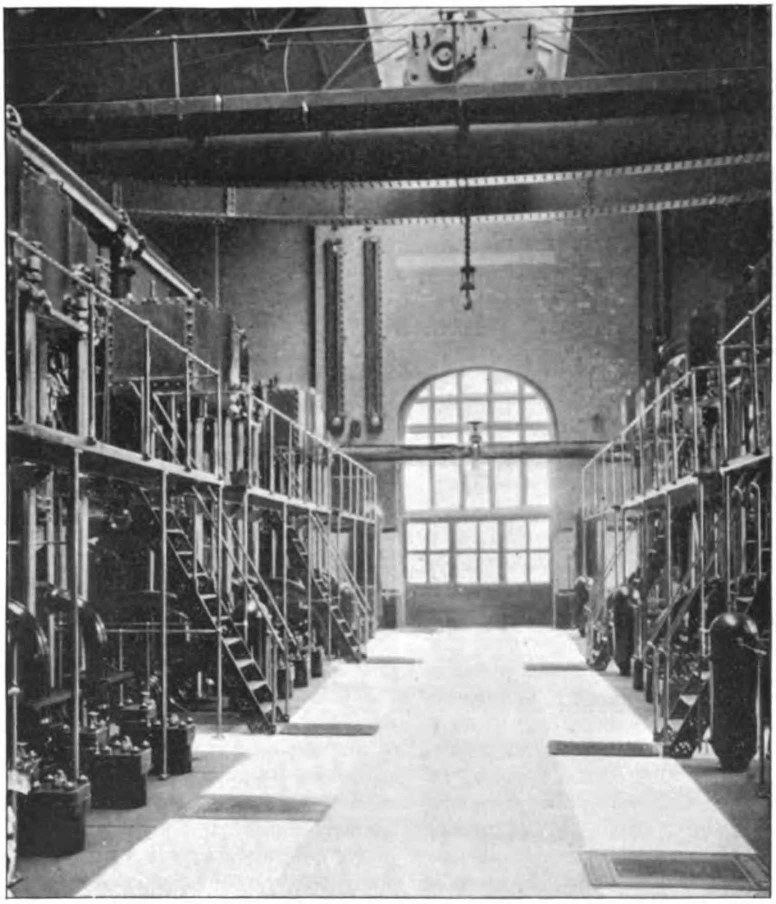
That really represents the essence of the matter, for there is no radical distinction between a hydraulic lift and a hydraulic press, and the continued and increasing growth of the London hydraulic power system in the face of the powerful competitors in the shape of gas and electricity, shows that this common-sense view of the situation is well understood by engineers and architects.

The principal competitor of the system is not, however, either gas or electricity from street mains, but, as in the case of electrical supplies, it is the steam boilers and engines on the premises requiring power. In such cases the dominant factor is the cost of the power.

The lowest rate charged for hydraulic power in London is 1s. 6d. per 1000 gallons. The pressure is 750 pounds per square inch, so that each 1000 gallons contains 8.738 horse-power-hours of energy; 1s. 6d. per 1000 gallons is, therefore, equivalent to say 2d. per horse-power-hour. It is only the largest hydraulic plants, pumping 20,000,000 or more gallons per quarter which are capable of pumping at this cost, if to the actual pumping expenses are added the interest and depreciation on the capital value of the plant, and the value of the space occupied by it.

The largest private pumping plants existing in London are at the railway goods depots, and at one of the principal and most modern of these depots, at which over 100,000,000 gallons per year are pumped, the pumping cost, exclusive of interest and other charges, is 9d. per 1000 gallons and the total cost would be very little, if at all, below 1s. 6d. per 1000 gallons. There is, however, great difficulty in properly apportioning the expenses of an establishment having many branches, and wild estimates and statements are frequently made as to the cost of running private plants. Many who could most advantageously use the public supplies of hydraulic power and electricity still adhere to the old system of private producing plant under the impression they are making a saving, when, in fact, they are working at a loss. As such private plants become worn out and antiquated, they will, no doubt, cease to be used, and public supplies will be taken in nearly all cases as a matter of course.

The hydraulic power works in London were established in 1882. The first and central pumping station is situated on the Surrey side of the Thames, near Blackfriars bridge. This station was fitted out with four sets of inverted vertical three-cylinder pumping engines of 200 I. H. P. each, with four Lancashire boilers, and two hydraulic accumulators, loaded to 750 pounds per square inch. Ten miles of hydraulic



A PUMPING STATION INTERIOR.

mains were laid in the first instance in the city and Southwark, the two sides of the river being connected by two 6-inch mains, carried across Southwark bridge. Power was first supplied through the street mains in the autumn of 1883, and the history of the undertaking has been one of continuous progress since.

At the present time there are eighty-six miles of mains under pressure in London, extending from Kensington, in the west, to beyond the London docks, in the east. During the first year about 100 machines, principally lifts and cranes, were connected to the mains, and about 500,000 gallons of power water were delivered in a week. Now, nearly 3000 machines are working from the mains, and the supply has reached nearly 10,000,000 gallons of power water at 750 pounds pressure in a week. There are four large stations, containing, in all, engines of 3800 horse-power.

The Westminster station is about to be considerably enlarged, and the horse-power available will be increased to 4600. The increase in the supplies given during the past two or three years has exceeded all past experience, and it is obvious that the system is regarded by the public with increasing favour for the special purposes for which it was started.

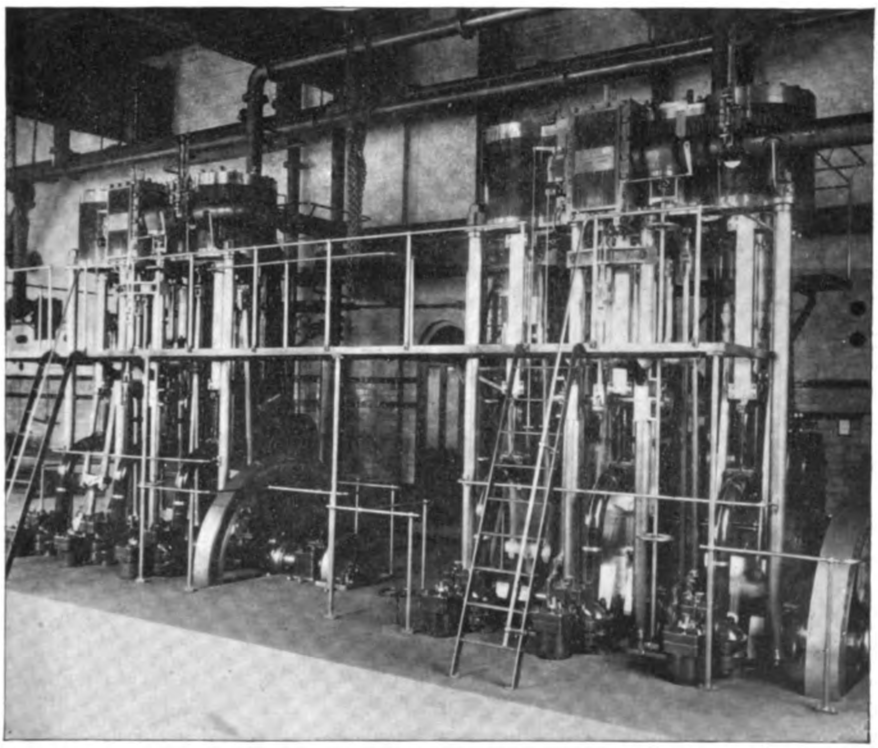
The first public works of the kind were erected in Hull. Proposals had been made quite early in the century by Bramah himself to utilise his hydraulic press for lifting, and he actually constructed a hydraulic crane, and contemplated laying down a general supply of hydraulic power in London; but the time was not ripe.

It was not until Mr., now Lord, Armstrong took up the question in 1848 that Bramah's idea became practicable, and it was not until the works in Hull were established by the writer in 1876 that any public supply was available in the streets of a city. There were numerous and very large and important systems of distribution in the docks in England and abroad, but nothing like a public distribution of the power.

That the system has met a real public demand is evidenced by the figures already given and by the fact that the present income from the power supply in London alone is over £65,000 per annum. It may be interesting to give the number of the machines worked with the power. Approximately they are divided as follows:—

Passenger lifts	650
Goods lifts and cranes	2,000
Presses of various kinds	90
Motors	95
Fire hydrants	80
Total	2,915

With regard to the motors, the most recent improvement consists in the use of Pelton wheels which are giving very satisfactory results. The high speed at which these motors have to run with a pressure of 750 pounds per square inch, and the small diameter of the jet for small powers, makes perfect governing with a consumption of power proportioned to the load a difficulty. Improvements in the governing apparatus have, however, recently been made, and a considerable number of them are now being set to work. A few of the



ANOTHER VIEW

motors are used for generating electric current. There is a loss on small machines of 45 per cent. in the conversion.

A very considerable use is about to be made of the hydraulic power supply in the works of the Central London railway by the different contractors, for lifting the spoil from the tunnels. In place of the noisy, rattling steam cranes usually employed for such purposes, quiet, smooth and rapid hydraulic machinery will be substituted, and will, no doubt, be appreciated both by the contractors and the public. A large hydraulic builder's derrick-crane has been used for the erection of many buildings on the line of mains in London during the past seven or eight years.

The question of the cost at which hydraulic power can be produced and distributed, as compared with its competitors, is so important that, even at the risk of repeating what I have written previously, I propose to go further into details. I cannot do better than take for my text the table of figures below, taken from a paper of mine, read at the summer meeting of the Institution of Mechanical Engineers, held at Glasgow last year. This table is, I take it, absolutely conclusive as to the relative cost of producing hydraulic power and electricity, as actually being accomplished, and shows unmistakably the great relative economy of the hydraulic supply.

It must be remembered that the hydraulic supply and the Westminster electric supply are given within the same area under conditions which are precisely alike in many important respects. The electricity demand is mainly during the night, and the hydraulic demand is mainly during the day. These demands, however, overlap considerably during the winter, and in both cases the supply is kept up day and night.

A more important difference is in the load factor. I am now using this term as indicating the proportion of the actual average output per hour of the plant throughout the year, to the actual maximum recorded during any hour of the year. Now the load factor of the hydraulic supply has been for several years about 0.33, or, on an average, eight hours' work in the twenty-four at

Comparison of Hydraulic Power Supply and Electric Supply, compiled from the reports of the London Hydraulic Power Supply (L. H. P.) and the Westminster Electric Supply (W. E. S.) for the year 1894.

1894.	Totals. L. H. P.	Totals. W. E. S.	At Gallons at 1,730 Feet Head. L. H. P.	At Gallons at 1,730 Feet Head. W. E. S.	At Board of Trade Electric Units. L. H. P.	At Board of Trade Electric Units. W. E. S.
	£	£	Gallons.	Gallons.	Electric Units.	Electric Units.
Capital outlay	471,552*	411,018				
Output	....		400,313,000	396,256,000	2,609,240	2,582,801
Quantity sold	....		332,390,000	333,430,000	2,166,520	2,173,298
Received for supply	49,237	50,729				
Average price obtained	....		Per 1,000 Galls. 35.55 Pence.	Per 1,000 Galls. 30.51 Pence.	Per unit. 5.45 pence	Per unit. 5.6 pence
STATION COSTS.	Totals.		Per 1,000 Gallons at 1,730 Feet Head.		At Board of Trade Electric Unit.	
	£	£	Pence.	Pence.	Pence.	Pence.
Coal	3,276	5,842	1.964	3.539	0.301	0.543
Oil, Water, and Engine-room expenses	1,351†	1,228	0.810	0.743	0.124	0.114
Salaries and Wages	3,071	6,345	1.841	3.839	0.282	0.580
Repairs and Maintenance	929	1,478	0.557	0.893	0.086	0.137
Totals	8,627	14,893	5.172	9.014	0.793	1.383
Individual Station	Wapping §	Davies St. ¶	Wapping §	Davies St. ¶	Wapping §	Davies St. ¶
	£	£	Pence.	Pence.	Pence.	Pence.
Coal	1,242	3,263	1.084	3.006	0.258	0.600
Oil, Water, and Engine-room expenses	385	600	0.522	0.718	0.080	0.110
Salaries and Wages	1,072	2,500	1.453	2.003	0.223	0.450
Repairs and Maintenance	382	931	0.518	1.114	0.070	0.171
Totals	3,081	7,294	4.177	8.731	0.640	1.340

* Including £56,000 for new site and station, started October 1894. † Including £400 for water rights and £129 for gas lighting. § Wapping Station only; output 177,000,000 gallons in 1894. ¶ Davies Street only; output 1,306,794 units in 1894, equivalent to 200,400,000 gallons.

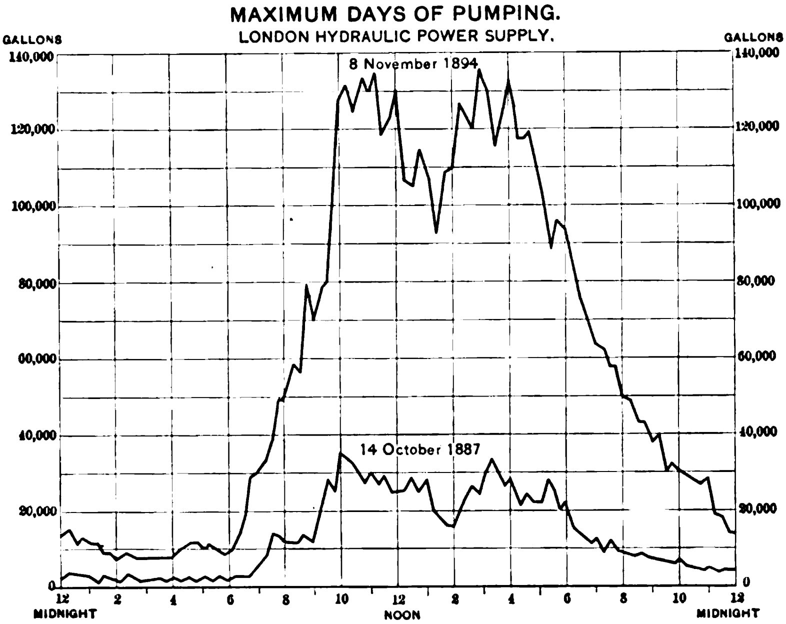


DIAGRAM SHOWING AMOUNTS OF POWER SUPPLIED AT DIFFERENT HOURS OF THE DAY.

the maximum rate. The supply is, of course, given during the twenty-four hours, but at varying rates. (See diagram on this page.)

The electric load factor in the Westminster district was about 0.18. The load factor must have some influence on the cost, and the question is, how much? Electrical engineers generally attach great importance to it, but in the case of hydraulic supply its effect on station costs is not by any means overpowering.

There are certain weeks in the year, at Christmas and Easter especially, when the load factor is reduced to 0.20 or approximately the same as the Westminster Electric Lighting Supplies. Now, I find, from using the records of these weeks, that if the load factor had been, say, 0.20 for the whole year, or a reduction of more than one-third, the station costs would have been increased from 5.172d. to, say, 6.5d. per 1000 gallons, as against an equivalent cost of 9.014d. for the generation of electrical energy. As the Westminster electric cost of supply is the lowest in London, it is clear that the generating cost of the hydraulic power is less than 75 per cent. of the electrical after making full allowance for the influence of the comparatively high load factor of the hydraulic supply. This comparison is, however, too favourable to the electrical supply in one important particular, in as much as the hydraulic supply is given over an area five times as great as the Westminster electric area; and as the proportion of energy sold to that produced is the same in both, the differences being largely accounted for by losses in transmission, it follows that if the same electric energy had been distributed over the large area of the hydraulic supply, the losses would have been greatly increased.

In fact, the main difference in fuel cost between the two systems is found, after allowing for the difference in load factors, to depend upon this question of distribution, for it is practically necessary for economy in the electrical system to place the electrical stations close to their work, thereby generally necessitating the use of non-condensing engines and the burning of more expensive coal.

The next largest difference is due to the fact that more skilled supervision is required in an electrical supply, which is shown in the higher cost of salaries and wages. The wear and tear of the high-speed engines and dynamos seem to be greater also than in the case of the slow-running pumping engines, and what difference of cost remains, after allowing for these items, seems to be principally due to the load factors having a more important influence on the economy of electric stations than on hydraulic, owing to the speed of the engines having to be constant in the former, irrespective of load, while in the latter it is the speed which varies.

I have found, however, that even in the hydraulic stations only about 60 per cent. of the coal burnt would actually be used if the efficiencies of trials at full speed were maintained throughout the year. Few electrical engineers would admit that they could not do as well, even when the load factor was a low one.

Though the station costs are of the greatest interest and importance as an engineering problem, unfortunately any probable reduction that may be made in them in the future would, after all, make but little difference in the cost at which the supply would reach the consumer. The distribution and general charges and management expenses amount, in the aggregate, to more than the station costs, while, assuming only the moderate return of 5 per cent. on the capital to cover interest and replacements of plant, the charges under these heads amount to more than the station costs, distribution and establishment charges added together. Also, the charge has to be made on the quantity of energy sold and not on the quantity produced at the stations which increases the station charges as given in this table in about the proportion of 40 to 33.

I find that the total cost, including all charges, in the year 1894 of the London hydraulic supply came to just over 13d. per 1000 gallons sold, equivalent to 2d. per unit of electricity, while 5 per cent. on the capital employed amounts to over 16d. per 1000 gallons sold, so that a charge of, say, 30d. per 1000 gallons is necessary to secure even a small return on the capital employed. I have elsewhere stated that I think the effect of a low load factor on station costs has been overrated, because by no conceivable arrangement without large storage, owing to the overlapping of day and night demands, and the effect of Saturday, Sunday and other holidays, can as high an annual load factor as 0.4 be obtained, and even if obtained the principal portion of the existing discrepancy between the actual coal consumption and the results of trial runs would remain.

While I have no doubt of this fact, it must be admitted that in regard to the cost at which the supply can be given to the consumer, the influence of the load factor is by far the most important. Assume that the load factor of the Hydraulic Company in London was reduced from 0.33 to 0.20, and other conditions remained the same as regards establishment charges, capital, number of consumers, etc.; then while the actual station cost per 1000 gallons would only be increased from 5.172d. to 6.5d., the total cost per 1000 gallons sold would be increased from 13d. to over 18d., and the interest charges from 16d. to 24d., or a total increase of more than 1s. per 1000 gallons.

This is the real justification for substantial reduced charges to consumers whose consumption tends to improve the load factor, and both the hydraulic and electrical supplies are given in certain cases at rates which are only a little above the actual cost price of production under the average existing conditions.

Having regard to the very low cost at which the hydraulic stations are now run, it is an outside assumption that the station and other costs could be reduced even 2d. per 1000 gallons, so that I am of the opinion that we have reached, under existing trade conditions, the limit of economy of production within, certainly, 15 per cent. Some charges are always growing; thus, the local rates that are being paid by the London Hydraulic Power Company, which were only one-third of the coal bill a few years ago, will this year be at least 25 per cent. more than the coal bill, and it will be seen from the table that if the coal cost nothing and its cost were taken off the price, it would effect a reduction of only 6 per cent. in the average price.

There is the further question as to how far an increased scale of production may diminish its cost. There does not appear to be any reason to anticipate any great effect from this cause if it is unaccompanied, as it has been in the past, by an improvement in the load factor. There has, however, been a continual reduction in the capital outlay per unit of output since the commencement, and this will, no doubt, continue, so that the interest charges required to render a supply profitable may be thereby reduced.

The ultimate lowest cost at which hydraulic power supply can be reasonable expected to be profitably given in London, or any place similarly situated, would seem then to be approximately as below. I assume a load factor of 0.38 and an efficiency of 90 per cent. (*i. e.*, 90 per cent. of the quantity produced is assumed to be sold), while the total output is taken at twice what it was in 1894 as shown in the table.

	Cost per 1000 Gallons Sold.
Station expenses	4.5d.
Distribution and general charges	3.5d.
Rates	2.0d.
Five per cent. on capital	12.0d.
	22d.

I have taken the capital at £1 per 1000 gallons sold in a year.

I am now dealing with average rates. The station expenses are very much the same for all consumers per 1000 gallons, but the general charges and the capital employed vary greatly according to the conditions of supply; but, after making all allowances, it would seem that the present minimum rate of 1s. 6d. per 1000 gallons or 2d. per horse-power-hour is about the minimum rate at which the power can be profitably supplied in London under the most favourable conditions.

It may be stated with some confidence that no other competitive system of general supply of power in towns could show so low a result. It can now be understood how it is that hydraulic power stands unrivalled for lifting purposes; when thus applied there is obtained the cumulative effect of cheap production of power and direct action. For general purposes the difficulty that presents itself is in the application without undue loss.

The Pelton wheel of small power, and working at 750 pounds per square inch, under the best conditions will not give more than 75 per cent. efficiency, and this compares somewhat unfavourably with prime movers of other systems; but I would again emphasise the statement that true economy can be no more obtained by buying the apparently cheapest power than it can be, when one is engaged in shopping, in buying the cheapest goods offered for sale.

No one system of distribution of power is the best for all purposes, and in any particular case the decision as to which method, or methods, should be used depends on practical considerations which do not admit of precise definition.

As circumstances vary, so must the power to be used most advantageously vary, and the more choice there is, the better for the consumer, and, possibly, the better for engineering science.

POWER TRANSMISSION BY ALTERNATING ELECTRIC CURRENTS.

By Dr. Louis Duncan.

An extract from a paper entitled, "The Present Status of the Distribution and Transmission of Electric Energy," recently read before the American Institute of Electrical Engineers.

A LARGE proportion of the transmission plants that have been installed in the last few years have been of the alternating current type. These have, as a rule, given satisfactory results, and the installations that are now being erected or planned are almost exclusively on an alternating current basis. The great advantage of this system lies in the fact that it is possible to change the voltage of the current without the use of rotating apparatus, and at once economically and safely. Low voltage dynamos may be used, the voltage may be increased in any desired ratio by stationary transformers, the energy may be transmitted at an increased voltage, and at the receiving end the voltage may again be reduced by transformers.

If we compare this method with the continuous-current system, we will see that to obtain an alternating current of the required pressure at the receiving end of the line, we would use the same number of transformations required by he continuous-current system.

We have the great advantage, however, that our changes in voltage have been obtained by the agency of stationary apparatus, which is much cheaper, is more efficient and is safer than that required in the continuous-current system. It is possible to increase the voltage, by means of transformers, to almost any value with perfect safety, and with an efficiency as high as 98 per cent. or 99 per cent.

If, then, our alternating current, when it has been reduced at the receiving end, is as valuable for distribution as the current obtained by the direct current system, there will be no doubt that alternating transmission has great advantages over continuous currents.

If we consider the relative cost of copper in the line for a given amount of power transmitted, and for a given maximum potential between the conductors, we will find that the relative amounts for the continuous current and the different alternating current systems will be as follows:—

Continuous current	100
Single-phase alternating	200
Two-phase	200
Three-phase	150

I do not think it necessary to explain minutely the difference between these systems, as they are well understood. In a single-phase system a single alternating current is used; in a two-phase system two alternating currents, whose phases differ by 90 degrees, are employed; while in the three-phase system there are three currents, differing in phases by 60 degrees.

I shall consider the characteristics of these three systems, as there has been much discussion, especially as to the relative value of the last two of them for transmission work. There is no single-phase motor in successful commercial operation that does not require to be started from rest by some outside means. This prevents a single-phase current from being used at the present time for power distribution; and, as in most transmission, the distribution of power is an important item, single-phase currents are not suitable for this purpose. In a two-phase system the currents are usually carried on separate pairs of wires, while in the three-phase system three wires are generally used, a common return being unnecessary, as the sum of the currents is zero, unless the circuits are unbalanced. In distributing on the three-phase system, a fourth wire can be employed, as it gives an advantage in the amount of copper used.

In all these alternating systems the great difficulty lies in the fact that the inductance of the circuit causes the current to lag behind the electromotive force. This decreases the amount of energy transmitted by a given current at a given voltage; it causes a drop in the voltage of the line, and it increases the armature reaction of the dynamo for a given current. The total inductance of the circuit is made up of the inductance of the transformers, of the dynamos, of the receiving apparatus and of the line.

In the case of transmission to very long distances, the line inductance is a large proportion of the total, while the inductance of the receiving apparatus depends upon whether lights or motors are to be supplied and upon the construction of the latter. When the different wires of the multiphase system are fed from windings on the same dynamo armature, then the drop in voltage, due to any excess of load on one of these circuits, cannot be compensated for on the dynamo itself.

If the amount of current and the lag of the current are the same for all of the circuits of the system, then it is easy by a compounding winding of the dynamo, or by changing the current in the field winding, if there is no compounding, to keep the voltage constant at either the sending or receiving end. When the load on the different wires of the system is not the same, however, it is, as I have stated, impossible to keep all of the circuits at the proper voltage.

Where a two-phase transmission with separate circuits is used, then, if the separate circuits are wound on different armatures, each can be regulated to give a constant voltage at the receiving end. This is the case, for instance, in the large dynamos built by the Westinghouse Company for use at the World's Fair in Chicago.

The difficulty due to the uneven loading of the circuits is specially marked in the case of the three-phase system, and it is one of the principal objections that have been urged against the employment of this system for distribution. It should be pointed out, too, that it is not enough to balance the quantities of current for the three branches of the system; but the character of the current must also be considered. A non-inductive load on one wire, with an inductive load of equal value on the others, would cause an unbalancing just as if the currents differed in amount.

In most of the transmission plants that are being operated and that are proposed, it is required to run both lamps and motors from the same circuits, and while a slight variation of potential on the motors would not cause any particular trouble, yet the successful operation of the lamps requires a practically constant voltage. I think, however, and the same grounds have been taken by others, that in any practical transmission of considerable size, it is possible to so balance the loads that this difficulty will not exist to an extent to cause any serious trouble.

When the distributing part of the lines is reached, it is usually the custom, when a three-phase transmission is used, to employ four instead of three wires. As for line inductance in the two-phase and three-phase systems, there is no question that the latter has an advantage in this respect. By suitable arrangement of circuits the line inductance can be brought to a minimum,

THE PRINCIPAL LONG-DISTANCE ELECTRIC TRANSMISSION PLANTS NOW IN OPERATION.

Name.	Type.	Distance in Miles.	Line Voltage.	Horse-Power.	Remarks.
Ouray, Col	Direct.	4	800	1,200	Successful, increasing.
Geneva, Switzerland	"	20	6,600	400	Successful.
San Francisco, Cal	"	12	8,000	1,000	Successful, 9 years.
Brescia	"	12	15,000	700	
Pomona and San Bernardino	Single phase Alt.	13½ to 28¾	1,000	800	Successful, increasing 4 years.
Telluride, Col	"	3	3,000	400	To be increased, 3200 H. P.
Bodie, Col	"	12½	3,400	160	Successful.
Rome, Italy	"	18	6,000	2,000	Increasing to 9000 H. P., 3 years.
Davos, Switzerland	"	2	3,660	600	Successful.
Schongeisung, Germany	"	4½	2,600	820	"
Springfield, Mass	2-phase.	6½	3,600	820	"
Quebec, Canada	"	8	5,000	2,130	"
Anderson, S. C	"	8	5,500	200	"
Fitchburg, Mass	"	2¼	2,150	400	"
Winooski, Vt	3-phase.	2½	2,500	150	"
Baltic, Ct	"	5	2,500	700	"
St. Hyacinthe, Canada	"	5	2,500	600	" 2 years.
Concord, N. H	"	4	2,500	5,000	" 2 years.
Fresno, Cal	"	35	11,000	1,400	" to be increased.
Big Cottonwood to Salt Lake City, Utah	"	14	10,000	1,400	"
Lowell, Mass.	"	6 to 15	5,500	480	"
Sacramento-Folsom, Cal	"	24	10,000	4,000	1 year.
Redlands, Cal	"	7½	2,500	700	3 years, extending lines in other towns.
Lauffen to Frankfort, Ger	"	100	30,000	300	(Experimental.)
Lauffen to Heilbronn	"	9	5,000	600	Successful.
Oerlikon Works, Zurich, Switzerl'd	"	15½	13,000	450	"
Portland, Oregon	"	12	6,000	5,000	"
Silverton Mine, Col	"	4	2,500	400	" to be increased.

and this is of the utmost importance in long-distance transmission.

I will not take into account the supposed increased efficiency of three-phase motors and dynamos as against two-phase apparatus, as there is a question as to whether a superiority exists; but, simply considering the decreased amount of copper required and the decreased inductance of the line, there is no question, in my mind, that, for transmission, the three-phase system is superior to the two-phase.

It is well known, of course, that the inductance of the circuit can be, in some measure, compensated for by the use of condensers or over-excited synchronous motors. The first of these remedies is, however, a very uncertain quantity commercially, while the second should be used as much as possible; that is, as many synchronous motors should be connected as is practicable. The best remedy, as things stand at present, lies in the careful construction of the line and the apparatus, so that the effects, although they exist, can be reduced to a minimum.

It has been shown by Mr. Scott and others that it is possible to transform a two-phase into a three-phase current, to transmit it and to transform it back again to a two-phase current. This will allow us, if we wish, to use two-phase dynamos for generating the current, to transmit with the advantage incidental to the use of three phases and at our reducing end to use two-phase circuits for transmission. This has some advantages, as far as balancing the voltage on the circuit goes, and it has been proposed in the case of several plants whose installation is being considered.

Looking broadly at the value of alternating transmission as against continuous-current transmission, we have a gain in the simplicity and safety in the transmission, and at the distributing end the use of multiphase currents enables us to supply both lamps and power with an economy and success comparable to that of the continuous-current system.

If it is necessary to use continuous currents for certain types of distribution at the receiving end, they can be obtained by the use of rotary transformers by which the alternating current is transformed into a continuous current. These machines have approximately the efficiency of corresponding continuous current dynamos, while the output for a given size is about 50 per cent. greater.

Possible Voltages and Distances of Transmission.

A number of calculations have been made as to the possibility of transmitting electrical energy to very long distances. If the question of cost of transmission alone is considered, then where water powers or culm heaps are within distances of 100 miles of some large centre of consumption, it has been shown that it would be profitable to generate and transmit electrical energy. In these calculations, however, voltages are assumed that have never been employed for commercial plants, and whose availability is problematic, while sufficient stress is not apparently laid on the question of the reliability of the power.

If the industries of a large city depended upon a single transmission plant, it is evident that the question of reliability is of paramount importance. Where energy is supplied to manufacturers, to street car systems, and for lighting, a break-down that would involve the cutting off of current for a day would mean an enormous pecuniary loss to the community. As the distance of transmission increases, the possibility of accident is increased in greater ratio, because we have not only the higher voltages to control, but the length of the line that must be looked out for is also increased.

The best guide lies in the practical experience which has been obtained in the present transmission plants and the consideration of the difficulties that have arisen and the remedies that have been employed. I have prepared a partial list of the principal transmission plants that are now in operation.

It will be seen that the longest transmission is at Fresno, Cal., the distance being about thirty-five miles. The highest alternating voltage used is 13,000 volts at Zurich, Switzerland. The highest direct potential is 15,000 volts at Brescia.

All of these plants are working successfully, and this fact will lead to still longer transmission and higher voltages. No limit of either distance or potential has, as yet, been reached. If we consider the record of the present transmission plants, we can safely say that it would not be going outside of the safe limit of development to transmit at least fifty miles at a potential of 20,000 volts, provided the energy could be delivered at such a price as to be considerably lower than the cost of a corresponding amount of energy obtained from a steam plant. This, of course, is a matter of local condition entirely, and the commercial value of such a transmission will depend upon local conditions.

Long-Distance Transmission for Railroad Work.

The possibility of long-distance electric railroad lines is intimately connected with the possibility of long-distance transmission of power. We have seen that it is possible to transmit considerable distances from a single station. The current so distributed is not, however, such that it can be applied directly to railroad motors, but it must be transformed at points along the line, the distance apart of these points of distribution depending upon the system that is employed.

At present, continuous-current motors are used, and considerations of safety would lead us to use line potentials not greater than 700 volts. By distributing rotary transformers, five or six miles apart, we would be able to supply motors with current without any great investment in copper. The amount of copper required could be still further reduced by using rotary transformers with storage batteries, thus keeping a constant load on the transmission line. It will be found, however, that on any long-distance railroad line, the load on any section of the line is exceedingly variable and the discharge rate of the batteries will have to be very high in order to prevent excessive cost for the reducing stations.

A MODERN VERTICAL COMPOUND BEAM BLOWING ENGINE, BUILT BY THE EDWARD P. ALLIS CO., MILWAUKEE, WIS.

AMERICAN BLOWING MACHINERY.

By John Birkinbine.

WITH the exception of apparatus for raising water, there are probably no combinations of mechanical appliances of greater antiquity than what may be termed "blowing machinery," and any discussion, to be complete, must at least notice the crude arrangement which stimulated the fires utilised for the early production of metals.

The use of hollow reeds to direct upon incandescent charcoal the vitiated air ejected from human lungs, may be considered as the primary step, but the weakness and uncertainty of such blast, and the physical exertion demanded, led to the application of human energy in ways less exhaustive which would deliver air in greater volume and under augmented pressures.

The bamboo cylinders with wool or feather pistons, skins serving as bellows worked by the hands or feet, and subsequently the ordinary hand bellows, were primitive blast machines, and in parts of the world each of the ancient methods is still followed. The writer saw in Mexico a silver smelting furnace which received blast from large leather bellows operated by the feet of peons who had performed this duty for eight hours daily for so many years as to become badly deformed.

The continuous work demanded and the power required directed attention to other motive force than it was possible to obtain from man or from domesticated animals, and water early became an approved and useful substitute. The variety of arrangements used to produce blast by water power, if detailed, would be amply sufficient to furnish data for a magazine article, but these, as well as the blowing machinery worked by manual or by animal labour, have been described in standard works, and a discussion of blowing machinery in America may properly omit consideration of the details of all but such as were used liberally in that country. It will also be advisable to confine such a review to machines which have been, or are, generally, employed to furnish blast for metallurgical processes, without entering into the merits of various kinds of pneumatic appliances utilised for other

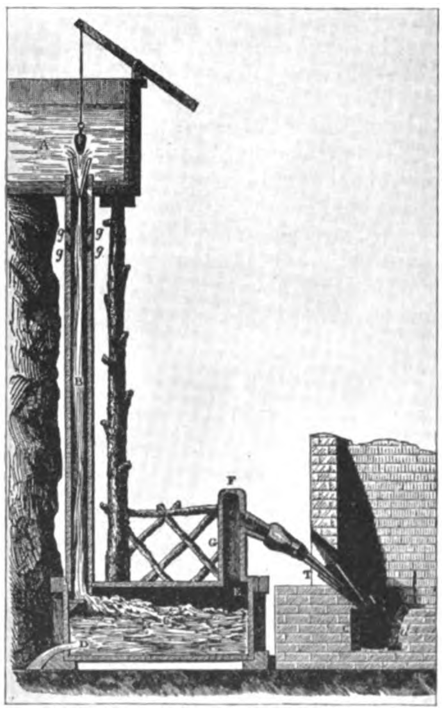


FIG. 1. THE TROMPE.—The water, rushing from the tank *A* into the tube *B*, draws in air at *g g* and delivers it into the lower tank *C*; from this the water escapes at *D*, while the air collects in the wind chamber *G*.

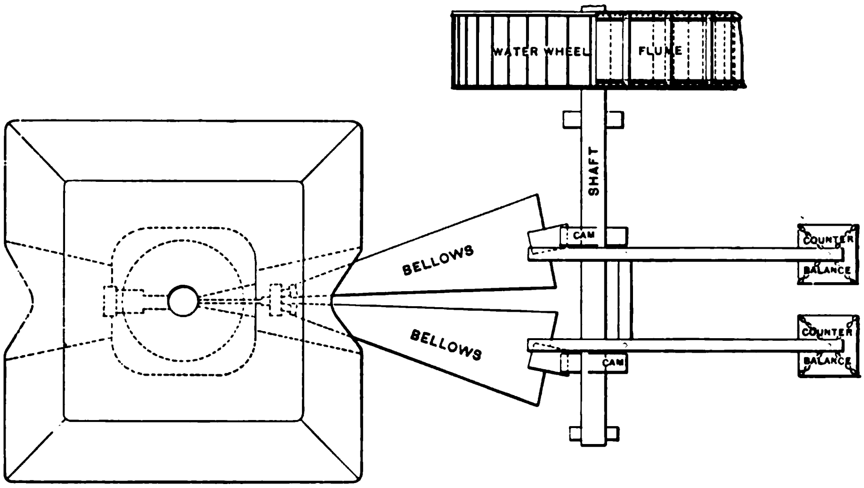


FIG. 2. A PAIR OF BELLOWS DRIVEN BY A WATER WHEEL. A DESIGN OF 1810.

purposes. Blowing machinery may be divided into four general classes:—

A.—Rotary blowers, such as fans and other valveless blowers for forced draught against limited resistance.

B.—Blowing engines, adapted to produce blast at moderate pressure, as for iron smelting furnaces, etc.

C.—Blowing engines or machinery delivering air at higher pressure for converting metals, etc.

D.—Compressors, from which the air is supplied under still greater pressure for producing power in other machines, such as air drills, air brakes, pumping water, etc. Compressors, however, having special applications are not, as a rule, classed with blowing machinery and will not be described in this article.

It is unlikely that blast under pressure or in volume sufficient to demand any mechanical appliance was required in the United States until iron ores were smelted, and as the pioneer efforts in this industry were introduced by Europeans, the blast was furnished by apparatus similar to that already in use in England in the seventeenth and the early part of the eighteenth centuries.*

Large bellows, receiving motion from

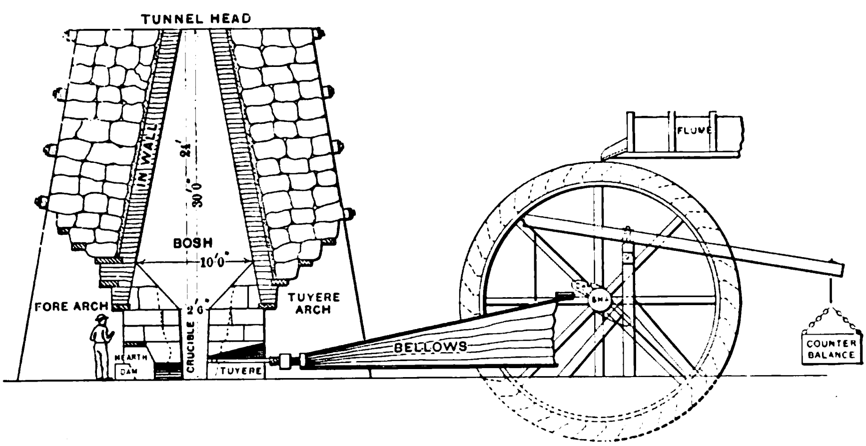


FIG. 3. SECTIONAL ELEVATION OF THE DESIGN ABOVE.

a water wheel or the trompe, by which air was drawn into a tube by a falling body of water and forced from it through a wind box to pipes leading to the forge fire or furnace, were the early blast machines. The trompes, although differing somewhat in detail, were all of the same general construction, but the power bellows (by which name all blast producing mechanisms were then known) varied greatly in form and size, and passed through a development which may be briefly summarised as follows:—

One or more large bellows were operated from the shaft of a water wheel as shown by Figs. 2 and 3, the bellows being made of two triangular or wedge-shaped wooden boxes (one moving within the other, and suitably packed) or constructed of wooden tops and bottoms with leather sides. In a popular arrangement cams on the revolving water wheel shaft compressed the bellows, thereby driving the air to a wind box, the bellows being expanded in the intervals between the return of the cams by counterweights acting through levers. Records show that at some American iron works the bellows were more than twenty feet in length. The illustration on page 110 shows a pair of bellows and the method of operating them from a water wheel in use at an iron blast furnace in the State of New York about 1810. A section of the furnace and the air connection from the bellows to the furnace crucible are also shown.

As greater volume and increased pressure of air were demanded, the bellows were supplanted by blowing tubs made of wood and properly braced or banded. Some of these tubs, which were square in cross section with the corners filleted (the pistons being supplied with leather or wool packing so as to fit snugly to the tubs), were braced by wooden beams held by iron bolts; but a majority of the blowing tubs were made cylindrical in form, being constructed of staves secured by iron bands.

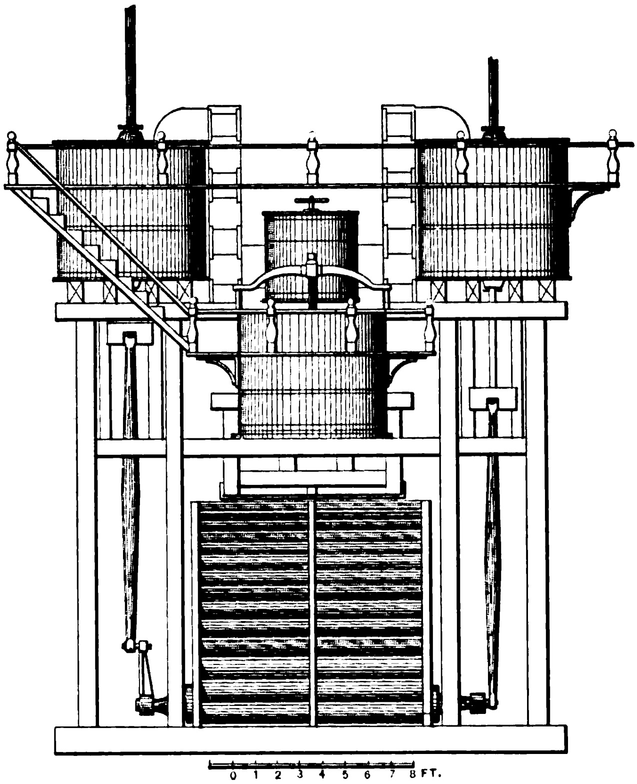


FIG. 4. BLOWING TUBS DRIVEN DIRECTLY FROM A WATER WHEEL SHAFT.

These tubs, ordinarily operated in pairs, were from four to seven feet in diameter, but the pistons had short strokes, seldom over two feet. The tubs were generally single-acting, with but one head, viz., that on top, the leather flap inlet valves being placed in the piston, and the outlet valves in the head. As the pistons in the two tubs alternately descended, the valves in them opened, admitting air between each piston and its tub head, which was expelled on the up-stroke through valves in the head to a third tub or cylinder, provided with a weighted piston to

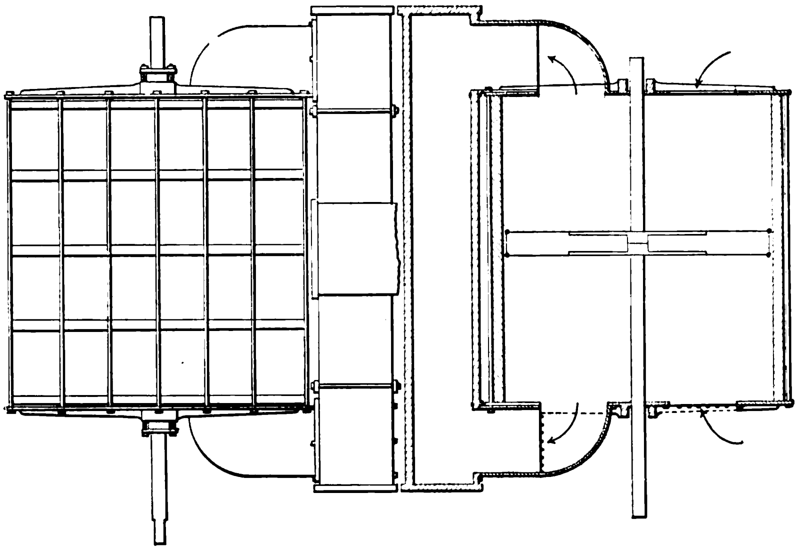


FIG. 5. ELEVATION AND SECTION OF BLOWING TUBS AND THEIR CONNECTIONS.

maintain the blast pressure desired. The pistons in the working tubs received motion from connecting rods coupled to a counter-weighted beam which was operated by a connecting rod and crank on the water wheel shaft. Wooden blowing tubs, connected with counterbalanced levers somewhat after the manner of the bellows shown in Figs. 2 and 3, were known as "pacers." Fig. 4 shows blowing apparatus in which the wooden blowing tubs had somewhat longer piston stroke than commonly used, and the pistons were operated directly from the water wheel shaft.

The capacity of a pair of wooden blowing tubs seldom exceeded 1000 cubic feet of air per minute, delivered under one-half to one pound pressure, and mechanisms such as above described were in use at some of the older American charcoal blast furnaces twenty years ago. The progress made is indicated by the statements that there are to-day at American blast furnaces single blowing engines which deliver 25,000 cubic feet per minute and over, at pressures of from ten to fifteen pounds, and others of smaller capacity which have worked against still greater pressures. Blowing machinery aggregating a capacity of 200,000 cubic feet per minute is, in one instance, concentrated in a single building for the supply of a blast furnace plant.

Promptly following the introduction of steam as a motive force and as a supplanter of water power, it was applied to engines which were connected with the wooden blowing tubs, the name "bellows," however, being maintained. But as mechanics advanced in knowledge and as machine tools were perfected, the blowing tubs or cylinders were constructed of iron and made double-acting. At first, the facilities of machine shops restricted the dimensions of these, so that, if of large diameter, they were of short stroke, while if of small diameter, the stroke could be increased; but some cylinders of large diameter were made in short sections bolted together. As the machinist was enabled to secure powerful tools, and his facilities increased, the blowing tubs or air cylinders became the "big work" of machine shops and foundries, the demands of the iron smelter for greater volumes of air spurring the mechanic to increase the dimensions of his castings and to enlarge his tools for boring and facing them.

Mr. William Firmstone, in a review

of the equipment of iron blast furnaces about the year 1840, gave the dimensions of some of the water power blowers and steam blowing engines then in use as follows:—At one furnace a 15-inch steam cylinder at eighteen revolutions per minute operated the pistons in two iron blast cylinders, each 40 inches in diameter and of 6-foot stroke. At a second furnace a 12-inch steam cylinder with a 4-foot stroke, at a speed of thirty revolutions per minute, gave motion, through gearing, to the pistons of two blast cylinders, each 40 inches in diameter and 42 inches stroke. At a third furnace a steam cylinder 12 inches in diameter and of 3½-foot stroke, with the shaft running at twenty-five revolutions per minute, furnished power for two blast cylinders, 32 inches in diameter and 5 feet 4 inches stroke at fifteen revolutions per minute. A fourth furnace had an overshot water wheel, 14 feet in diameter, with 3½-foot buckets, which drove two single-acting wooden blowing tubs, each 6 feet in diameter and 11 inches stroke, at a speed of twelve strokes a minute, delivering together about 600 cubic feet of blast a minute. At a fifth furnace the power employed was a water wheel 12 feet in diameter with 2½-foot buckets, driving two blast cylinders, each 5 feet in diameter and 6 feet stroke, running ten revolutions per minute.

The wooden or iron double-acting blowing tubs were placed either horizontally or vertically, the pistons receiving motion from a water wheel or steam engine through gearing; in the former case the motor revolved more slowly than the cranks which gave mo-

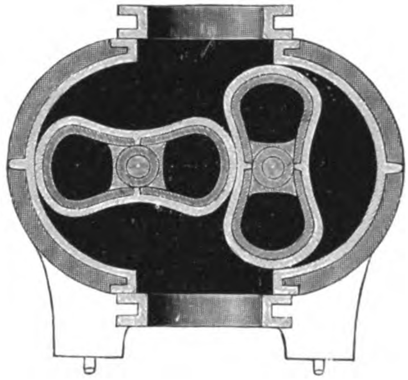


FIG. 6.—SECTION OF PRESSURE BLOWER, MADE BY THE CONNERSVILLE BLOWER CO.

tion to the blowing pistons; in the latter case the reverse generally prevailed. As a rule, two blowing cylinders were connected to a water wheel or steam engine, but sometimes three or even four cylinders were so combined. Occasionally a steam and a blowing cylinder arranged tandem, were in use, but the prevailing practice was to have the air cylinders placed horizontally, the steam cylinder or water wheel being to one side, the main shaft of the motor passing in front of the crank shaft for

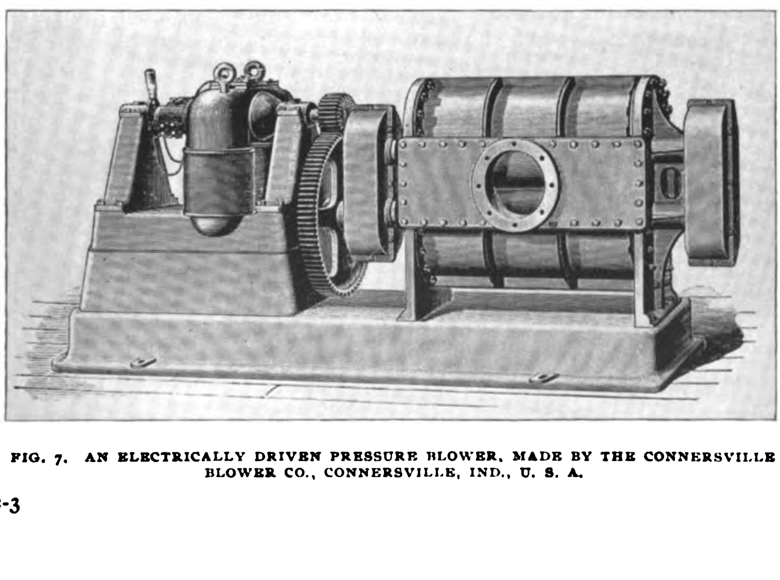


FIG. 7. AN ELECTRICALLY DRIVEN PRESSURE BLOWER, MADE BY THE CONNERSVILLE BLOWER CO., CONNERSVILLE, IND., U. S. A.

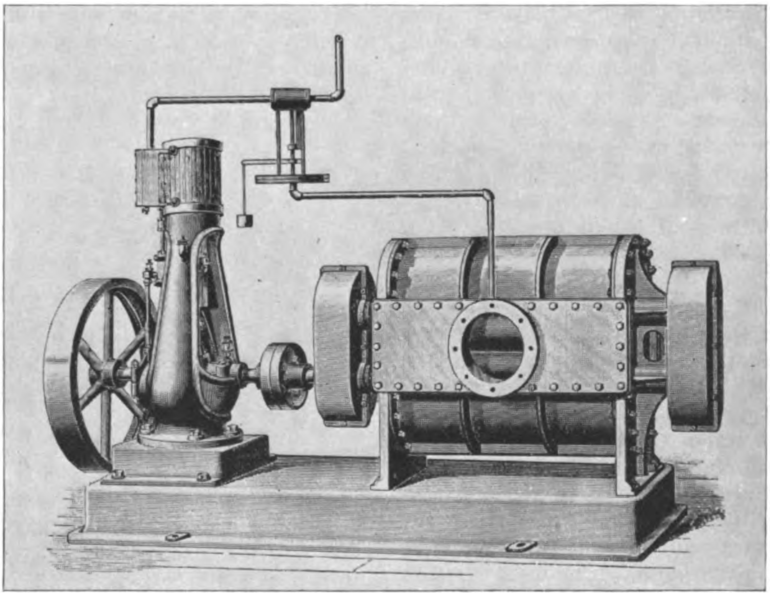


FIG. 8 A STEAM-DRIVEN PRESSURE BLOWER, MADE BY THE CONNERSVILLE BLOWER CO.

the blowing cylinders, and gearing connecting the two shafts.

The air valves were placed in the blast cylinder heads, part of the space being devoted to receiving and part to discharge valves. These were of the flap type, faced with leather, and closing against gratings; but, being of large size, unless these valves were properly bridled or caged, they seated so late that the length of effective stroke was diminished. The air delivery was also curtailed by the excessive slush room at the heads, the air compressed at one stroke expanding so as to neutralise part of the intake on the return stroke.

With the older form of flap valves the area of inlet or outlet rarely reached 10 per cent. of the cylinder area, and some engines lately built are equally deficient in this particular. In the Philadelphia Centennial engine, described later, the areas of admission and discharge exceed 20 per cent. of the piston area, and good practice indicates that a blowing engine should have inlet and

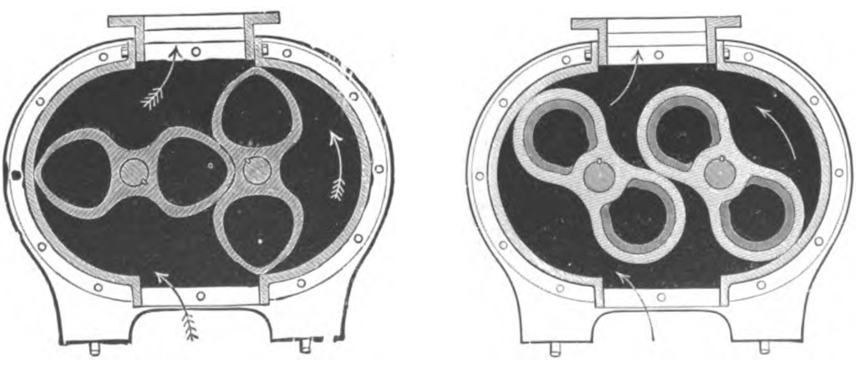


FIG. 9. SECTIONAL VIEWS OF PRESSURE BLOWERS, MADE BY THE P. H. & F. M. ROOTS CO., CONNERSVILLE, IND.

outlet areas for air each equal, at least, to 15 per cent. of the cylinder area.

The older blowing cylinder pistons were packed with leather, one approved arrangement being a recess in the piston rim which was fitted with a leather bag stuffed with wool. Later improvements include making deep pistons with a central recess in which strips of hard wood, soaked in oil, are placed. Other blowing pistons have metal packing and followers. Each of the builders who make a specialty of constructing blowing engines of large capacity, claim special advantages in piston construction, valve arrangement, etc.

Before considering the later designs of blowing engines now used as a part of the equipment of modern smelting plants, attention may be diverted briefly from reciprocating piston blowers to those dependent upon the rotation of a series of blades, as in the ordinary fan blower, or to forms of rotary pistons of various shapes which, being placed on parallel shafts, mesh into each other, and supply air under pressure superior to that of the common fan, but inferior to what is obtainable from cylinders fitted with pistons.

These pressure blowers have found liberal application for many purposes, and are produced in large numbers and of various designs. They are dependent upon power applied by belt, gearing, or from steam engines, water wheels or electric motors, connected to one of the parallel shafts. They have no valves. The general construction of well known types is illustrated on pages 113 to 117. The rotary pressure blowers are employed in large numbers to supply air to furnaces smelting ores which yield precious metals. As these furnaces are generally of small size as compared to iron smelting furnaces, a number are often grouped together and the power house in which is the steam engine, driving by belts a number of blowers, is an impressive building, containing a powerful equipment.

Some fan blowers of sizes worthy to be considered enormous, are connected with mines to assist in the ventilation, or are placed in large buildings to force air to heating chambers so as to supply it at desired temperatures in all parts of the structure. Large fans are also employed as ejectors to relieve mines of foul air, or draw a supply of fresh air through the shafts or slopes. They are supplied to large buildings as ventilators, and find liberal use in manufactories, either as blowers or exhausters, to remove dust, waste from woodworking machinery, cotton or other materials, and also to handle grain at elevators, mills, etc. Fan blowers are in use in sizes ranging from a few inches in diameter, for furnishing blast to a portable smith forge, to immense structures over 30 feet in diameter, demanding a large building for their protection.

A rotary blower of novel design, constructed some years ago, was never publicly introduced, because of the death of the inventor, the late P. L. Weimer, of Lebanon, Pa. A casing in which

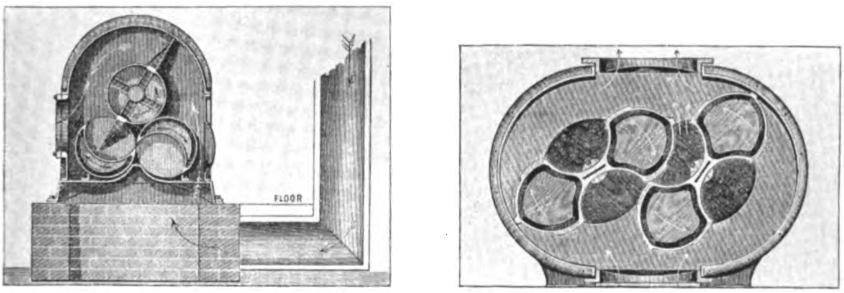


FIG. 10. SECTION OF BAKER AND GREEN PRESSURE BLOWERS, MADE BY THE WILBRAHAM BAKER BLOWER CO., PHILADELPHIA, PA.

were four hollow arms revolved about a central shaft provided with cranks. In each of the hollow arms a rectangular piston as wide as the arm, and as long as the casing, was fitted, which received motion through connecting rods, from the cranks on the main shaft. As the casing revolved and each piston was withdrawn to the limit of the inboard stroke, the open end of the arm entered a wind box, and as the revolution advanced, the returning piston forced the air from the arm into this receiving chamber.

Although the primary application of steam was in connection with horizontal blowing cylinders, the advantages of the vertical type were early recognised, and these were constructed with various modifications. The steam cylinder was placed above the air cylinder, in some cases resting upon it; but the difficulty of obtaining access to valves, and the dripping from the glands brought this form few champions. A steam cylinder, placed between two air cylinders, on a bed plate common to all, with flywheels outside of the air cylinders, and a long cross head serving the three cylinders, also met with but limited favour.

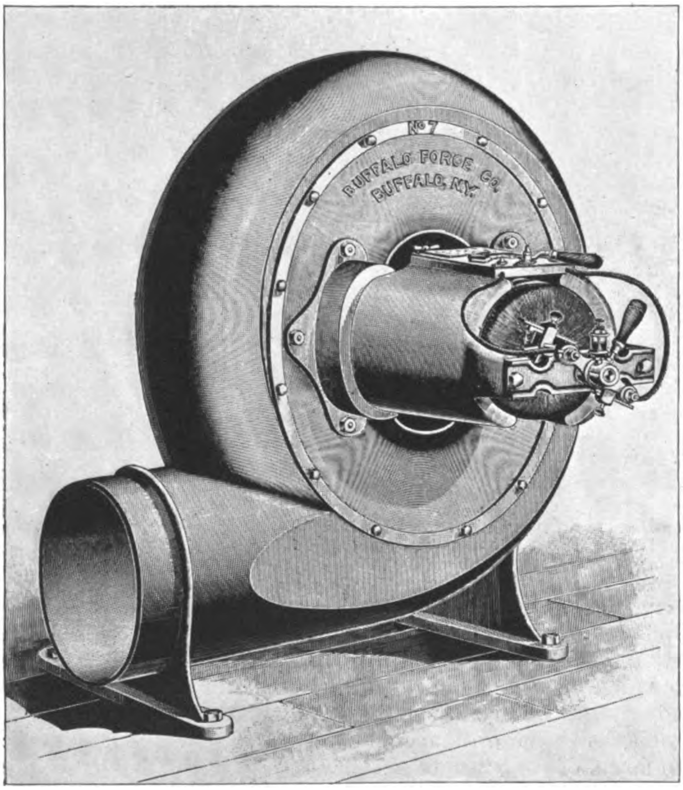


FIG. 11. AN ELECTRICALLY DRIVEN FAN BLOWER, MADE BY THE BUFFALO FORGE CO., BUFFALO, N. Y.

The air cylinder and steam cylinder were connected with overhead, underhand or side-lever beams, and when beams were employed, the engines were generally fitted with air pumps and condensers so as to work with low steam pressure. Modifications wherein a horizontal steam cylinder was connected to a vertical air cylinder or vice versa, have also been in use. But the pre-

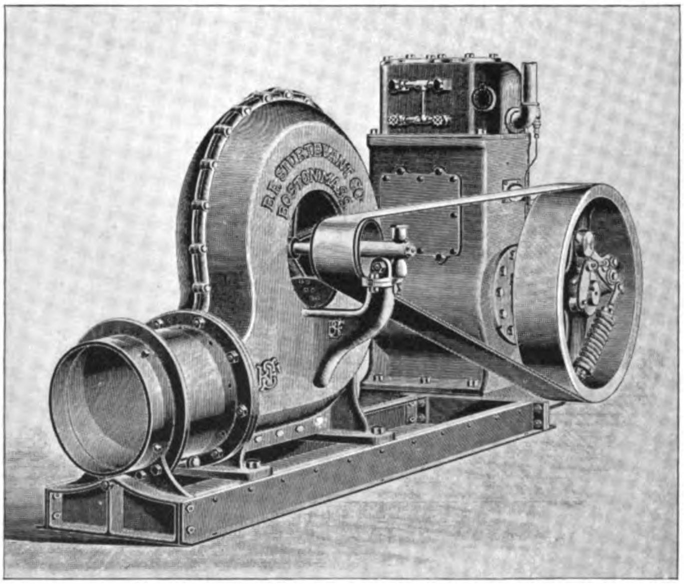


FIG. 12. A BELT-DRIVEN FAN BLOWER, MADE BY THE B. F. STURTEVANT CO, BOSTON, MASS.

vailing types of blowing engines at iron smelting works are:—

A.—Vertical engines (bull engines) with air cylinder carried above the steam cylinder.

B.—Beam engines with vertical steam cylinder and air cylinder at the opposite ends of an overhead beam.

C.—Horizontal engines with steam and air cylinders arranged tandem.

The compounding or combining of either vertical or horizontal engines, or the use of underhand or side beams is the exception rather than the rule.

In the bull type of blowing engine the steam cylinder is usually placed between, and supported by, columns or more commonly by housings, which are strongly ribbed castings, extending from the bed-plate, upon which they rest, to the lower head of the air cylinder, and carrying the cross head guides. The bed-plate is a single heavy casting on which the main shaft, and the column or housing bearings are fitted. The main shaft has a fly-wheel secured on each end, these wheels being fitted with wrist pins, which, acting as cranks, are coupled by means of connecting rods to the cross head. The piston rods, both air and steam, are attached to the cross head by means of a swivel block, which permits the cross head to adjust itself to the varying lengths of the connecting rods.

Modifications of the bull type are found in compound engines having two steam cylinders side by side between the housings, and in double engines having a fly-wheel placed between two air and two steam cylinders; but the form most in use is that above specified. Independent condensers and exhaust pumps are attached to a number of bull engines. Some blowing engines have the steam cylinders on the bed-plate, and the air cylinders superposed on housings or A frames, with one end of a beam connecting by short rods to the piston rods of the two cylinders, the outer end of the beam being connected by a rod with a fly-wheel.

A form of underhand beam engine has the piston rod of an 84-inch air cylinder connected to one end, while the piston rod of a 42-inch steam cylinder and the connecting rod of a 24-foot fly-wheel are at the inner end of the rock-

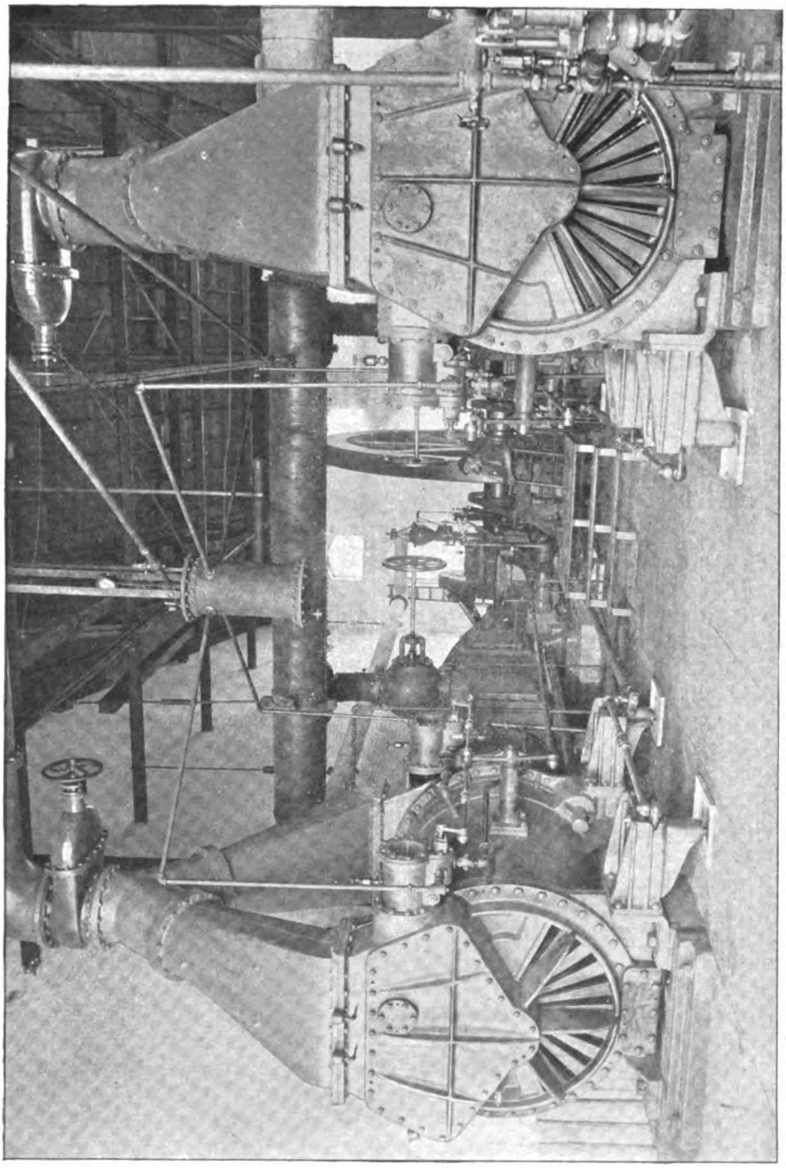


FIG. 13. HORIZONTAL TWIN BESSEMER BLOWING ENGINE, WITH POSITIVE INLET AND AUTOMATIC OUTLET AIR-VALVE GEAR, BUILT BY THE SOUTHWARK FOUNDRY AND MACHINE CO., PHILADELPHIA, PA.

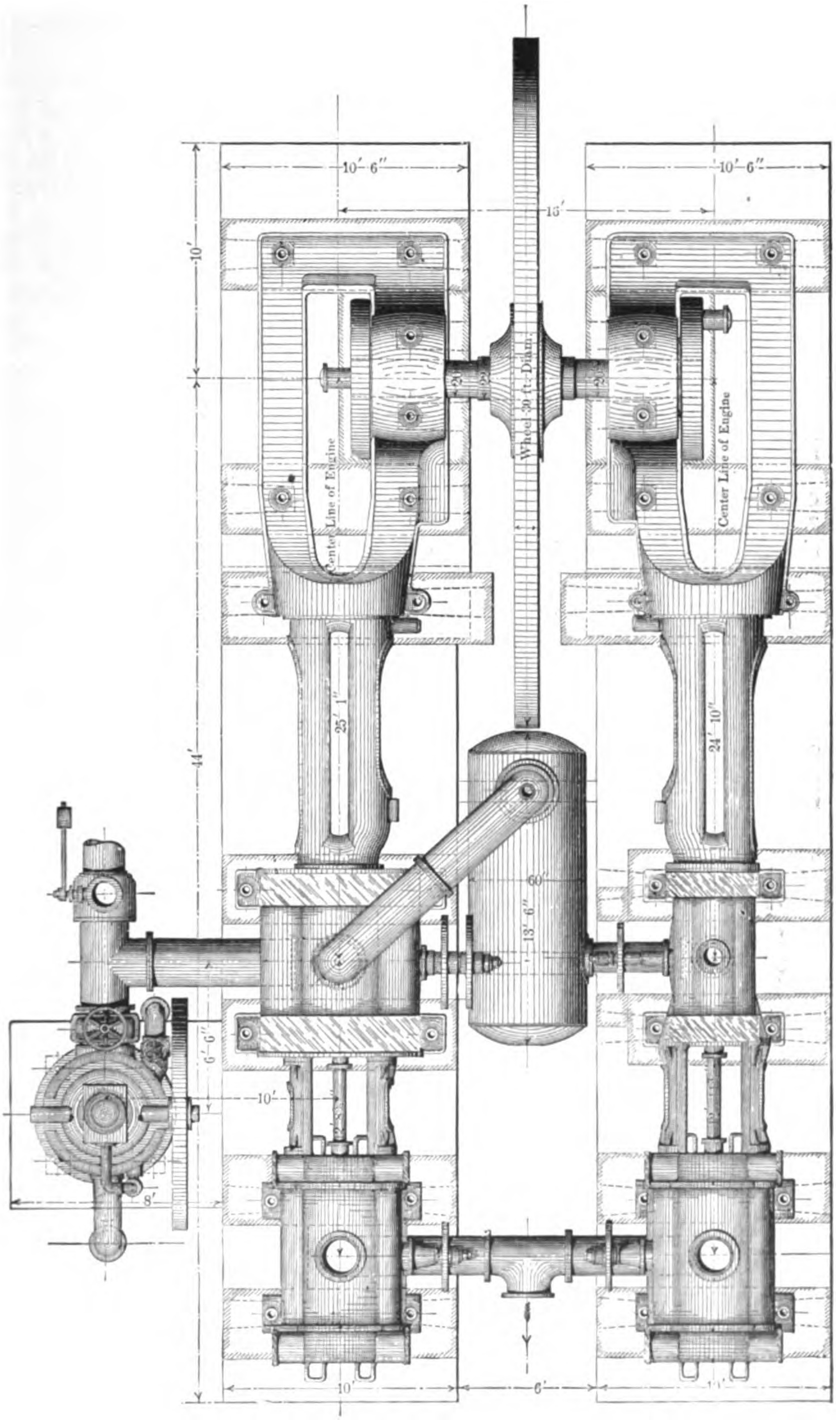


FIG. 14. A CROSS-COMPOUND TANDEM, HORIZONTAL BESSEMER BLOWING ENGINE, BUILT BY THE E. P. ALLIS CO., MILWAUKEE, WIS. 40X78X60-INCH STEAM CYLINDERS AND 60X60-INCH AIR CYLINDERS.

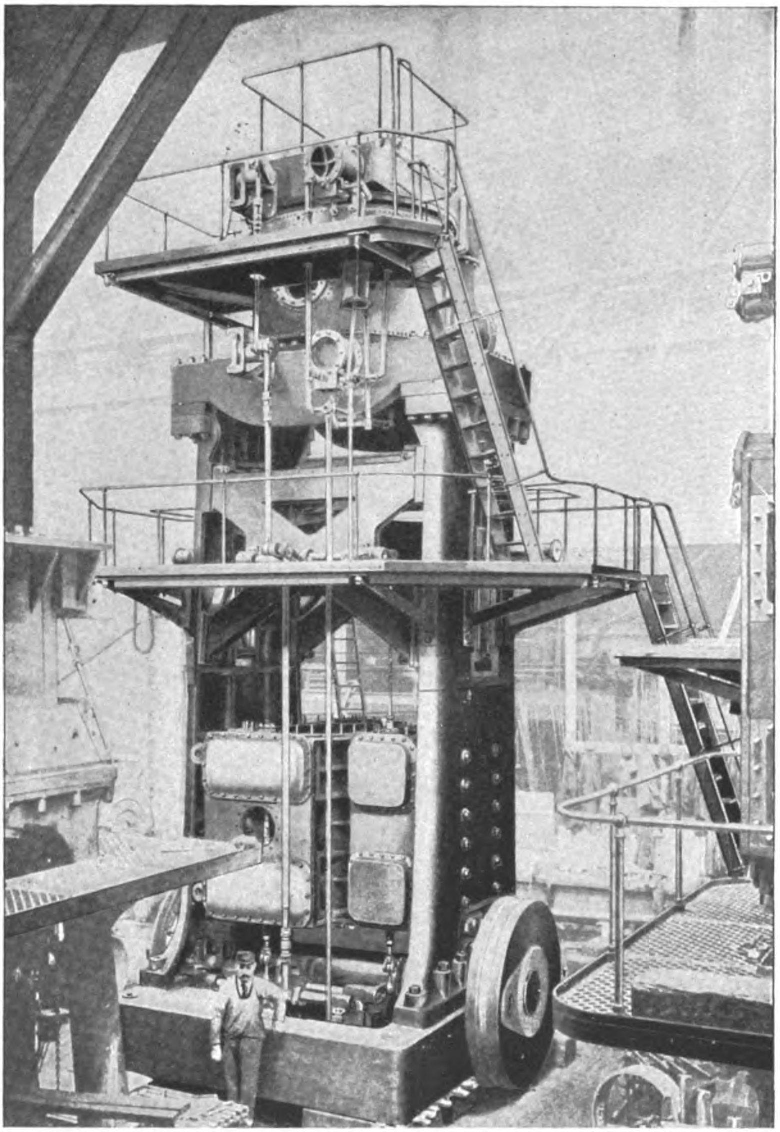


FIG. 15. VERTICAL BESSEMER COMPOUND CONDENSING BLOWING ENGINE, WITH POSITIVE INLET AND AUTOMATIC OUTLET AIR-VALVE GEAR, BUILT BY THE SOUTHWARK FOUNDRY AND MACHINE CO.

ing beam. The stroke of both pistons is five feet. A comparatively recent design of cross-compound tandem, horizontal blowing engine is shown in Fig. 14.

Fig. 15 is a compound vertical blowing engine built by the Southwark Foundry and Machine Company, of Philadelphia, for furnishing blast to Bessemer converters. It is shown in an unfinished state to illustrate the details of construction. The blowing cylinder with heads and actuating gear is erected complete. The hubs of the fly-wheels are secured to the main shaft, the rims and spokes not being yet in place. The two steam cylinders are 32 and 60 inches in diameter, respectively, and the air cylinder is 80 inches in diameter; all have a 48-inch stroke. The steam cylinders, which are placed side by side, and are attached to the housings, have a single cross head.

Another arrangement, built by the same works, consists of a pair of disconnected compound vertical blowing engines for operating a blast furnace, the high-pressure engine having a steam cylinder 40 inches in diameter, and an air cylinder 72 inches in diameter, with a stroke of 60 inches; the low-pressure engine has a steam cylinder 75 inches in diameter, an air cylinder 72 inches in diameter and a 60-inch stroke. The low-pressure engine is entirely separate and independent of the high-pressure engine, the only connection between the two being the receiver for reheating the steam.

A system of gate valves is provided, so that either engine of the pair can be run separately, condensing or non-condensing, as occasion may demand. These engines are fitted with positive-motion grid-iron valves. Those for the inlet of air are controlled by means of a cam, actuated through the medium of rods and levers, from an eccentric on the main shaft, while those for the outlet of air receive their movement from a piston on the stem of the valve upon which the pressures in the air cylinder and in the receiver act alternately to open and close, and are claimed to be automatic at any pressure. These valves are either rectangular in form, or of fan shape, the latter being applied to large horizontal cylinders such as shown in Fig. 13.

This illustrates a horizontal twin Bessemer blowing engine with steam cylinders 44 inches in diameter, air cylinders 60 inches in diameter, by 60 inches stroke of piston, built by the same firm. This pair of engines works with cranks placed at 90 degrees, the bed-plates extending from and including the main bearings to the steam cyl-

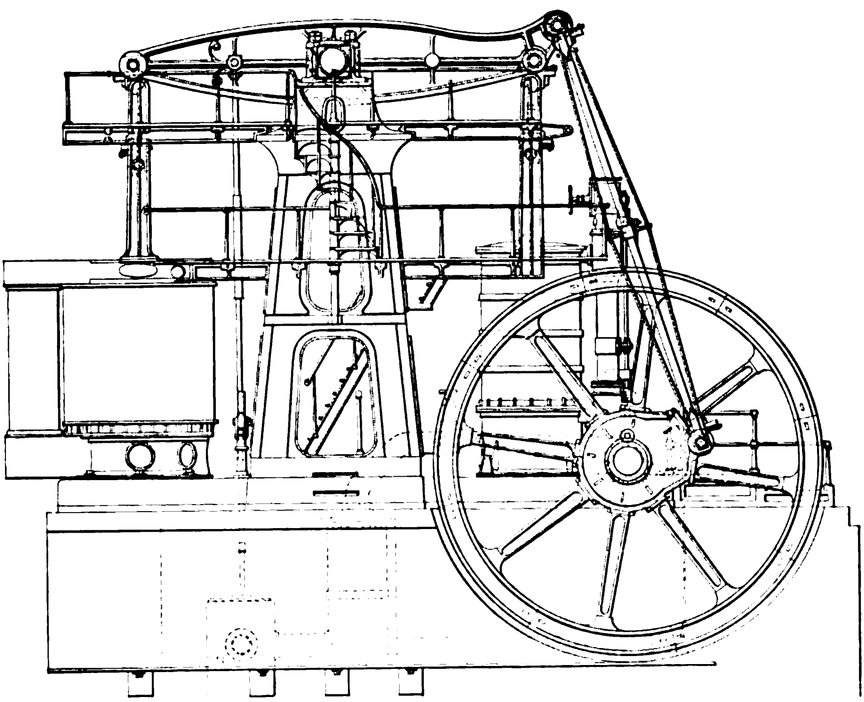


FIG. 16. A BEAM BLOWING ENGINE, BUILT BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHIA.

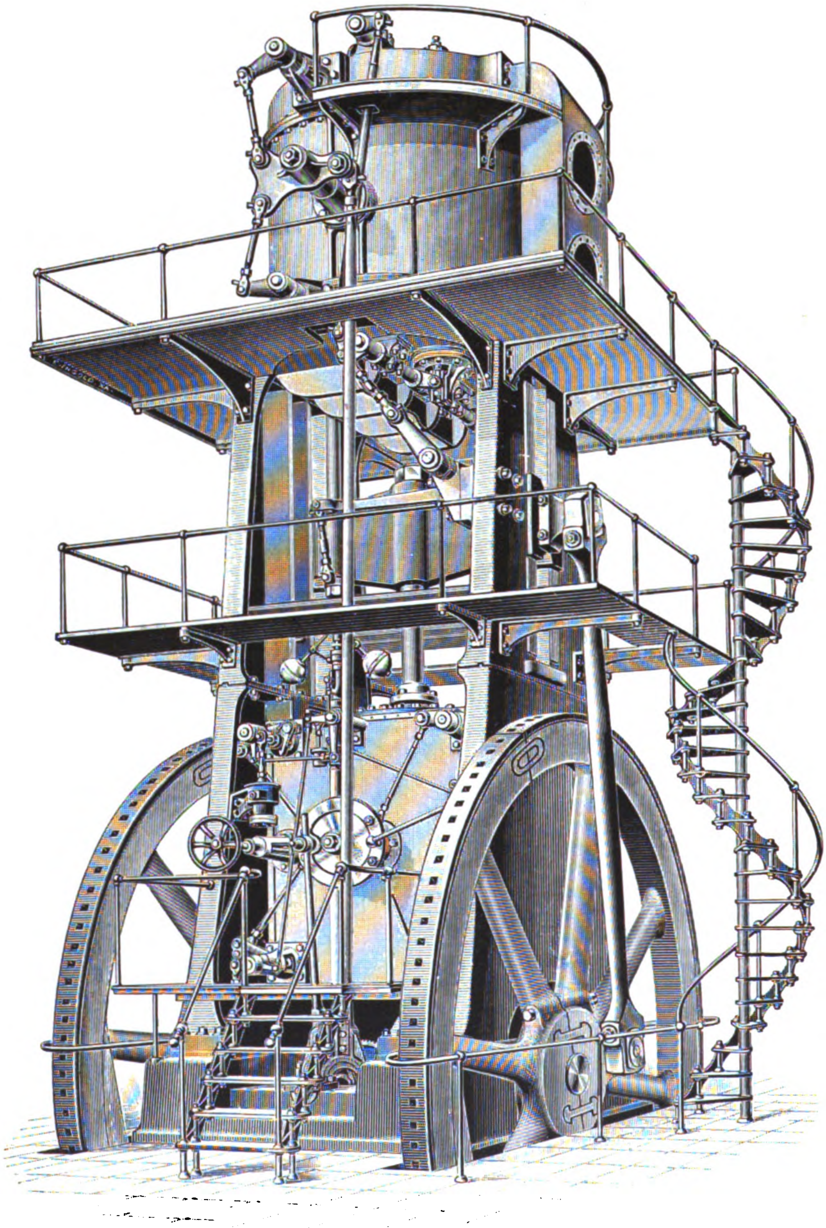


FIG. 17. A BULL TYPE OF BLOWING ENGINE, BUILT BY THE E. P. ALLIS CO., MILWAUKEE, WIS.

inders which are directly bolted to the hood of the beds. The air cylinders are placed tandem to the steam cylinders, and are connected to the bed-plates by means of heavy tie rods. They are also further supported by independent sole plates, extending under, and attached to, the steam cylinders.

Fig. 16 illustrates an overhead beam engine constructed by the William Cramp & Sons Ship and Engine Building Company, formerly Port Richmond

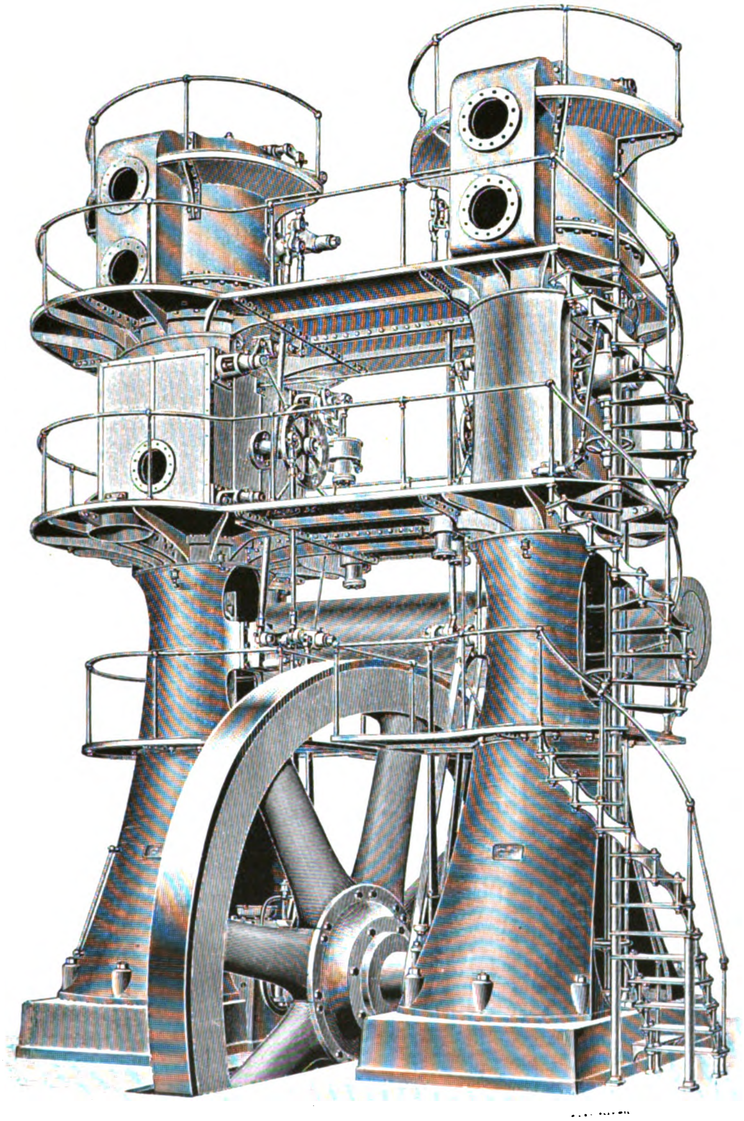


FIG. 18. AN ALLIS VERTICAL CROSS-COMPOUND BLOWING ENGINE.

Iron Works, of Philadelphia. These engines have double beams, and two fly-wheels, placed on either side of the steam cylinder. The one shown has a steam cylinder 60 inches in diameter and 7 feet stroke at one end of the beam, and a blowing cylinder 84 inches in diameter and 7 feet stroke at the other end of the beam, an intermediate connection being made for the air pump of the condenser. The fly-wheels are 20 feet 3 inches in diameter and weigh 37,300 pounds each. With steam at thirty pounds pressure and a speed of fifteen revolutions per minute, these engines are calculated as being capable of delivering 8000 cubic feet of air per minute at eight and one-half pounds pressure.

On page 108 is shown a type of vertical compound blowing engine, constructed by the E. P. Allis Company, of Milwaukee, Wis. The dimensions of the machine shown, which is for Bessemer service, are, high-pressure steam cylinder, 40 inches diameter; low-pressure steam cylinder 78 inches diameter; two air cylinders, 76 inches diameter; stroke of all cylinders, 5 feet. The fly-wheel, which is to be attached to the main shaft shown in the foreground, is 24 feet in diameter and weighs 100,000 pounds. The steam cylinders have Corliss valve gear, controlled by a governor. Air is admitted to the air cylinders through rotary valves, mechanically operated, the discharge valves being mechanically seated, but free to open automatically when the cylinder pressure equals the receiver pressure.

Fig. 17 is a bull type of blowing engine constructed by the same firm, and adapted by the relative proportion of the cylinders to either Bessemer or blast furnace work. In this cut the Corliss valve motion and the mechanism which operates the air valves is prominently indicated. Fig. 18 shows the construction adopted by the same firm to dispense with the long cross head common to the bull type of engine. It can be arranged either as a single high-pressure engine, or a double compound engine, as shown. In the latter case the fly-wheel is placed between the two housings. The blast cylinder is carried above the steam cylinder, and one connecting rod to each engine conveys motion to the main shaft.

Fig. 19 shows a horizontal tandem blowing engine, built by the Philadelphia Engineering Works, Limited, Philadelphia, Pa. The Corliss valve motion of the steam cylinder is operated by two independent eccentrics, and a third eccentric gives

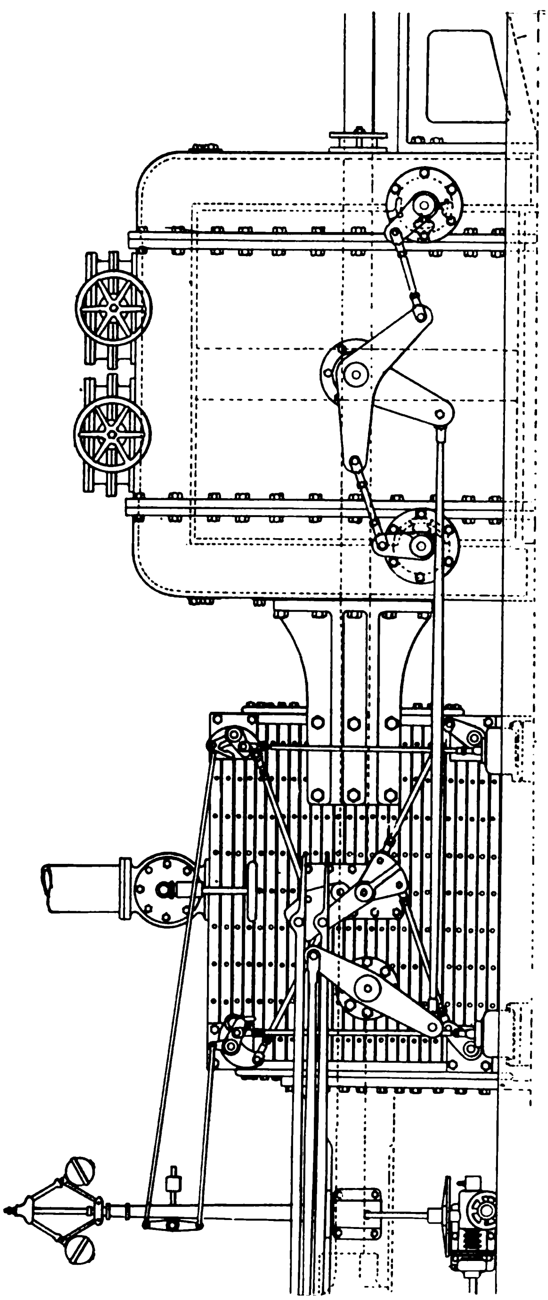


FIG. 19. HORIZONTAL TANDEM ENGINE, BUILT BY THE PHILADELPHIA ENGINEERING WORKS, LTD., PHILADELPHIA, PA.

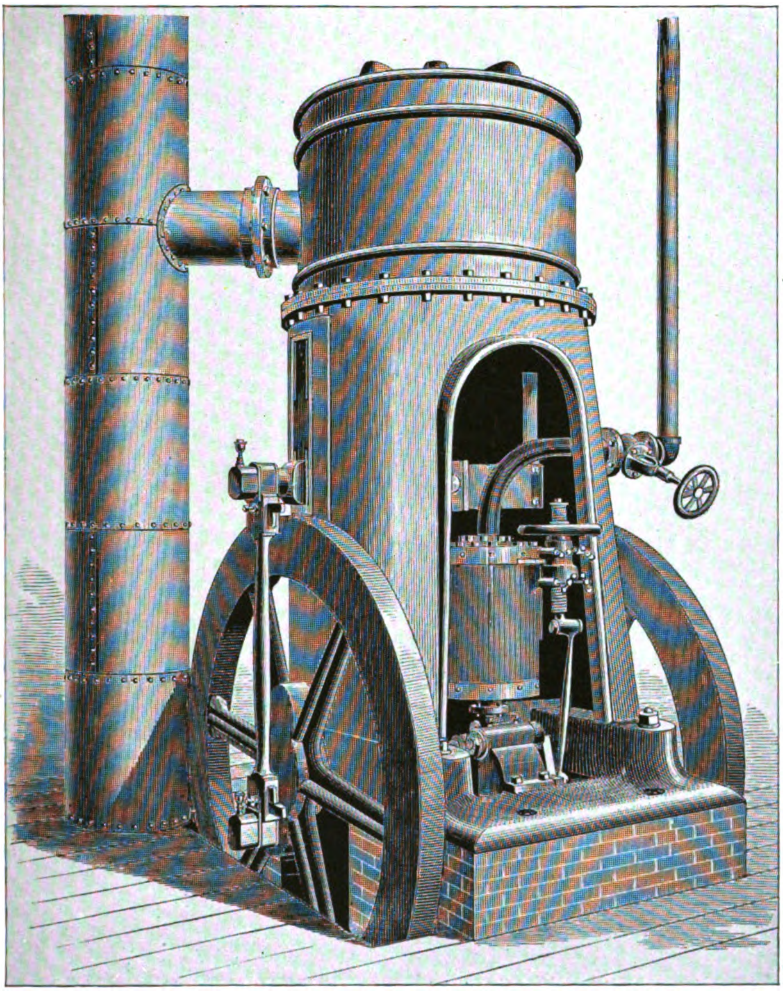


FIG. 20. A BULL TYPE OF BLOWING ENGINE, BUILT BY THE WEIMER MACHINE WORKS CO., LEBANON, PA.

motion to the inlet valves of the blowing cylinder. The inlet valves are segments of a tube, 15 inches in diameter, extending across the width of the air cylinder, and are arranged to open and close rapidly. The outlet valves have flat seats against which they close, an air cushion being formed by a piston upon the stem, the seating of the valve being assisted by a spring.

Most of the earlier steam blowing engines used flap valves,—leather discs, fitted in iron frames or strapped with iron, closing against iron gratings, the valves being secured at one side, or end, as a hinge. These were practically in universal use to within twenty years of

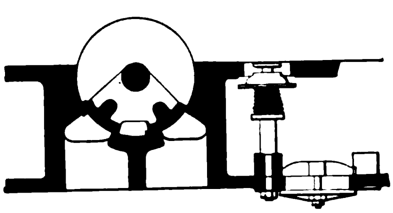


FIG. 21. AIR VALVES OF THE PHILADELPHIA ENGINEERING WORKS ENGINE.

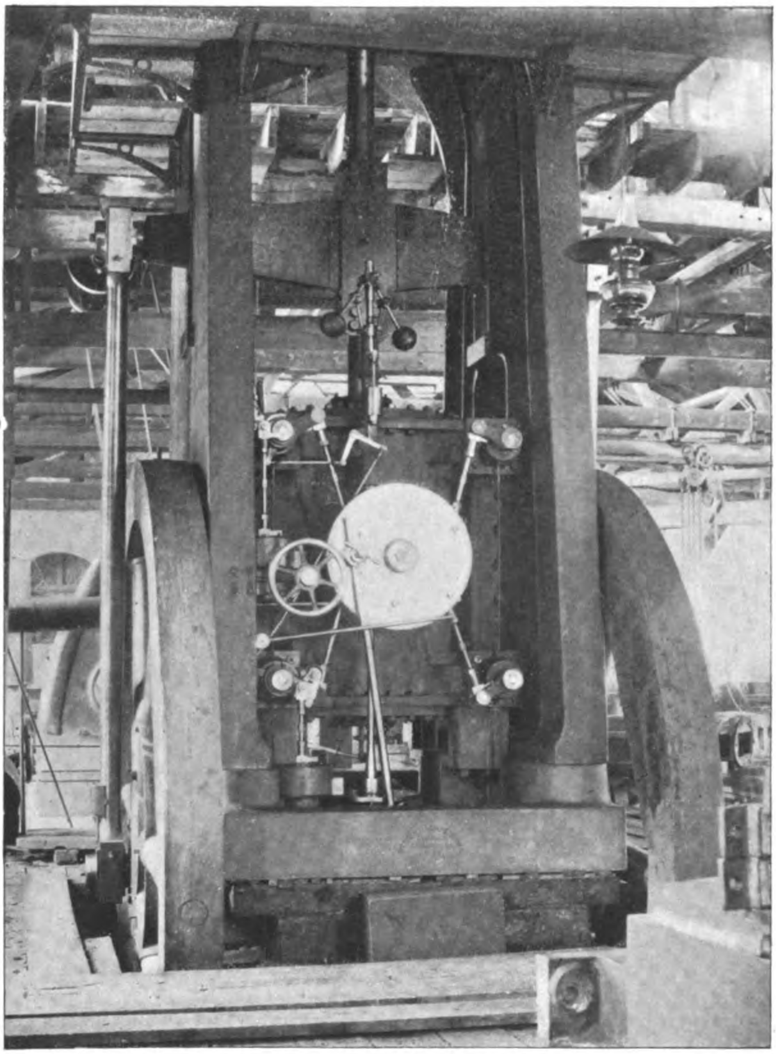


FIG 22 THE VALVE GEAR OF A WEIMER BLOWING ENGINE

the present time, the size and arrangement of valves being adapted to the cylinder. In some cases the valves were square or rectangular in shape; in others segmental forms were introduced to fill the spaces between the stiffening ribs of cylinder heads, and in others the heads were stepped outward to form valve seats and thus gain greater inlet area. When vertical cylinders were used, the discharge valves in the lower heads were provided with springs, or were counter-weighted, to insure their closing against gravity.

The flap valve, by its slow movement, restricted the speed of blowing engines within narrow limits, and the area exposed, together with the heat produced by compression, prevented the working of blowing engines fitted with such air valves, at air pressures and volumes now considered desirable for iron smelting.

A radical departure was introduced

in 1876 by a blowing engine built by the Weimer Machine Works, of Lebanon, Pa., shown in motion at the Centennial Exposition at Philadelphia in that year. By reason of the valve arrangement this engine was able to run at speeds which up to that time had been considered as impracticable. This exposition engine, which is still in use, has a steam cylinder 20 inches in diameter, a blowing cylinder 48 inches in diameter, and a stroke of 24 inches.

The construction is of the bull type of blowing engine with the steam cylinder fitted with slide valves. The cylinder head is provided with a series of recessed iron boxes, the bottoms and sides of which consist of alternate openings and strips of metal, thus forming gratings or grid-irons for receiving valves; similar gratings surround the periphery of the head for the discharge valves.

The openings in these boxes were covered by a series of strips of leather suitably joined together, and the motion of these was limited by grid-iron plates against which they lifted. As the piston traversed the air cylinder,

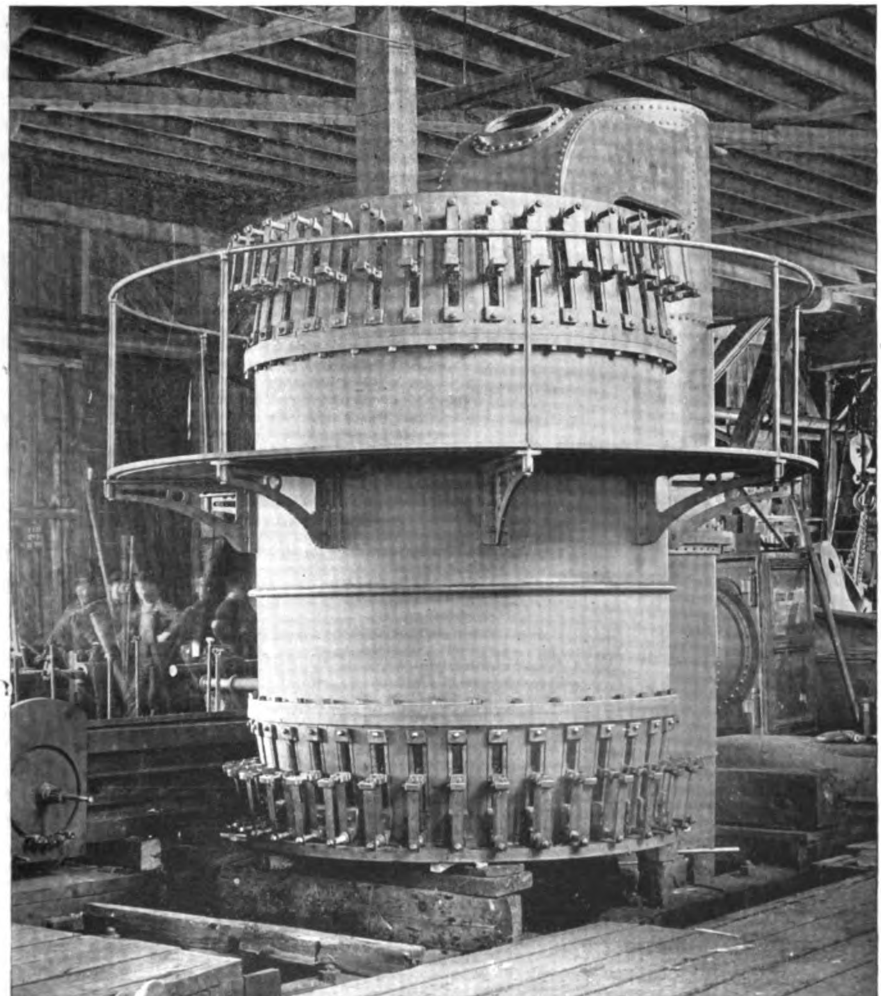


FIG. 23. A WEIMER BLOWING CYLINDER, SHOWING THE RECEIVING VALVES.

the valves moved against the guide plate, the air passing first through the openings in the boxes, and then through slots in the leather valves and guides into the cylinder. In expelling the air, a similar arrangement was used, permitting of a large area of inlet and outlet, with but slight horizontal or vertical motion of the valves, and speeds were obtainable which practically made a relatively small engine of equal capacity with a large machine, and of greater efficiency as to steam.

An engine with a blast cylinder 60 inches in diameter and 4 feet stroke could produce as much blast as one fitted with flap valves in a blast cylinder 84 inches in diameter and 6 feet stroke of the older construction. To improve the efficiency of the engine, the piston was made with a wide face and with radial arms, the arms extending into the spaces between receiving valve boxes and the rim, and to those between the receiving and discharge valves, so as to thoroughly expel the air at the expiration of each stroke.

Various modifications of these gridiron valves were subsequently introduced, and to secure large volumes from small compact engines, a number of disc valves, similar to those in use on compressors, closed by springs or by weights, were arranged about the cylinder heads. Some builders placed as many as 200 valves in a single head. Some of the disc valves were swung upon two parallel rods, so as to give prompt seating, and to accomplish the same purpose rectangular valves, closing against sloping grid-iron seats, were hung on metal links, or valves made of leather strips, were seated by two parallel strips of spring steel.

Valves of this character are shown in Fig. 23, which illustrates the construction of the blowing cylinder of the engines made by the Weimer Machine Works Company, of Lebanon, Pa., and this cut in connection with Fig. 22, which shows the bed-plate, housing, fly-wheels, steam cylinder, Corliss steam valve motion, piston and connecting rods and cross heads, represents a completed engine of the bull type as constructed by this company. The principal uses to which blowing engines are applied demand constant service. At a blast furnace the machinery is expected to run continuously, day and night, for many months, and stops are made only in case of some disarrangement of the furnace or its appliances. Every minute of time lost on account of repairs to blowing engines means disturbed conditions, reduced product and greater cost of manufacture. In the steel converting works the machinery may rest one day each week, but to meet the demands of present practice it must respond promptly with the large volume and high pressure for the numerous heats which follow one another rapidly during the six working days. Consequently blowing machinery must be designed for continuous operation, with all parts made of ample strength and capable of sustaining the wear and tear of such service.

The development of American blowing machinery has been closely allied to the iron and steel industry, the demands of the smelting furnaces and converters being met by improved structural features in blast apparatus. When limited volumes of air, at low pressures, were fed to blast furnaces which demanded quantities of fuel greatly in excess of the theoretical requirements and when the waste gases were only partially utilised, economy in either blast or steam cylinder received little attention. But as competition became close, and the chemistry of iron smelting was studied, as larger furnaces were constructed and the value of high blast temperatures was recognised, or as the requirements of the Bessemer steel process were appreciated, the slow-moving and comparatively weak mechanisms gave way to less cumbrous, but more powerful, engines whose air cylinders were studied to obtain the best results, while the steam cylinders were fitted with cut-offs, governors, Corliss and other valves.

The engineers of prominent machine works each favour special valve arrangements for steam and air cylinders, and while some lay much stress upon the use of positive air valves, others claim that the power required to operate the moving mechanism and the necessity of exact adjustment at all times, give them no advantage over automatic air valves.

Indicator cards taken from the air and steam cylinders of blowing engines of late construction, show that the manufacturers are closely approaching theoretical perfection in their construction. Similar advancement may be noted in the proportioning of fan and pressure blowers, and the motors to propel them, and numerous installations of these must be maintained in continuous service to prevent chilling of smelters, or to supply fresh air to miners. The form and arrangement of blades, or rotating pistons, have been carefully studied to obtain the best result, and compound steam engines or improved electric motors furnish the power to drive the blowing apparatus. In short, modern American blowing machinery may be justly credited as being abreast of improved practice in mechanical details.

EFFICIENCY OF COMBUSTION IN MARINE BOILERS.*

By J. R. Fothergill.

WE may reasonably assume increased boiler pressure looms in the near future, and although it is impossible to foresee to what pressures we may ultimately go, yet 250 pounds to 280 pounds may be considered within the bounds of probability; it thus becomes of the utmost importance to consider whether the present type of cylindrical return-tube boiler with circular furnaces is the most efficient as an apparatus for combustion, generation of heat, and transmission of that heat to the water. It is freely admitted that this type of boiler has been, and is, up to certain pressures, the most simple, the most "get-at-able," and serviceable marine boiler of any type introduced; but does this hold good for higher pressures?

The important objections seem to be weight, thickness of plate, particularly such places as are heating surface, heavy close staying, and especially small diameter of furnaces. The writer is well aware that small furnaces are occasionally used, but this is usually due to some peculiar necessity, and not from choice. Neither the Board of Trade nor Lloyd's rules prevent the use of fairly large furnaces of the corrugated or ribbed types under high pressure, but the necessity for keeping the diameter of the boiler shell as small as possible, to avoid exceptional thick plates and additional weight, etc., compels the use of furnaces of small diameter.

All engineers of practical experience fully appreciate the efficiency of large furnaces, and this is readily understood if we consider what takes place when fresh coal is thrown on the fire of a furnace in active condition. The coal at once absorbs heat, which disengages the bituminous hydrocarbon constituents by volatilisation, or, in other words, generates the gaseous portion of the coal by distillation. Until this process is completed, the fixed carbon or coke is not consumed.

Volatilisation is the most cooling process in nature, due to the quantity of heat which is directly converted from the sensible to the latent state. It is, in particular, due to this cause that heavy firing is so disastrous, and should be carefully avoided. As the hydrocarbon gases are volatilised by the first application of heat and pass off, hydrogen, having a greater affinity than carbon for oxygen, readily unites with oxygen to the production of water—steam.

* From a paper read before the North East Coast Institution of Engineers and Shipbuilders.

The carbon thus liberated must be supplied with its necessary proportion of oxygen for the production of carbonic acid, otherwise it will be precipitated in an extremely divided state and pass away as smoke, or, if from various causes the supply of air to the gases should be exceptionally small and badly distributed, carbonic oxide will be produced with serious loss in the amount of heat generated. For carbon, consumed to carbonic acid, evolves 14,500 units of heat, which, if consumed to carbonic oxide, would yield 4400 only. Although carbonic oxide may be produced under exceptional conditions, yet, fortunately, it does not appear from the analysis of funnel gases to be generally present, and when present it is usually in inappreciable quantities.

To ensure complete combustion, it is essential that not only the air supply must be sufficient, but that it shall be properly distributed in such manner as will readily facilitate completion of the combustion of the hydrocarbon gases as they leave the surface of the fire, as well as the fuel on the bars. This question of air supply is one of considerable difficulty, and has exercised the ingenuity of many capable men. The difficulty is materially increased by reducing the diameter of the furnace, and thus the height above the fire. It is of material importance that the necessity for maintaining at high temperatures the hydrocarbon gases as they are evolved should be thoroughly understood. Hydrogen effectively unites with oxygen at not less than 600 degrees Fah., and carbon with oxygen at not less than 800 degrees Fah. The higher they exceed these temperatures within certain limits, the more readily they unite and the less surplus oxygen is required. Volatilisation being the most cooling process in nature, it is imperative that the greatest consideration be given to raising the temperature of the hydrocarbon gases as they are evolved, that they may immediately take up and unite with the necessary oxygen to complete combustion and generation of heat. Perhaps in this respect the most serious difficulty to overcome is that great bugbear—heavy firing.

Unfortunately, this appears inevitable where the manipulation of the fires is left to the capricious and prejudicial bias of the stokehold. Large quantities of coal thrown on the fire at once reduce the temperature, and frequently to such a degree that the gases evolved cannot take up the oxygen required, and thus they pass away, forming the huge volumes of smoke so commonly seen immediately after firing.

The smaller the furnace, the greater the evil, in that the furnace crown is very much closer to the fire; in fact, without very careful and judicious firing —and where will you find it in the ordinary mercantile marine?—the surface of the fire is so close to the crown that immediately the gases are evolved, they come in contact with the crown plate; and if we consider that at 250 pounds pressure, the temperature of the water, and hence the plate is, say, 400 degrees Fah., we at once realise the deleterious effect this must have in keeping the temperature of the evolved gases far below that necessary for complete combustion.

Again, the smaller the furnace, the less the sectional area above the fire, and thus the velocity of the gases leaving the furnace must be considerably increased; moreover, this velocity is greatly augmented by the necessity to largely increase the consumption per square foot of grate, due to the small grate area obtainable. To obtain this necessary high velocity of the gases, a lofty funnel with high temperature of the escaping gases must be used, or some system of induced draught.

High velocity of the escaping gases is, in many respects, a most objectionable feature. Time is an essential element in the completion of combustion, in the union of carbon with oxygen, and in the transmission of heat to the water. At this high velocity the temperature of the gases as they escape from the tubes into the uptake must be abnormally high. True, much of this heat may be utilised in various ways, but it is a costly process.

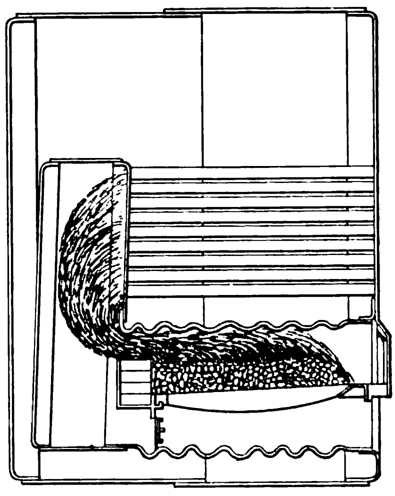
There is another important feature which does not appear to have attracted sufficient consideration, namely, the gases of complete combustion do not transmit heat by radiation, but by conduction. The sectional area through the tubes, being in all cases larger than the outlet from the furnace, facilitates the gases passing from the furnace at high velocity into the tubes in the most direct course without coming in close contact with the large heating surface of the combustion chamber; and probably the draught may be so great, when large quantities of coal are burnt per square foot of grate, as to draw the whole of the gases through the lower rows of tubes, leaving the top rows useless.

In the annexed diagram the writer has endeavoured to depict the course which gases at high velocity, due to excessive funnel or induced draught, will probably take when passing from the furnaces into the tubes; from this it will be seen that practically a large percentage of the combustion chamber heating surface is rendered of little or no use, due to the inability of the gases to transmit their heat other than by conduction. It would appear as though many of the objectionable features referred to are obviated in the water tube boiler. Of course there are water tube boilers and water tube boilers, some to be entirely avoided, others specially designed and satisfactory for certain purposes only.

For the purpose of this paper, a type of water tube boiler known as the Babcock & Willcox is taken. The writer has selected this particular boiler as one that he is somewhat acquainted with, and suitable to the requirements of the ordinary mercantile marine. He specially desires to say that he has not selected this boiler in detriment to other types of water tube boilers, but principally because he has evidence of its success, as fitted in several steamers.

In the Babcock & Willcox type of boiler we have a large grate area, suitable to the best conditions for complete combustion. The furnace is supplied with two doors sufficiently large to facilitate the distribution of the fuel, and at that convenient height which gives the fireman complete charge over his shovel, a matter of no small importance, particularly with untrained men. By firing at each door intermittently, you have always one side of the furnace incandescent when the other is being fired, and thus the hydrocarbon gases evolved are readily heated up to the necessary temperature to their union with oxygen to complete combustion and generation of heat. The height of the lower row of tubes above the fire offers a great advantage for the supply of air to the surface of the fire.

The writer is not aware whether the



THE EFFECT OF EXCESSIVE DRAUGHT.

following arrangement has been tried, but it would appear to offer some advantages:—Say, for a distance equal to one-third the length of the grate, specially designed slabs of fire brick be suspended to the underside of the bottom row of tubes, or otherwise fixed. As the fire burns down and becomes a mass of incandescent coke, the fire-brick would store up a considerable amount of radiated heat, which, in its turn, would be given off in heating up the gases as they are evolved to complete combustion and production of heat.

Such an arrangement would necessitate placing the coal principally at the front of the fire and pushing it back on the grate after the gases were given off.

Provision is made to deflect the gases in their passage through the boiler.

This is one of the most important features of the water tube boiler, and the fact that this was not appreciated in the earlier types, was undoubtedly responsible for much of the loss of efficiency in those boilers, as the gases of combustion passed direct from the fire to the funnel without coming sufficiently in close contact with the heating surface. No doubt, the most efficient position in which to place these deflectors is open to some argument. Whether they should be horizontal or vertical, viz., in a line with, or at right angles to, the tubes is debatable. Horizontal deflectors offer convenient shelves for the accumulation of soot and small ashes, etc.

The writer in his forced draught trials had strong practical evidences of increased efficiency by keeping the gases passing through the boiler under slight compression. Take the case of the steamship *Iona*, one of the steamers tested by the committee of the Institution of Mechanical Engineers, and under the writer's supervision, and fitted with his system of forced draught. During the whole of the trial the damper in the funnel was only one-sixth open; this gave just sufficient compression to bring the gases into intimate contact with every square inch of heating surface, both in the tubes and in the combustion chambers, to the greatest advantage in the transmission of heat, as shown by the low temperature of the funnel gases. From frequent trials, all other things being the same, the difference in maintaining steam with the damper full open and only open one-sixth was most marked.

It will be readily understood that this closing of the damper cannot be utilised with natural draught. It is more than probable that the application of some such system of slightly compressing the gases in water tube boilers would do much to improve their efficiency and obviate the necessity for deflectors and baffles, which in itself would be a considerable improvement.

PROFESSOR FRANZ REULEAUX.

A Biographical Sketch.

By Professor Hans Zopke, Royal Prussian State Engineer.

I wish to express my gratitude to my friends and colleagues, in The Columbian University, Washington, D. C., Professor Hermann Schoenfeld, Ph. D., and Professor E. S. Farwell, C. E., for kind assistance in the preparation of this sketch. To Professor Reuleaux I am especially indebted for unprinted and original sources placed at my disposal, which materially supplemented my views, acquired during a long personal co-operation with, and under, him.

IT was England that gave to the world, in its very first monument of invention, the steam engine, that brilliant product of human creative genius which was to become the starting point of a revolution of the material and social conditions of mankind. But while England was the cradle of modern practical machine construction, it is, nevertheless, in France that the scientific treatment of mechanical engineering began with the foundation of L'École Polytechnique in Paris.

To the German scholars, however, belongs principally the distinction of having developed, deepened, and brought to a climax the mechanical sciences introduced by the French. The brilliant spirit of investigation and the thorough methods of the German scientists insure to them still the first rank in the various branches of the science of machines. The life and work of one of these creative and pioneer spirits, the greatest machine philosopher, Franz Reuleaux, the results of whose investigations have become common international property and have taken the firmest roots in the English and American worlds, will be here briefly presented.

Franz Reuleaux was born on September 30, 1829, the fourth son of Johann Josef Reuleaux, who had founded one of the first machine shops in Germany, at Eschweiler, near Aix-la-Chapelle. After a thorough preparation in the natural sciences, and considerable practical experience, he studied mechanical engineering at the Polytechnic school at Carlsruhe.

It was just at this time that the famous Redtenbacher occupied the first German chair of machine construction, and it was his influence and work that for many years gave to the school at Carlsruhe a powerful advantage over the other technical schools of Germany. Redtenbacher recognised immediately in his pupil a nature congenial and equal to his own, in which was the harmonious blending of all the intellectual gifts necessary for the scholar in engineering and from which the world might expect creative activity.

The result of his studies had shown Reuleaux the engineering sciences, then fragmentarily arranged as to their phenomena and purposes, in a narrow view, and this did not satisfy his philosophical mind; hence, he wavered for a time in his resolution to follow mechanical engineering as a profession.

At this time there was no separate science of machines. Out of the chaos of the existing conceptions, Redtenbacher was the first to attempt the creation of a science of mechanical engineering which would exist only for the sake of the machine and machine problems. Reuleaux studied the philosophical branches at the University of Berlin

(1852-3) and at the University of Bonn (1853-54). At Bonn, assisted by the mechanical engineer Moll, he edited his first work "Strength of Materials."

Before its advent, all calculations relating to the resistance of materials were referred to the limit of rupture fixed by experiment, and, according to the character and use of the constructive part under consideration, various factors of safety were employed.

These conditions were entirely done away with by Reuleaux's principle that we must introduce the internal molecular forces, or the alterations of form, which, in every case, indicate whether the limit of elasticity is passed or not, and which define precisely how near one is to this limit. In place of the obscure and insignificant factors of safety, appeared the important molecular stresses and elastic changes which disclose the real character of internal strain.

In 1854 Reuleaux, again assisted by Moll, began to edit his work on "Theory of Construction of Machines," which he, alone, completed at Zurich, in 1861. The methods originated by Reuleaux in his first work were adopted by him also in the calculation of springs which could not be calculated till that time. The work published by Reuleaux in 1857, on "Theory of Springs Used in Machine Construction" (Wurster & Co., Winterthur, Switzerland), is still in use and is much employed in America. It may be remarked here, as characteristic of Reuleaux's greatness, that many of his ideas have spread so rapidly that already the originator has been forgotten.

It happened with his ideas what happens with the most beautiful melodies of composers and the profoundest truths of poets,— they become "winged words" whose originators are forgotten. They have found their way to every individual and pervade the intellectual life of whole nations. The influence upon the whole world is so deeply rooted, that it is apparently impossible that they should have been planted by one man.

By virtue of his scientific work the young scholar was called, in 1856, as full professor of mechanical engineering to the newly founded Polytechnic School of Zurich where he and Gustav Zeuner together in a short time brought the mechanical department to such an ideal development and fame that students repaired to Zurich from all parts of the world.

It is a remarkable act of Providence that these two bright stars should have found the starting point for their careers at the same time and at the same place. The Zurich polytechnic school has, moreover, the glory of having had, during the comparatively brief period of its existence, more technical men of first rank as members of its faculty than any polytechnic school of Germany. Zurich was for Reuleaux the starting point for all his researches—even the latest. It is a remarkable fact that the sum of Reuleaux's researches are comparable to a powerful stream from the waters of which the strongly characteristic colours of the source cannot be wiped out or destroyed. The very elements of his scientific works are so peculiar that they can be traced in their further development and in the result, and ever again fixed as essential constituents.

After Reuleaux's philosophical treatment had fixed "the machine as a combination of resistant bodies, so arranged that by their means the mechanical forces of nature could be compelled to do work, accompanied by certain determinate motions," he inferred from this definition the necessity of the division of the science of machines into four classes, characteristic of the nature of machines. Each of these four classes is treated as a special science which is to be developed independently in its particular domain. All the four special sciences have a common object,—to elucidate the casual connections of machine phenomena.

They comprise, first, the study of machinery in general which treats descriptively of all actual machines as an entity.

Second, the theoretical study of machinery, which treats of the machine known according to its purpose and construction and which teaches what quality is to be imparted to it, in order that it may best fulfill its purpose. It occupies itself primarily with prime movers.

The third science is that of machine design, the object of which is to teach how capacity for resisting alteration of form is to be given to the pieces constituting the machine.

The fourth science is that of kinematics. It is the science of that particular arrangement of the machine by virtue of which the motions of its members, considered as changes of position solely, are to be determined. The complete solution of machine problems is accomplished only by the unification of all the four sciences. Reuleaux is the creator of the fourth special domain. Science has surnamed him "Father of Kinematics," while Gustav Zeuner's great merit lies in the domain of the theoretical study of machines which owes to him the building up of the theory of caloric engines upon the principle of the conservation of energy, discovered by the German physician Robert Mayer.

In Zurich was also laid the foundation of a thorough and systematic treatment of the elements of machines and the details of machinery. The fruit of this effort appeared in 1861 in his practical hand-book of machine design, "The Constructor," which grew, in the fourth edition, to a voluminous work and has been translated into French, English, Swedish, and Russian.

The conception of scientifically differentiating the elements of machinery was first formed by Reuleaux. The excellent and very painstaking English translation of the fourth edition of "The Constructor" was made by Henry Harrison Supplee, of Philadelphia. In the domain of details of machinery also, Reuleaux has done original work and enriched the subject with numerous new views and methods.

His investigations into the inner nature of the machine led, after long preliminary work, to kinematics, which he placed on an entirely new foundation. Kinematics is the science of the constrained or machine motions which can be produced only in one and the same predetermined manner. These principles are universally recognised at present.

The kinematic laws discovered by Reuleaux were disclosed by him for the first time in 1864 before the Society of Swiss Scholars of Natural History and its German guests. At the occasion of the 150th anniversary of its existence the society made Reuleaux and Zeuner honorary members.

Reuleaux discovered, and proved, in 1864, that all machines consisted not of single elements but of kinematic pairs of elements, as for instance the shaft and the bearing, the screw and the nut, etc., which can be determined with mathematic accuracy and combined to form what are called kinematic chains. A kinematic chain becomes a mechanism, when one of its links is fixed in position relatively to the surrounding space, according to which principle every kinematic chain furnishes as many mechanisms as it has links. By this process a very remarkable simplicity of facts was reached, inasmuch as different and distant mechanisms were recognised as closely related, old things were connected with new, order and law were put into a wide domain of supposed-to-be different things, or were proven to exist at the bottom of things.

Reuleaux showed further that the number of the elements forming a pair was not unlimited, as heretofore considered, but was limited to some twenty, while their combinations into kinematic chains, it is true, can be widened to an immense, but definite, number of possibilities.

The solitary theories of Poinsot on relative motion, which, up to Reuleaux's time, were quite strange to machine construction, he incorporated as geometrical principles into the science of machine motion and assigned to them thereby a practical use not dreamed of before.

Reuleaux laid down his kinematic principles in his fundamental work on "The Kinematics of Machinery," in 1875, a work which was soon translated into Italian, French and English. The classical English translation is by Professor Alex. B. W. Kennedy, of London. The work has bestowed upon Reuleaux's name an international fame and insures to him an imperishable monument in the history of science.

Shortly after the publication of his kinematic laws, Reuleaux received an honourable, as well as enticing, call to Riga to found a new Imperial Institute of Technology,—a call which he, however, did not accept. But soon afterwards, in consequence of his reformation of the science of machines, he was called to the Royal Technical Academy of Berlin, as professor of mechanical engineering and kinematics. In 1868 he was appointed president of that institute and honoured with the title of royal privy councillor.

For the illustration of his kinematic idea, Reuleaux had begun, while at Zurich, to sketch and elaborate kinematic models which form an unconditional necessity for the successful instruction and study of kinematics. But in Berlin, Reuleaux, provided by the Prussian government with very ample means for the building up of his science, created an entirely original collection of models,—the kinematic cabinet,—which is an ornament to the Royal School of Technology in Berlin and an attraction for technical scholars everywhere.

The collection embraces about seven hundred models which represent the kinematic pairs of elements and all the kinematic chains as far as they are in practical use, in simple construction and systematic order. These chains are then combined as mechanisms in all the various applications for the formation of machines. A complete reproduction of the Berlin collection is to be found at McGill University of Montreal; Cornell University in the United States possesses more than one-half of the models.

The instructive value of these models is almost inestimable, provided that they are used in Reuleaux's sense, and the many fine points of the invention are understood and wisely used. A slight alteration of the model, a different view of the same, leads to a new kinematic idea and unveils often in the simplest and clearest manner the genesis of the most complicated machine phenomena which, without this preliminary step, are incomprehensible. In Berlin this collection is not only used for instruction, but is also much studied and consulted by inventors.

Very frequently it happens that the inventor, after a correct kinematic study of his own invention, discovers by virtue of the Reuleaux models, that the motion discovered has been known for a long time, but that it appeared veiled in its nature owing to an odd design of the moving parts. It is, moreover, remarkable that certain problems of motion for which all kinematic possibilities of solution have already been exhausted, still have a never-ceasing attraction for inventive genius.

Mental labour and money is again and again bestowed upon them, while the result can give only old and well known results. For cases of this kind nothing is more convincing than kinematic models which show systematically how one and the same kinematic thought can be worked out and put into different forms.

The models can be studied in motion, and are so constructed that from each individual mechanism, whatever constructive forms its single members may present, the fundamental kinematic thought shines forth clearly and convincingly. As a science, Reuleaux's kinematics is treated conspicuously in McGill University, Montreal; Cornell University, Ithaca, N. Y., and Lehigh, South Bethlehem, Pa. In Germany the most prominent representative of kinematics is Reuleaux's pupil, Professor Wilhelm Hartmann, of Berlin.

To his theoretical kinematics Reuleaux adds applied kinematics, to which the former serves as a scientific basis. While theoretical kinematics is occupied with solving the questions, "what is machine motion," and "by what means can it be produced," applied kinematics treats of the question, "what purposes do given machine motions serve?" This point of view leads not only to separating the machine into its kinematic elements, as theoretical kinematics proves it to be possible, but to separation into higher units or mechanisms, from the combination of which the machine has arisen for a special object.

Reuleaux calls a mechanism which, as a unit, forms a part of a machine, a train; consequently a machine consists of a combination of trains. From the standpoint of applied kinematics, therefore, machines are distinguished only through the method of combining the trains contained in them. The number of all the trains which have been used for the purpose of machine construction, is, in spite of the broad extent of modern mechanical engineering, comparatively small and has been accurately fixed by Reuleaux. All the trains out of which machines have heretofore been built, and are daily being built, can be exemplified by the models of his kinematic cabinet.

Each individual train in machine construction may be given a great variety of applications, serving different objects, which can also be shown, to a certain degree, by the models. The numerous purposes of trains can, however, be reduced to four principal functions characteristic of controlled motions, viz., guiding, storing, driving and forming. In the fourth edition of "The Constructor" the study of machine construction has, for the first time, been based upon a kinematic foundation and the four functions of the machine just mentioned. This was a Herculean task possible only to a genius.

Reuleaux belongs to the most prolific technical authors and it is, therefore, impossible in a limited space to enumerate his many scientific and technical works. All of them bear the stamp of the great philosophical thinker; everywhere the law is put in the foreground, or, where it is not known, he endeavours to evolve it, searching out the general element in the great mass of special things. Afterwards the individual phenomenon is logically deduced from the law of the general case.

Still, I cannot leave unmentioned his address on "Culture and Technics," delivered in 1884 in Vienna, before the Trade Association of Lower Austria. This belongs to his finest works. The fundamental thought of all his writings, extending from his special profession, of the science of mechanical engineering to the outward world, is expressed in the most brilliant way,—namely, mechanical engineering in organic union with universal culture. He expresses in this oration in an admirable manner the difference between the great civilised nations and the rest of the nations of the present and the past, a difference which rests mainly upon scientific technics, based upon scientific knowledge of natural laws.

Since Reuleaux's appointment as president of the Royal Technical Academy of Berlin, it was possible for him to realise his plans of organisation for technical instruction. These plans tended to prevent a one-sided professional training by the introduction of many scientific branches of a philosophical nature to extend the student's horizon and raise his intellectual standard. For instruction he required everywhere the highest form that would place the creating of new matter upon the basis of the scientific knowledge of what had been already done.

Collections of a technical and artistic character were increased under his guidance, and made accessible to the community at large. He also endeavoured to introduce scientific laboratory work in the department for mechanical engineering, but was unable to obtain adequate means for this purpose. This scientific work in laboratory instruction has meanwhile been largely developed in the United States, especially by Professor R. H. Thurston, of Cornell University, with the idea that experiment and independent investigation must alternate and be connected in adequate manner with the purely intellectual means of education in engineering instruction.

Reuleaux developed the institute entrusted to him, in a short time, to a considerable degree by steadily increasing the number of lectures and professors. He receded from the presidency in 1879 when the combination of the Royal Academy of Architecture and the Royal Technical Academy into the Royal Institute of Technology (Kgl.-Technische Hochschule) was effected. The customary arrangements in the German universities were adopted and the rector (president) was annually elected from the professors.

For the academic year 1890-1 Reuleaux was elected rector of the Royal Institute of Technology which is, at present, the greatest technical university in the world. It comprises a school of architecture, a school of civil engineering, a school of mechanical and electrical engineering, a school of naval architecture and ship machinery, a school of technical chemistry and metallurgy, and a school of auxiliaries of engineering sciences as mathematics, natural sciences, political economy, philosophy, language, literature and law and has a staff of 330 professors and assistants. There are about 3000 students.

The number of students annually attending Reuleaux's lectures amounted last year to 360 in his machine elements, and 200 in kinematics. With the first of October, 1896, Reuleaux concluded his career after more than forty years of academic work. He continues, however, his membership in the Royal Technical Deputation to which he has belonged since 1864.

Reuleaux's lectures will never be forgotten by those who had the good fortune of hearing them. He, himself, bears the stamp of superiority, to the influence of which nobody can help succumbing. The shining eyes under the bushy eyebrows indicate the sharp penetrating glance of the genius; the broad, arched forehead gives testimony of his powerful creative mental activity.

But Reuleaux's name is not simply connected with the history of sciences, but also with the history of international expositions. He was vested with the honourable office of judge of awards in the expositions of London (1862) and Paris (1867), where he entered upon close and friendly relations with the first professional men of the world. His co-operation with the commissions of awards at Vienna (1873) and Philadelphia (1876) enlarged the circle of his knowledge and scientific-technical friends.

At Philadelphia, where he was Imperial German commissioner, induced by the failure of the German department, he proved the necessity of transforming the economic convictions of the time, so that in the competitions of industries the rivalry of the quality of the products must stand above that of price. The severe and harshly striking expression with which Reuleaux at that time wounded the unworthy principle of German industries to the quick, aroused a storm in the interested circles of his fatherland,—a storm which to this very day has not entirely subsided. The scholar whose name became henceforth well known to the whole world, could stand this storm with perfect equanimity.

From day to day he saw the fruit of the great service he had rendered by his frank confessions at Philadelphia. For the correct understanding of the questions hinted at, the study of Reuleaux's letters from Philadelphia, the third of which is the most important of all, is indispensable, as well as the flavour of "cheap and nasty" literature which arose in connection with it.

Reuleaux conducted the exhibits of Germany in both the Australian expositions at Sydney and Melbourne (1879 and 1881), where Germany obtained great success and began the now highly developed trade with Australia. This trade could be developed still farther by the realisation of a steamer line between Germany and Australia, which Reuleaux had recommended to his government from Sydney in 1879. Reuleaux also participated by word and script in the movement for a German patent law in close connection with his dear friend Werner von Siemens, Germany's greatest electrical scientist and engineer.

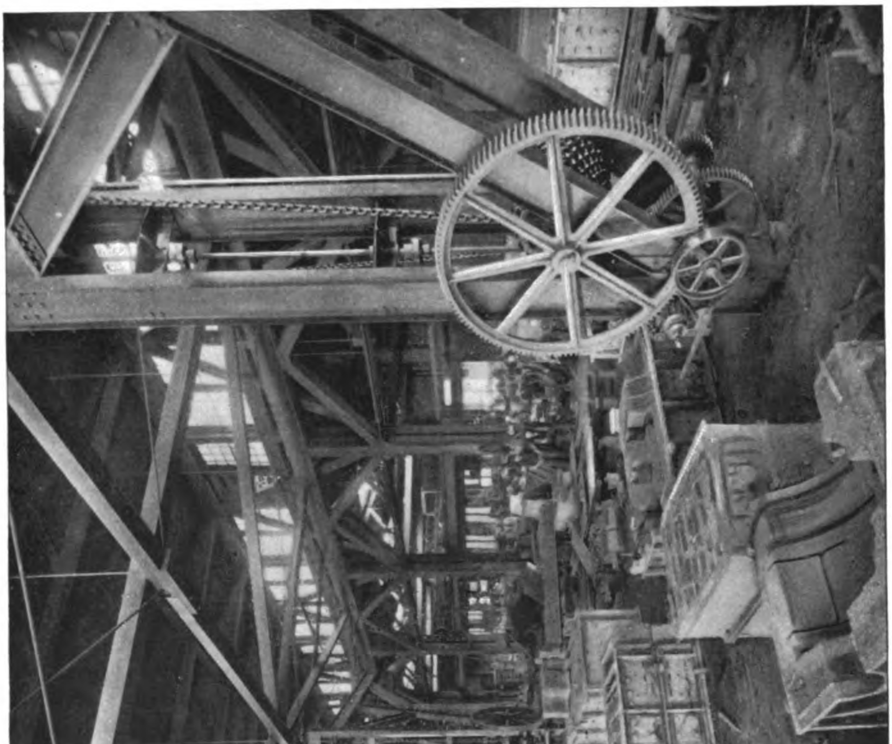
For eight years Reuleaux was a member of the imperial patent office. Owing to the rare manysidedness of his knowledge, his sagacity for the essential and characteristic in the phenomena and his understanding of the work of foreign countries, he was better fitted for all these different positions than any one else.

His experiences at the various expositions Reuleaux depicted in a recently published pamphlet entitled, "Development of Expositions." Here, too, appears his immense ability to draw the essential and fundamental element from the multitude of single phenomena and to obtain fruitful consequences from the practice of systematic observations. German industry owes to Reuleaux not only its most valuable suggestions in the way of technics, but the art trade equally enjoyed his intelligent and fostering care.

He conducted the selection and the purchase of a great number of objects of art which can be found now in the magnificent Royal Museum of Arts in Berlin whose trustee he is to this very day. The identity of their ideal endeavours for the promotions of national art trade brought Reuleaux into the closest and warmest relation with Dr. Salvini, the reviver of the wonderful Venetian glass painting, and Sir Philip Owen, the founder of the South Kensington Museum in London. It is characteristic of Reuleaux's standing in art trade that for five years he was president of the Association of German Art Trade. If German industries have to-day become a power in the world's markets, whose growth is attempted to be explained abroad by the most various reasons, it must not be forgotten to remember those men who, as enlightened leaders, have shown the way, and for decades have laboured in raising the industrial standard in all domains with a clear consciousness of the aim to be attained.

Reuleaux is also one of the leaders in the movement for the purification of the German language and belonged for ten years to the board of directors of the German Language Association of Berlin, which excels all other German linguistic associations by its extraordinary activity. The beauty of the German language does not lie in euphony, but in ideal strength and depth, in vigour and fullness of expression. To fight for its purity means fighting against laziness of thought, confusion and superficiality. Reuleaux's writings, the technical as well as those on art, on travels, on the various domains of science are models of German style.

Thus Franz Reuleaux stands before us as a universal genius, epoch-making in his profession, a creator and a leader in the most important domains of human science and knowledge, interested in everything that is noble and great, appreciating all that is eminent among foreign people, a cosmopolitan in the noblest sense of the word. While he lives and works for his people, he lives and works for the world.



THE FOUNDRY AT THE WORKS OF H. R. WORTHINGTON, BROOKLYN, N. Y.

AMERICAN MACHINE AND ENGINE BUILDING SEEN THROUGH EUROPEAN EYES.*

By Eugene François.

Translated and abstracted for CASSIER'S MAGAZINE by N. C. Twining, U. S. N., and Hermann F. Cuntz.

To Mr. François' observations it was thought interesting to add illustrations of some of the different kinds of American machine tools mentioned, and reproductions were therefore made from photographs of some of the latest designs, kindly supplied by the builders. A few illustrations also were added of typical American shops to which the author refers.—The Editor.

DURING a recent visit to the United States I had the opportunity of visiting a number of engineering establishments. My attention was almost exclusively devoted to their productive features, in the endeavour to learn how the Americans, paying from two to three times more for labour than is paid in Belgium, are able to sell their machinery, especially stationary and locomotive engines, at prices practically the same as ours.

The object of this essay is to trace a comparison between Belgian factories and those of the other side of the Atlantic, especially in regard to methods of manufacture. The investigation will be made under the following heads:

First.—The idea of simplicity and uniformity prevailing in the products of manufacture and the extensive use of cheap materials.

Second.—The equipment of the shops.

Third.—The methodical systemisation of work.

These are, in fact, the three points which enable American labour to achieve the results already noted.

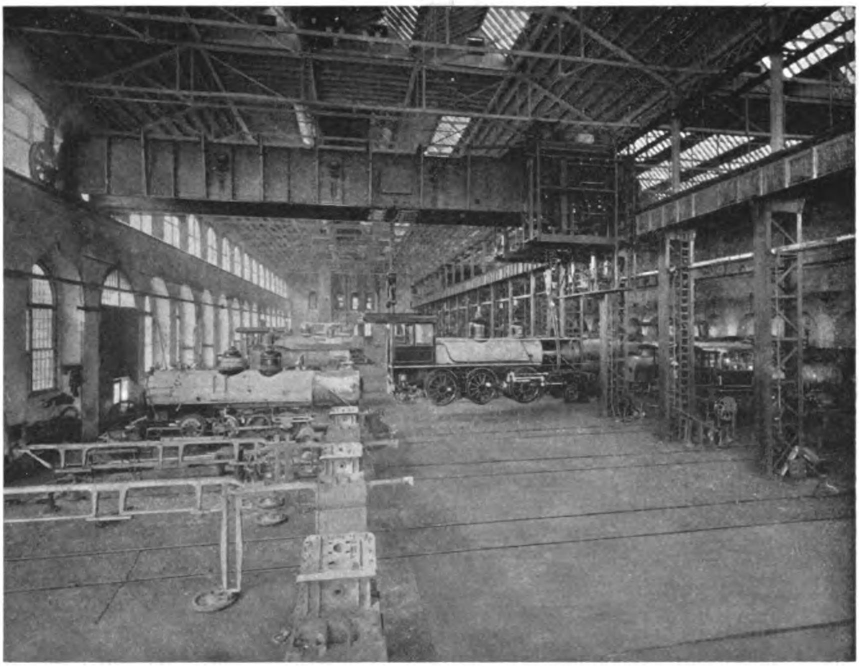
Before entering into an examination of these bases of comparison, it is necessary to make one restriction concerning business methods in America and in our own country. There the market is an extended one and the demand is great; consequently specialisation is much developed and the output is often enormous. Shops are, generally, true manufactories, making only a few standard machines, in serial sizes. Each new concern begins by creating a type.

With us it has long been, and still is, the custom for a manufacturer who wishes to buy a machine, to apply to a builder who has gained his confidence, and lay down certain requirements which serve as a ground work for the construction of the machine. In America he simply chooses from a firm's price-list the number of the machine which most nearly meets his requirements.

As to the great output, I cite some examples:—The Baldwin Locomotive Works, at Philadelphia, turned out no less than 956 locomotives in 1890; their capacity, it is said, is 1000 a year. The company employs about 5000 workmen, and has an assembling room capable of taking four locomotives on each of its nineteen tracks, or a total of seventy-six. This room includes two sections, each fitted with an electric travelling crane with two independent purchases, each of fifty tons, which gives each crane a lifting capacity of 100 tons. The assembled locomotive is slung in front and in rear and is moved from one track to another above the engines in course of erection.

The Westinghouse Machine Company, at Allegheny City and Pittsburg, puts on the market every year about

* From an essay written originally for the Association of Engineer-Graduates of the University of Liége, Belgium. M. François, at the time, was engineer for the Cockerill Company, at Seraing, Belgium.



THE ERECTING SHOP AT THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA.

600 high-speed steam engines, of from five to 1000 horse-power. These 600 engines may be said to represent, in the aggregate, 36,000 horse-power. About 250 men are employed.

The Worthington Hydraulic Works, at Brooklyn, employ 1500 men and test daily about thirty pumps for all purposes and of all sizes, from veritable toys, with steam cylinders of 50 millimetres (2 inches) in diameter to the most powerful pumping engines, capable of handling 60,000 cubic metres (13,000,000 gallons) in twenty-four hours.

The E. P. Allis Reliance Works, at Milwaukee, build annually about 300 engines of various kinds. They give employment to 2000 hands and enjoy the reputation of being able to have any engine of standard type ready to ship within eighteen hours.

For illustrations of the simplicity of American machinery I will take, first, the locomotive. This will enable me to make plain the sacrifices that American engineers make in the interest of simplicity of construction, and, which amounts to the same thing, to the end of reducing wage-expense,—the ultimate aim of all.

The great success of Americans in locomotive building is due to the fact that they can produce, other things being equal, as cheaply as we, and with similar terms of delivery, engines which, in the export market, are considered equal and sometimes even superior to ours, probably by reason of their accessibility and easy maintenance, and of their simple construction, whence results less chance of disabling accidents. They compete successfully with the best English and European builders, not only in South America and Australia, but even in Spain and Russia. In the matter of speed, America now possesses the fastest regular express train in service, and the locomotive which has shown the highest speed per mile, measured on a straight track. The train in question is the Empire State express of the New York Central and Hudson River Railroad, which makes the trip from New York to Buffalo, 708 kilometres (440 miles), in eight hours and forty minutes, including four stops. The fastest English express, the Flying Scotchman, runs from London to Edinburgh, 644 kilometres (400 miles), in eight hours and twenty-five minutes. For the Chicago World's Fair service, in 1893, there was established a special express, the Exposition Flyer, running from New York to Chicago in twenty hours, and making the distance between New York and Buffalo in 425 minutes, or at a mean speed of 100 kilometres (62 miles) an hour, including four stops. A locomotive built at the West Albany shops for the Empire State express, has shown, over a straight track on a level, and on a measured mile, a speed of 164 kilometres (102 miles) an hour.

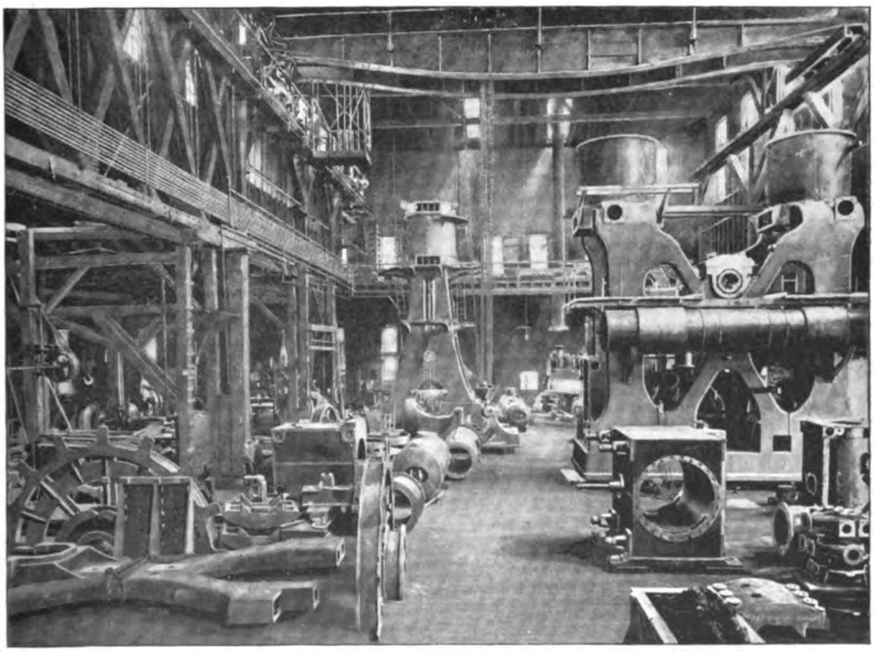
The American locomotive is capacious, long, and high; it is heavier than ours and the boiler is more powerful in proportion to the size of the cylinders. It generally has in front a bogey or centre-bearing truck.

The cylinders are always outside. The boiler is entirely above the frame, the cab-floor being about 2 metres (6½ feet) above the upper level of the rails. The fact that the boiler is placed high simplifies the construction and renders all the parts accessible. The fire-box is ordinarily of steel.

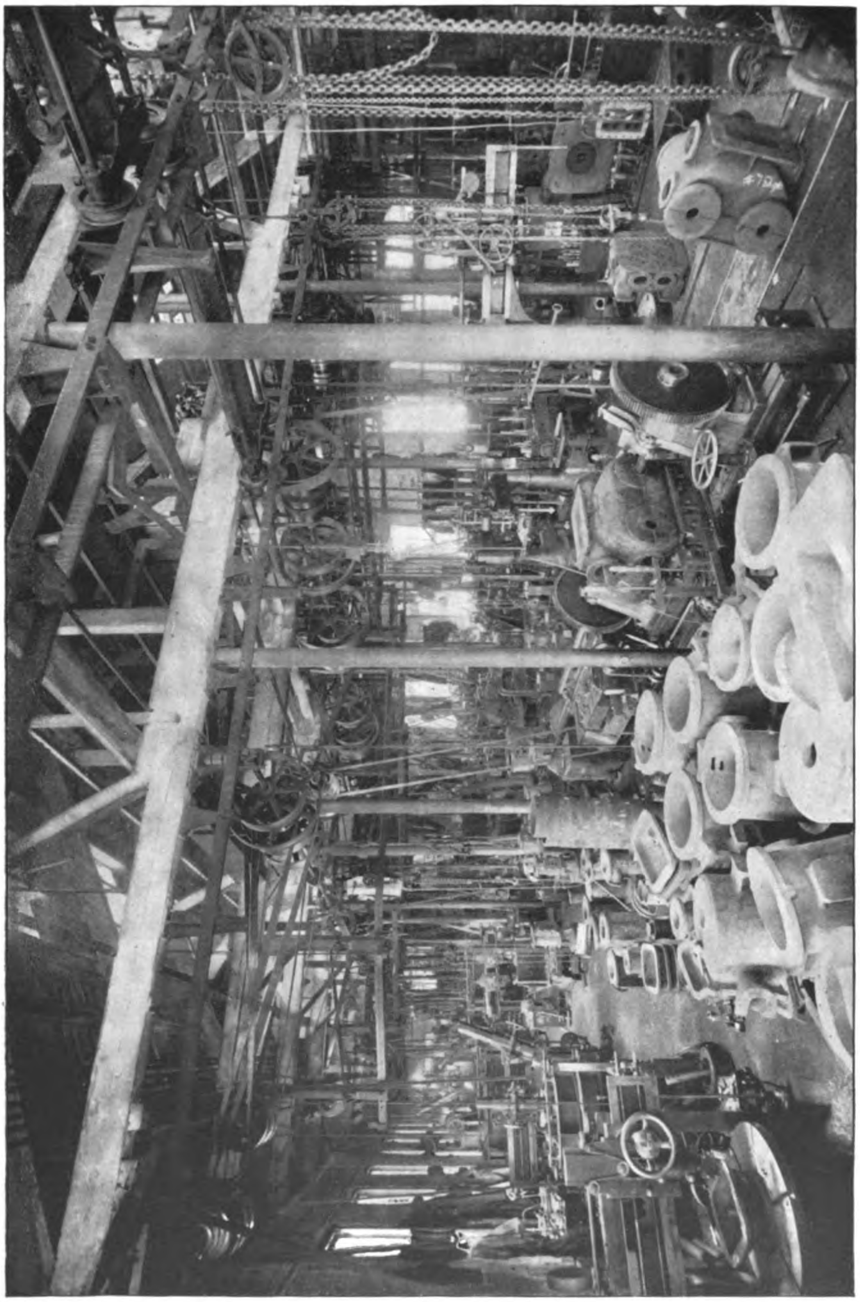
The wheel-bodies are generally cast. (This does not refer to the rims, which are forged and shrunk on.—Translator.) The frames are of wrought iron. There are certainly not more than one-third as many bolt and rivet holes in these bars as in ours of laminated plates. They also have the advantage of permitting free inspection of, and access to the inner parts. The various details for links, leaf-springs, and cross head guides, are very simple and are often left rough.

The steam chest is cast separately; the valve-face, being thus entirely exposed, is more easily planed and ground. The steam chest and the bonnet are secured in place by the same screw bolts, which thus serve for two joints.

The valve stem never has a guide, and the valve rod is connected with the stem by means of a keyed ferrule; even



ONE OF THE ERECTING SHOPS OF THE EDWARD P. ALLIS CO., AT MILWAUKEE, WIS.



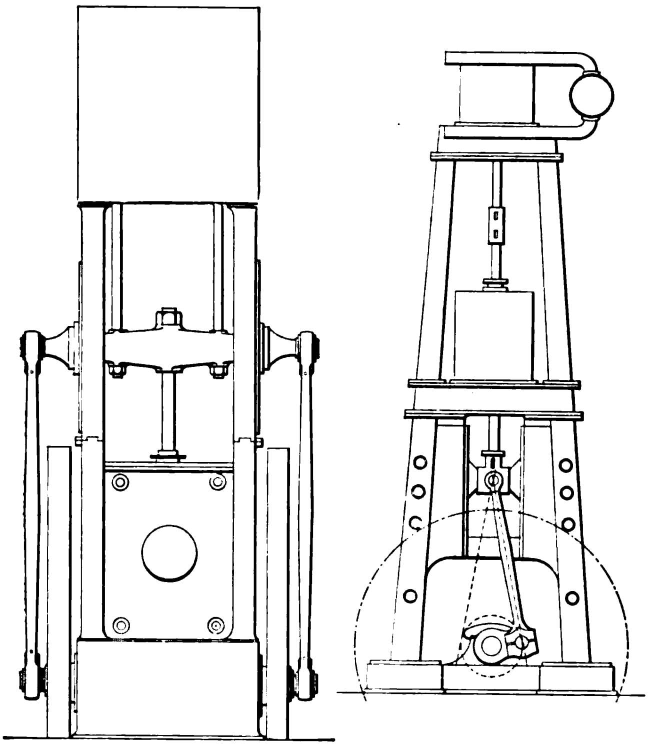
THE MACHINE SHOP OF H. R. WORTHINGTON, AT BROOKLYN, N. Y.

in this case, the Americans do not think a flexible connection necessary.

Following are further examples of simple construction and cheap manufacture:—In Worthington pumps the valve casings of the steam cylinders are cast separately, as in locomotives, and the two joints, between chest and cylinder, and between cover and chest, are sealed by the same set of bolts; these are outside of the body of the casing in which latter there are, consequently, no holes. Moreover, the facing surfaces before making joint, come finished from the foundry and no dressing is required. All the fitting is entirely rough, the two joints being made tight with vulcanised rubber gaskets.

Piston rods for steam cylinders and brass pump-rods are used just as they come from the special rolling mills of Jones & Laughlin and are not turned. The coupling sleeve is in two parts, very simple to make and to take down.

At the Allis works, at Milwaukee, the construction of cross-heads shows a novel detail; the keys or cotters, instead of being oblong in section, are circular. This weakens the piece somewhat, but nothing can be less costly or more quickly accomplished than the boring and reaming of a hole, or the turning of a key.



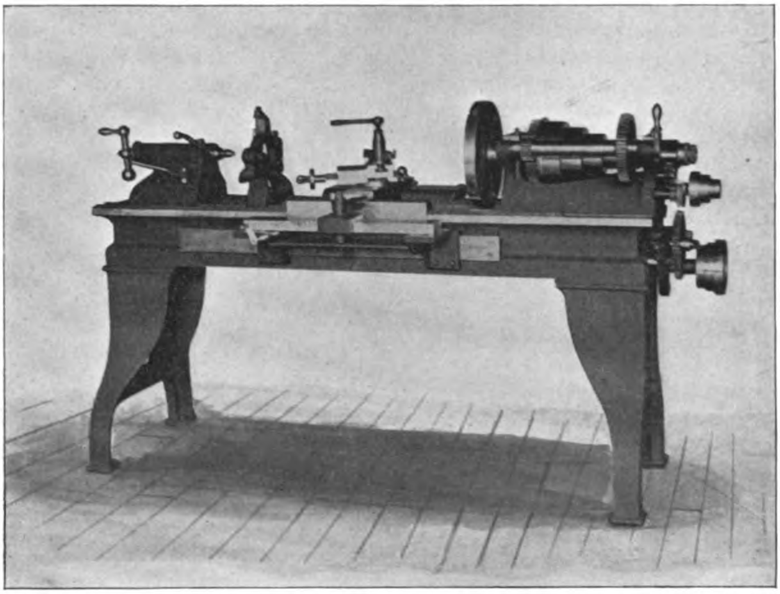
ALLIS. COCKERILL.

TWO TYPES OF BLOWING ENGINES.

These works produce a type of vertical blowing engine with combination cross-heads and two fly-wheels. At the Edgar Thomson Steel Works, near Pittsburg, I saw a set of five of these Allis blowing engines. These served two furnaces, each producing an average of 400 tons of pig in twenty-four hours. They were working, at the time of my visit, at a pressure of one atmosphere (15 pounds) and were making forty revolutions a minute.

Diameter of steam cylinder	$1^{m}.067$ (42 in.)
" " air "	$2^{m}.134$ (84 in.)
" " connecting pipe	$1^{m}.524$ (60 in.)

The steam delivery is governed by



A 14-INCH LATHE WITH TAPER ATTACHMENT, BUILT BY W. P. DAVIS, ROCHESTER, N. Y.

four Corliss valves with stops and dash-pots; the air cylinder is supplied by piston valves governed by an eccentric movement. The construction is of remarkable simplicity. The engine consists essentially of:—

First.—A cast iron bed plate.

Second.—Two upright, flask-shaped supports, with flanges, secured to the bed plate and braced at the bottom and to a considerable height by the steam cylinder, which is of square external shape. The air cylinder rests directly upon these two uprights. The cross-heads travel in slots cut in the two uprights.

I will compare with the Allis engine one which the Société Cockerill, at Seraing, Belgium, recently built for the Société de la Providence. The two examples, shown on the preceding page, will illustrate the difference in methods on this and the other side of the ocean. The American single cylinder engine is of ingenious simplicity. It is worked out with an eye to cheapness of production in large numbers and easy sale; it is an article of commerce that is offered, such as it is, to take or leave.

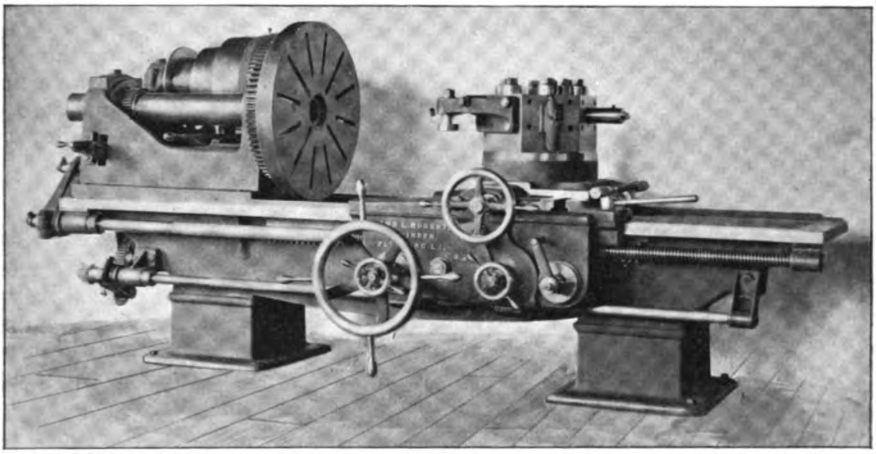
The Cockerill engine is compound, with two cranks 90 degrees apart; upon each of the two bed plates are planted two inclined supports of box section, upon which is placed the first platform. The steam cylinder rests on this in such a way that it is free to expand in every direction.

From this platform spring two other pillars supporting the air cylinder through the intermediary of a second entablature. The steam and air piston rods are independent, being connected by a union. The steam piston with its rod can be removed without dismounting the air cylinder. Moreover, that part of the rod which is cooled in the air cylinder never enters the steam cylinder. It is an engine of great durability, high efficiency, accessibility, easy to manage and to take apart. It is, in addition, a machine of pleasing appearance.

For a long time in America, and more recently here, auxiliary details have been undergoing a change. For hand made fittings there have been substituted, little by little, accurately made parts, more readily interchangeable. I may cite as examples the practice, now general, of using hydraulic press for setting cranks, pins, wheel-rims, bushings and the like; the abandonment of wedges, of conical adjustments requiring grinding; of cast sockets, in order to have collars or flanges capable of being turned; the replacing of joints packed with red-lead, mastic, sheets of paper, card-board, or flax, by dry-joints, ground; the general use of cylindrical pins, set by press, and with adjusting washers; the abandonment of bushed connections with keying up wear adjustment, in favour of a simple hardened steel ring, straightened after hardening; the more and more extensive use of friction adjustments; and the substitution of cast iron or steel bushings without flanges, lined with white anti-friction metal for composition. In America they go even further and cast the white metal directly in the body of a bearing.

I may add that while we, often at the price of costly complications, confine ourselves to the almost exclusive use of headed bolts with nuts, the Americans commonly employ threaded bolts or studs.

All these various practices have been in use in America for a long time and have been known to our best builders for some years, but they are not common here. I will cite still another practice, recently adopted, though it concerns only facility of preservation:—The bronzing or browning by oxidation of polished iron or steel pieces.



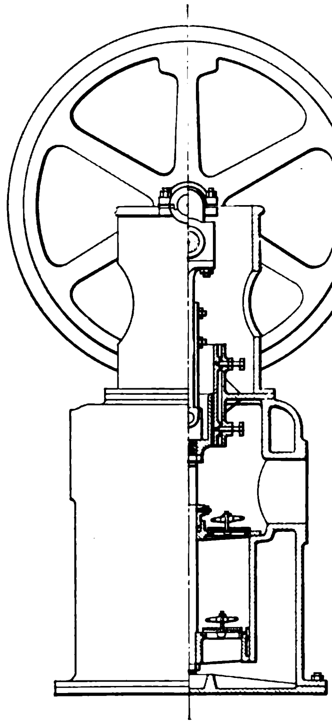
A MODERN 32-INCH TURRET LATHE, BUILT BY JOHN L. BOGERT, FLUSHING, L. I.

Touching the plan of uniformity which is followed in American construction, I will mention the three following cases, taken from the Allis works:—

First. — All horizontal or vertical steam engines, whatever their power, their number of revolutions, their use, have always the same type of cylinder with Corliss valves, cast in one piece and of square external shape, while we use, according to circumstances, sometimes flat and sometimes cylindrical valves, with cam or other gear.

Second.—Whatever the power of the engine, be it 50 or 1000 horse-power, the Allis works employ not only the same type of governor, but actually the same one (that is, of identical dimensions).

Third.—Independent condensers are extensively used in America. I may mention, as an example, a Worthington equipment which is neat, compact, and simple. The Worthington Company keeps in stock condensers of twelve sizes, air pumps of from 120 millimetres (4.7 inches) diameter and stroke, to 400 millimetres (15.75 inches) diameter and stroke. The air pump is duplex, comprising two steam cylinders, directly operating two double-acting pumps.

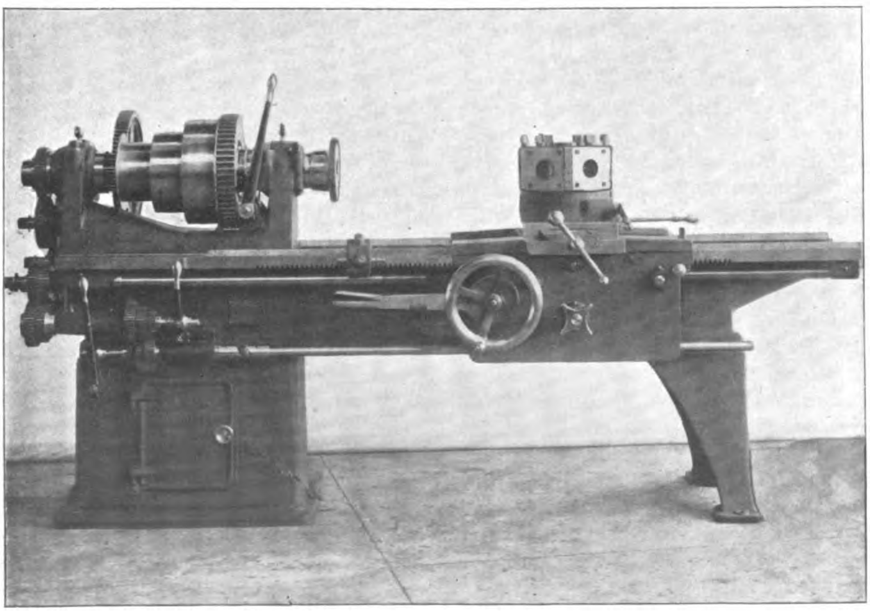


THE ALLIS CONDENSER.

The jet condenser is bolted upon the air pump and is so disposed that the force of the exhaust steam and of the injection water, are utilised to create a certain initial vacuum.

The Wheeler surface condenser is equally compact and is ingeniously arranged. The condenser, with Field water tubes, rests directly on the air pump at one side, and the circulating pump on the other. The communicating pipes between pumps and condenser are thus naturally disposed of. The two pumps are operated directly by one steam cylinder.

The Allis condenser is on the injection principle and consists of a vertical, single-acting air pump, operated by a steam cylinder, or by pulley and belt. The steam cylinder is at the top. This cylinder, the guide, which is cylindrical, the crank-shaft, and the air pump with condenser, are disposed vertically in the order given. Everything is on the same axis and may be very accurately made. The air pump, operated by two rods from the cross-head, is located very near the crank-



A TURRET LATHE, BUILT BY THE BULLARD MACHINE TOOL CO., BRIDGEPORT, CONN.

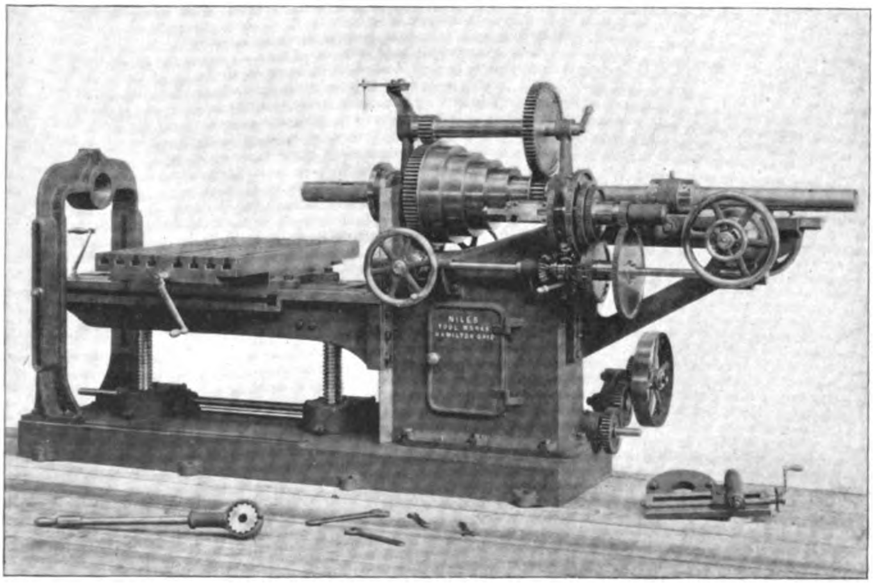
shaft, so that the whole occupies very little vertical space.

There are eight sizes of air pumps made at the Allis works, from 300 millimetres (11.8 inches) to 910 millimetres (35.8 inches) diameter, and 300 millimetres stroke, which is the same for all the twelve sizes of condensers. This fact permits the use of certain pieces of the same dimensions in machines of several successive numbers.

Besides the advantage accruing to the builder from the generalisation of an equipment that is a necessity, there are the further advantages of having only one type of air pump, which can be placed as local conditions may make most convenient; of being able to keep these pumps in stock ready for use; and of the opportunity it affords for making, in advance of orders, steam engines, without any danger of such and such a purchaser wishing an air pump on the bed plate operated by the crank pin or the cross-head pin, or placed on the engine pedestal in prolongation of the cylinder and operated by the piston rod.

Besides these advantages, an air pump being always more or less noisy, it is well to isolate it from the engine in order that the shocks produced shall not make themselves felt through the whole engine.

I may add that the air pump is a delicate apparatus which often threatens to compromise the success of the whole and it is best, on that account, to have it as a separate construction. With this disposition, insufficiency of the pump can be remedied, within limits, by increasing the number of revolutions.

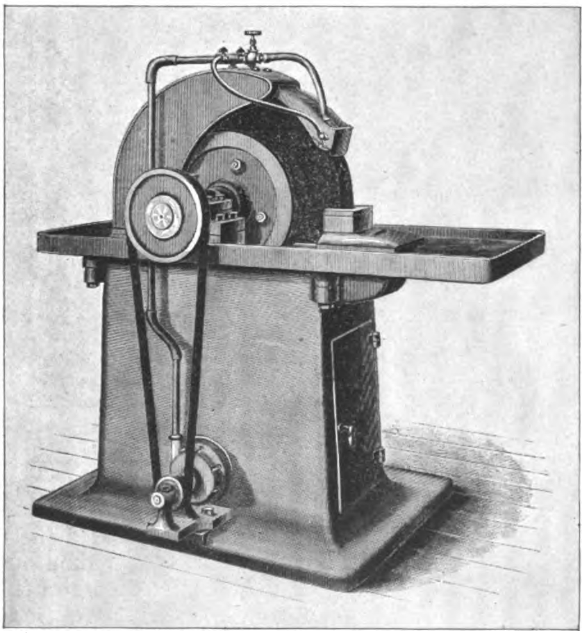


HORIZONTAL BORING AND DRILLING MACHINE, BUILT BY THE NILES TOOL WORKS, HAMILTON, OHIO.

Americans, recognising that a piece of cast iron is much cheaper than one wrought, make more general use of the former than do our builders. Such things as we make of iron, wheel-centres, bell cranks, and unions for joining two threaded ends, they cast. Cast iron pieces have a fair, smooth surface, clear and lustrous, and the metal has great strength. Moulding is generally done in green sand, so that the casting can be done at once; only the core is dry. Moulding machines are used to a considerable extent.

Small cast pieces are first trimmed and pickled in acid and are then thrown into a cylinder, with leaden and wooden cubes. By the rotary motion of the drum, the pieces are rubbed against each other, the sand is scraped off, and, thanks to the presence of the lead, the castings come out with a lustrous surface; it is not sufficient to coat the moulds with graphite. The pieces receive a final cleaning on the emery wheel; the chisel is never used. The Americans avoid, when possible, pieces requiring cores; they perfer the U, T, or cross, to box-shaped sections.

The small American forges are also quite different from ours. They generally have saws and shears, and a variety of shaping, swaging and cutting tools. Generally the forge-fires communicate with a common uptake provided with a blower, for drawing up the gases.



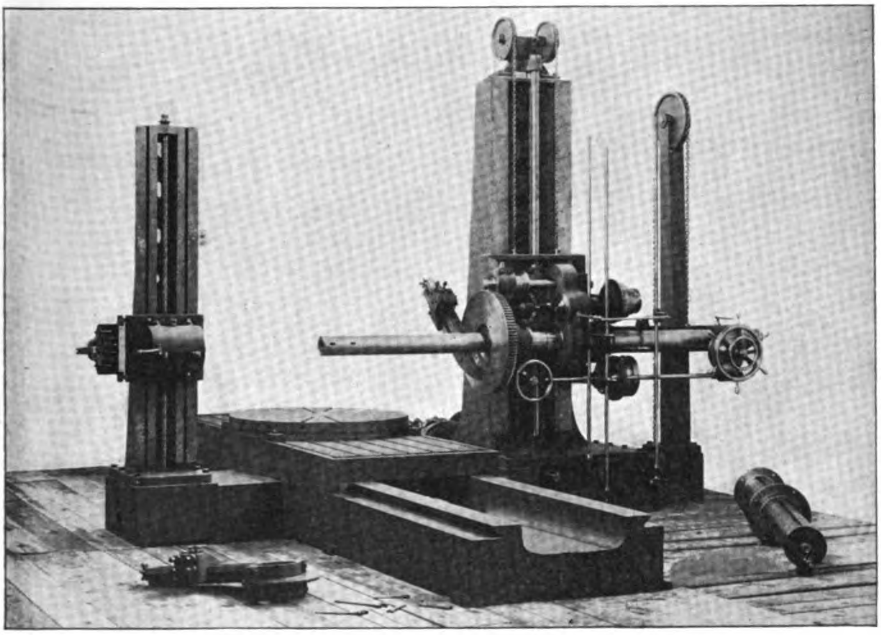
AN EMERY TOOL GRINDER, MADE BY THE STERLING EMERY WHEEL MFG. CO., TIFFIN, OHIO.

American machine tools merit special attention; now that they are well known amongst us, no one thinks longer of denying their superiority. The American machines are run at higher speeds than ours, and as automatic action is introduced to the greatest practicable extent, several machines can often be managed by one man. You will see, in American shops, relatively greater numbers of continuous-acting machines, such as lathes, milling machines, boring machines, drill presses, etc., while the number of intermittent-acting machines, mortisers, planers, and shapers, is reduced to a minimum.

The problem of obtaining from any given machine the maximum of work, is one of the utmost importance. There are two conditions which are materially in favour of Americans in the task of solving this problem:—the same workman often makes a large number of identical pieces on one machine; and, in my opinion also, the methods for sharpening milling tools, drills lathe cutters, etc., are of the best.

Lathes differ from ours. In order to economise labour, the Americans are obliged to build lathes of great productive capacity and easy of manipulation. The bed is wide, thus allowing considerable transverse movement to the tool, and at the same time assuring stability of the machine; the spindle is hollow, the headstocks are strong; the travel of the tool rest is long, and the driving belt is broad. The tool rest is compound. The ways, instead of being flat are of inverted V-shape, which, in case of wear, diminishes the chance of uneven turning of the piece in hand; however, the lubrication of a V-shaped guide is a more difficult matter, oil not readily adhering to an inclined surface; consequently the guide slots in the carriage are made very long.

The tool rest proper consists generally of a single post, and the tool is securely held in its seat by a single turn of the binding screw. Face plates have



HORIZONTAL BORING, DRILLING AND MILLING MACHINE WITH STATIONARY COLUMN, BUILT BY THE NILES TOOL WORKS.

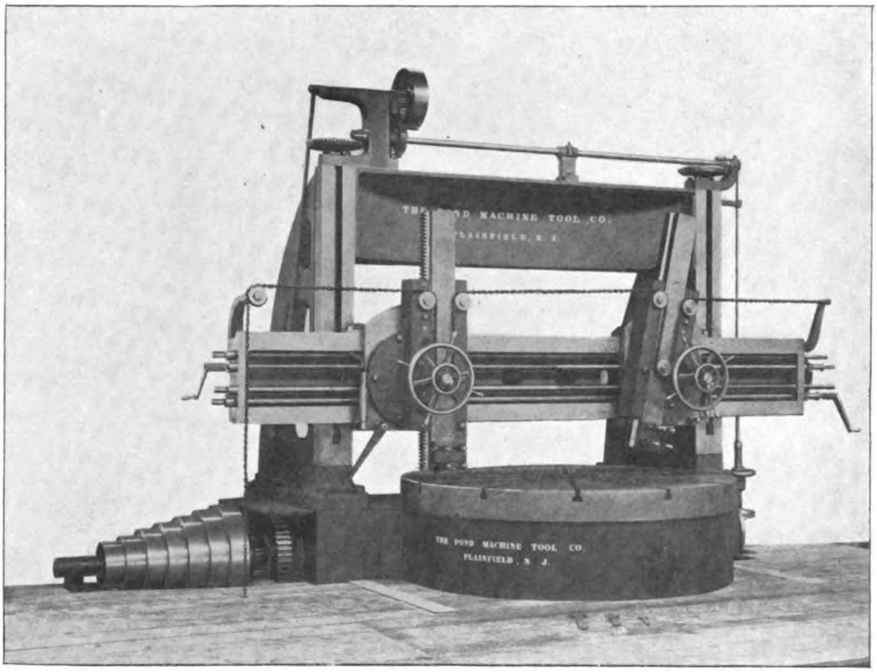
been replaced by screw chucks. Longitudinal and transverse movement may be given, rapidly by hand, or automatically by setting little hand wheels or grips of very practical form, which are placed on the apron, convenient to the operator's hand.

The various auxiliary attachments for removing the work from the tail stock centre easily and without resort to the hammer, for oiling this centre, for running by hand or by gearing, for engaging the gears, for changing the direction of the feed screw, and others, are of simple and ingenious design. Attached to the lathe is a table of gears, or index plate.

Ordinary engine lathes have but one feed-screw serving three purposes, which soon becomes inaccurate for thread cutting; American lathes are provided with a rack for rapid hand motion, a shifting bar for sliding cross-feed, and a feed-screw used only for thread cutting.

These lathes are sometimes supplied with other accessories, such as a small screw press for entering mandrels or chucks, and a little swinging crane mounted on the bench. These are two auxiliaries which are justified only on a lathe of great capacity; they may have also oblique guides for turning to any desired taper without the necessity of making preliminary trials or adjusting the centres; a triple speed head stock, allowing the lathe to be run at any of three different speeds, and of instantaneous change from one to another, while in motion and without shifting the driving belt; an equipment comprising a complete series of gear wheels, for instantaneously changing the speed as many as twelve times while in motion.

To cite a striking example of the tendency towards extreme production, I may mention a lathe with hollow spindle, for cutting off washers. The great capacity is, without doubt, due primarily to an ingenious arrangement of the cutters; but also,—and it is to this feature that I would especially call attention,—to the fact that the speed is gradually increased as the tool approaches the centre, so that the circumferential velocity is constant.



A BORING MILL, BUILT BY THE POND MACHINE TOOL CO., PLAINFIELD, N. J.

Turret lathes, with hollow spindles, are employed largely in America, not only for brass work and for the manufacture of bolts, but for a great many other things made in quantity. I will take as an example a turret with five tools:—A tail centre (which changes the machine into an ordinary double-centre lathe), an abutment or socket, a roughing-out tool, a finisher, and a chasing tool for cutting screw threads. Some of the turret lathes are powerful and of great capacity, finishing or rather cutting off, for instance, one hundred 25-millimetre (1 inch) bolts in ten hours from an 80-millimetre (3.15 inch) bar. The waste is great, but the output is enormous. The change of speed and the feed are accomplished automatically during the progress of the work, without any necessity for stopping the machine. Absolutely automatic turret lathes have also been in use for a long time for making screw bolts and studs from hexagonal bars in one operation. I have seen ten of these machines run by one man.

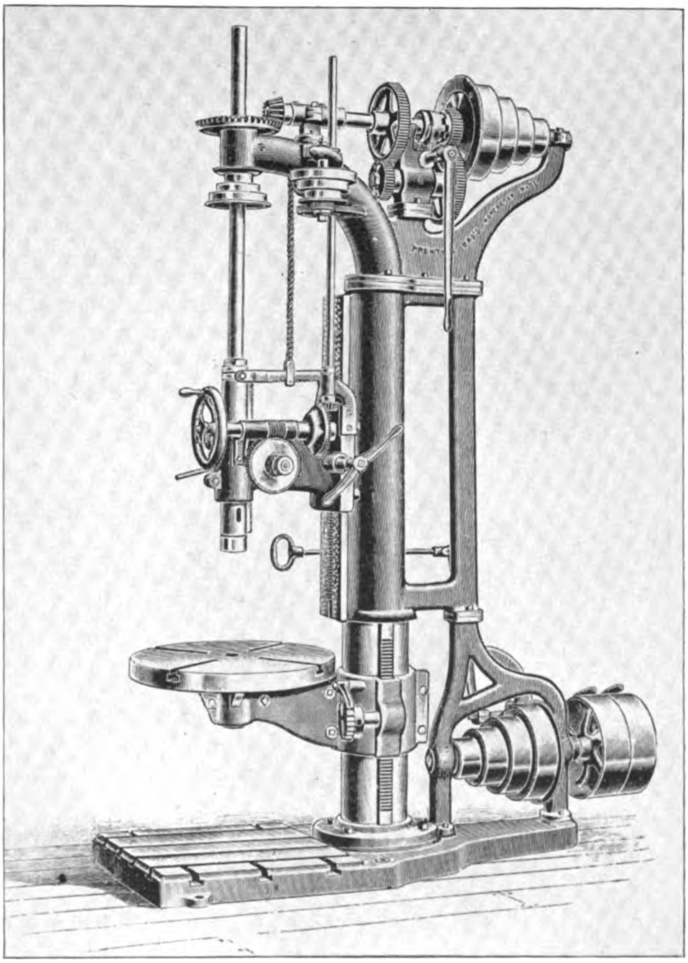
The vertical face-plate of our single-centre, or chucking-lathe, is almost entirely replaced by a horizontal face plate. Machines thus fitted offer valuable advantages in point of swinging up the work, and its easy and quick centreing.

Let us consider for a moment a vertical plate lathe on which an unsymmetrical piece is to be placed. The piece is tentatively swung up and is turned to test the centreing; if it is not accurately centred it must be removed, supported, by hand or otherwise, and shifted in the desired direction. It is thus a case of "cut and try," lifting, supporting, and reclamping, until the centreing is exact. Then, in order to restore equilibrium, the eccentric weight must be balanced by counter weights whose location again demands experiment.

If we pass now to the American lathe with horizontal face plate, we see the casting or forging laid on the plate by a hoist; one or two men can manage very heavy pieces, when only horizontal motion is necessary. Since the piece is naturally supported, there is no need of chucking it before turning to verify the centreing, nor of taking it off the lathe.

In the lathes under consideration, the plate, instead of being set at an angle upon the spindle, rests horizontally on a broad bed; the tool rests, generally two in number, and the plate itself are essentially one piece. These two points, and the ordinary solidity of their construction, permit these lathes to take chips of extreme dimensions and they are thus tools of great capacity.

They are, on the other hand, relatively more costly, and cumbersome, while the distance between the two tool rests, limits the diameter of the work that can be done on them. To eliminate this fault, some of them are so devised that the tool rests may be mechanically advanced or withdrawn and an extension bar for boring may be applied. To some machines of this kind the device already mentioned is applied, which increases the speed of revolution of the plate as the tool approaches the centre, so that the peripheral speed of the point at which the tool is cutting is maintained



AN UPRIGHT DRILLING MACHINE, MADE BY MESSRS. PRENTICE BROS., WORCESTER, MASS.

constant, thus deriving from the machine at every instant the maximum useful work.

American drill presses are lighter and more easily and effectively manipulated than ours. The twist is in general use and it is carefully ground in a special machine. Drill presses are also used as tapping and threading machines, and, to this end, they are so made as to be capable of being run in either direction. All parts movable vertically are counter-balanced. The face plate is always pivoted and is often double, so that a piece of work may be adjusted on one side while one is being drilled on the other.

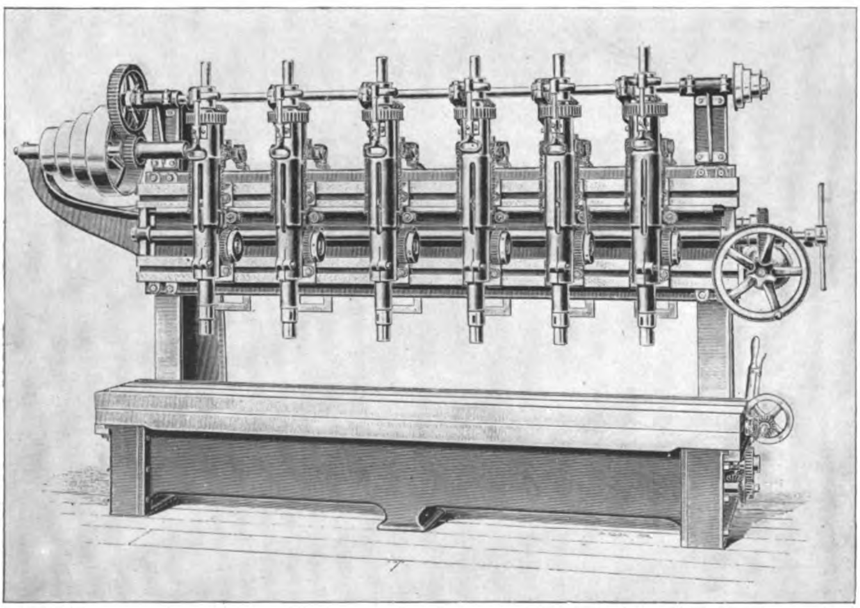
Multiple drilling is very common, jigs being extensively used; they have holes defining the points to be drilled and guiding the drills themselves. There are also a large number of universal drills in use, which may have one or two tool rests. With a drill of this pattern, having two columns, it is possible to drill, tap, and enter studs on three surfaces without shifting the piece; the head on which the tool is carried cannot only be raised and lowered in a vertical sense, but may also be rotated on its own axis so that either vertical or horizontal holes may be bored, or, if required, inclined holes.

A great many horizontal boring or drilling machines are in use. Machines for boring cylinders vertically are rare, but I saw one triple drill, which bored the four valve seats of a Corliss cylinder in one position.

In planers the time of the return motion must be reduced as much as possible; the arrangement long since in use, by which the motion in both directions is utilised for cutting, has not, in general, given good results; at Whitworth's, at Manchester, in England, however, the rotating tool holder is applied to all planing machines.

In American planers there is generally an automatic attachment for lifting the tool on the return and preventing it from being dulled by dragging along the piece. For the displacement of the belts at each end of motion, there is almost always an arrangement for shifting them, not simultaneously, but successively.

In the Seller's planer the bed is worked by an endless screw with inclined axis, engaging with the rack.



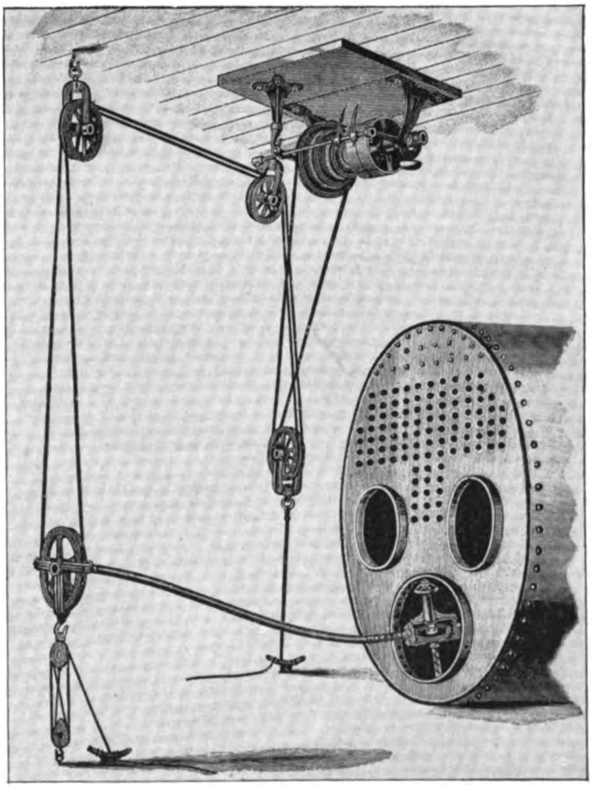
A GANG DRILL WITH SIX SPINDLES, MADE BY MESSRS. PRENTICE BROS., WORCESTER, MASS.

This movement, it is believed, is the smoothest possible, and the tendency of the tool to chatter is reduced to a minimum. These planers are driven by a single belt which always runs in one direction and is never shifted. The reversal of the motion of the table is accomplished by means of a friction clutch; the speed of return is eight times the working speed. The machine is easily managed, the speed and direction of motion of the table, and the automatic feed, in both directions, being always completely under the control of the operator. During the return motion, the tool is automatically lifted clear of the work.

Of all tools whose use is becoming more general and whose application is continually extending, the milling machine certainly occupies first place. The milling cutter is a very old tool, but the variety of its application has increased extensively only within a comparatively few years. It has long been used for letting into plates countersunk heads of bolts, screws, and rivets; it was, and still is, for this work a turned tool whose teeth, cut by hand, were, for that reason, somewhat inaccurate and rough. It was used with a tap-wrench or in an ordinary drill press.

It is only since machines for automatically and accurately cutting and sharpening all forms of milling cutters have been successfully made, that the use of this tool has been given a new impetus. The milling machine has, since, little by little, supplanted the shaper, the planer, and to a still greater extent, the slotter, for a great variety of purposes.

By the use of the miller much more work, which formerly could not be done by a planer or other machine, is now easily and accurately performed, such as the cutting of gears, twist drills, T-slots in machine tool beds, dressing of sides of steam ports, etc. With properly shaped cutters, the most intricate surfaces can be cut without previous marking out.

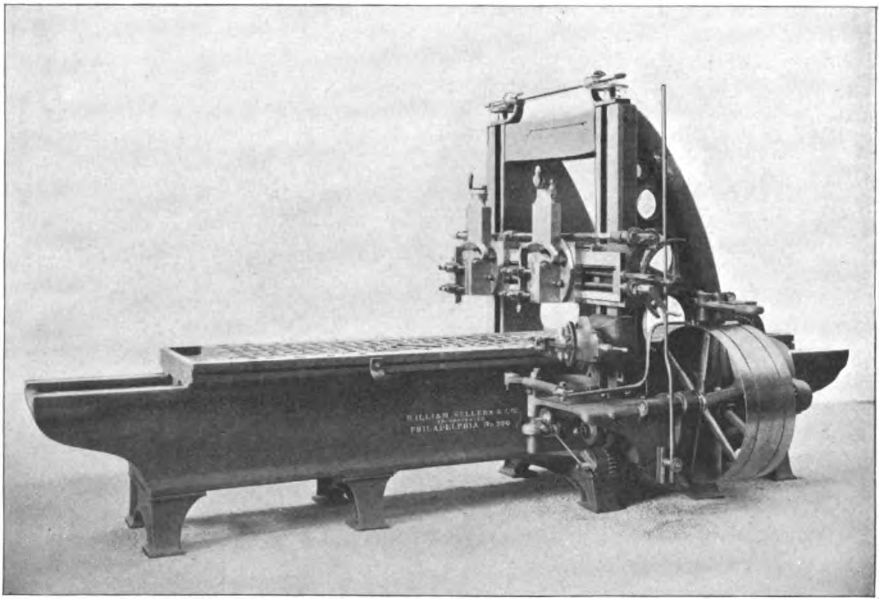


A PORTABLE DRILL WITH FLEXIBLE SHAFT, MADE BY THE STOW MFG. CO., BINGHAMTON, N. Y.

To sum up, milling machines work more rapidly, more exactly, and finish better; they do away with tracing and the use of the file, and permit of economical execution of work in any shape desired. They are now used in great variety; there are vertical and horizontal milling machines and others of great capacity having tables of long travel.

As to the milling tools themselves, they are of all conceivable forms; ordinary millers, with helicoidal or straight teeth, cutting-off millers, shaped millers, which can be sharpened without changing the contour, multiple surface millers.

The Americans have also made great



PLANING MACHINE, BUILT BY MESSRS. WM. SELLERS & CO., INCORPORATED, PHILADELPHIA, PA.

progress in automatic gear cutting machines. Machines for cutting straight teeth are well known, but they are economical only when several, six, for example, are run by one man. A machine for accurately cutting bevel gears is also perfected. The teeth are roughed out in a milling machine, but are finished with a planing tool.

Portable drills, which are coming more and more into vogue in shipbuilding and metal working establishments, are also being introduced in machine construction works. In the earlier ones, the drill received its power through the medium of a flexible shaft, from a small dynamo placed on a car. In assembling shops, portable drills are worked by a rope from the main power shaft. The machines permit of boring holes at any angle. They are especially useful for drilling holes in heavy and awkward pieces which it would be difficult to place on the tables of fixed machines.

Among other portable machines also of comparatively recent date and whose use is rapidly spreading in America, are those for making keys and cutting keyways. These machines are stationary or portable, depending on the nature of the work.

Shops that were formerly fitted with swinging derricks, slow, cumbersome, and wasteful of time and space, now have travelling cranes, generally only one, but sometimes as many as two or even three in each gallery, facilitating the handling of work, operating with certainty and delicacy, easily controlled and covering from 60 to 150 metres a minute (200 to 500 feet). These cranes generally have three electric motors controlling the vertical, transverse, and longitudinal movements, respectively. Consequently, drum, gear wheels, disconnecting gear, and shafts are done away with, or their number reduced to a minimum. Fitting shops with several floors have elevators.

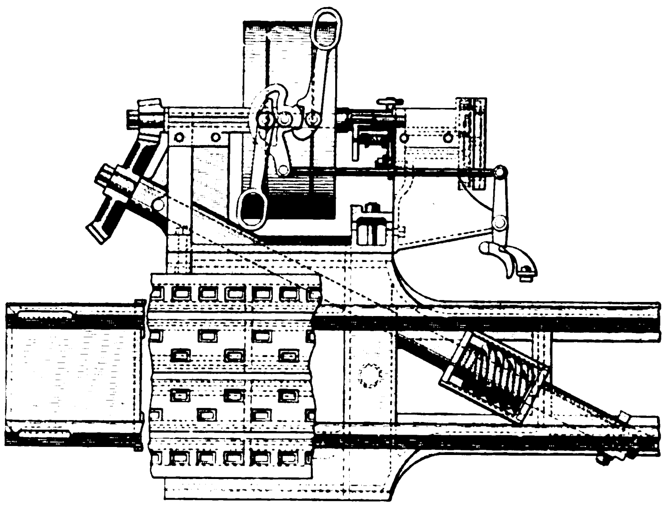
Machines are employed on a large scale for polishing working parts of steel, cast iron or composition. This method of polishing takes on a considerable importance, considering economy of labour and the reduction of the use of the file.

Take, for instance, a connecting rod. In this piece certain surfaces must be made exact, as they are required to true up with corresponding surfaces in other pieces. But the greater part of the rod, the curving body, and the outside contour of the head, demands no exactitude of execution. It matters little whether the body of a rod be one or several tenths of a millimetre more or less in thickness, or whether the outside shape of the head be exactly square, or not.

These parts, which are polished only to make them more pleasing in appearance, are, with us, machined, if not exactly, at least very closely, then filed and polished with emery. This work is done in a machine by a skilled workman, or at the bench by a finisher, in either case by highly-paid labour. What has been said in regard to connecting rods is true of many other pieces as well. In certain shops these pieces are now simply roughed out by machine and then go to the polishers where, in much less time, and without the aid of the file, they receive, at the hands of a cheap workman, a polish that could not be obtained by ordinary methods.

Composition pieces, such as cocks, oil cups, and ornaments, come to the polishing room rough from the foundry; they are machine polished with the greatest ease without the use of a file, no matter how complicated the surface may be. The polishing room is a special shop detached from the others. Each emery wheel is partially surrounded by a blast box which communicates with a main conduit through a flue. The dust is drawn up into this conduit and expelled by a blower. There are several varieties of wheels, some of solid emery, some of wood covered with emery leather, others of walrus hide, felt, or cotton.

Discs or pliable and flexible plates of felt and cotton, being easily forced into the angles of intricate surfaces, and being perfectly safe, are gradually displacing the others. To prepare these discs for the work of polishing, emery powder is glued to their circumference or they are dressed with some substance such as crocus, rotten stone, or polishing red. The workman simply holds the piece to be polished against the felt or cotton wheel, which is run at high speed. They are from 300 to 500 millimetres (12 to 20 inches) in diameter and are run at a speed of from 1500 to 2000 revolutions a minute and more.

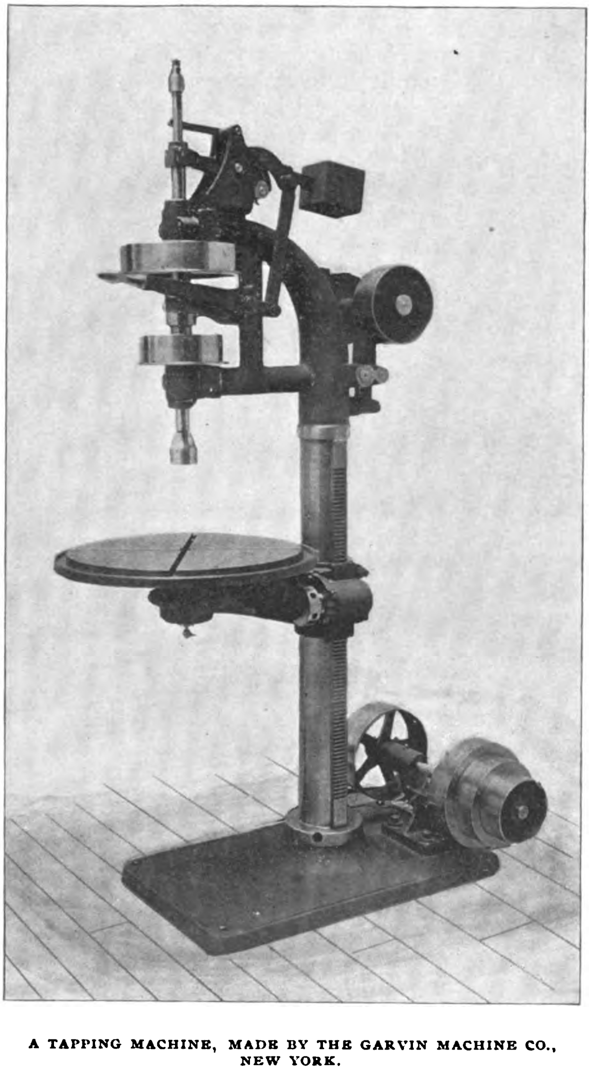


THE DRIVING GEAR FOR THE SELLERS PLANER BED.

Machine tapping is universal in America. It is done much more quickly than by hand labour, say in one-fifth the time, even by an unskilled workman. Besides, the work is better done.

Tapping may be done on a vertical or horizontal drill press by the use of a small special apparatus which can be mounted and removed with almost the facility of a drill bit. No additional handling is entailed, since the holes must, in any case, be drilled first; when this operation is finished, without removing the work, the tapping tool is substituted for the drill and the drilled holes are tapped.

The work has certain special features; thus, the speed of rotation of the spindle is greater for drilling than for tapping. Sometimes the drill press is arranged to turn in both directions; if not, the attachment should be furnished with a disconnecting apparatus for reversing the motion and drawing out the tap.

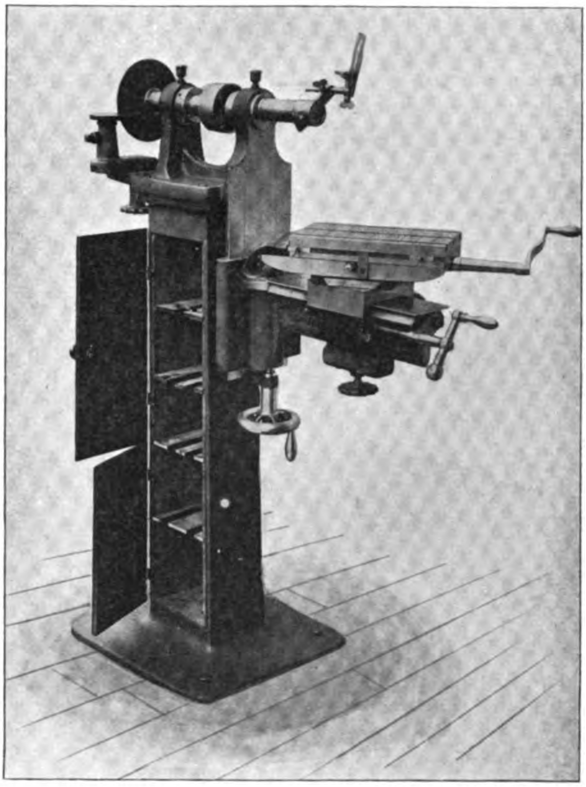


A TAPPING MACHINE, MADE BY THE GARVIN MACHINE CO., NEW YORK.

The consequence of negligence on the part of the workman must be noted; an instant, in fact, would suffice to bring the tap to the bottom of the hole and break it. This accident, which would be relatively frequent, must be forestalled in the design of the tapping attachment; this has a breaking piece or is so arranged that as soon as an undue resistance is felt, the tap becomes free to turn, by the action of a spring, for example.

American methods of power transmission shows some peculiar features. The shafting runs at a high speed (100 to 200 turns); belts are thinner, broader, and run faster than ours; wooden pulleys, which are lighter than metal ones, and assure greater adherence of the belt, are much used; the system of idle pulley, keyed pulley and differential speed cone, is replaced in great measure by ingenious devices, permitting of throwing in and out of gear while in motion and of changing the speed without shifting the belt.

In the draughting rooms vertical drawing tables are in almost universal use; these tables can be tilted at will. When a pencil drawing is to be made, the table is slightly inclined from the vertical; the draughtsman works seated. As the table can be raised and lowered at will and as the T-square is horizontal and balanced, he places the part of the



A CUTTER GRINDER, MADE BY THE GARVIN MACHINE CO.

sheet on which he is working at the most convenient height. When tracing or inking-in, the table is very slightly inclined from the horizontal. It cannot be disputed that the American system permits of drawing in greater comfort than ours, which requires the draughtsman to stand and to stoop constantly.

Tracings or original drawings are kept in the draughting room; the prints which go to the shop are mounted on card board, wood, or sometimes very thin steel plates. By this means, the drawings cannot be folded, and this precaution prevents the deterioration and rapid destruction of the tracings.

Drawings and models are systematically grouped, so that a record clerk's memory is not the only index to their whereabouts. Each tracing has a corresponding card. These are placed on edge in drawers and grouped in a certain order. In front of each group is a colored card bearing in large letters the title of the group.

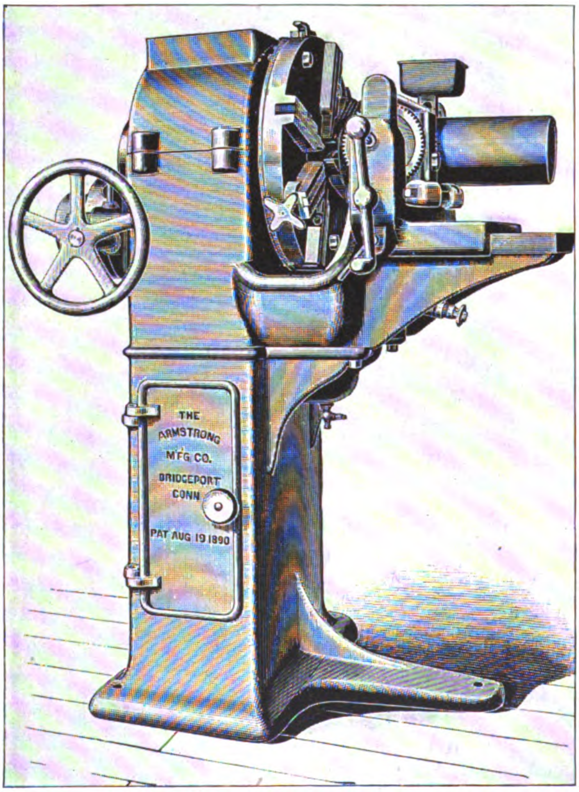
The tracer, needing a drawing, begins by selecting and examining the corresponding ticket; this gives all necessary information, the number of the tracing, the number of the drawer containing it, the nature of the tracing, the name of the man who drew or traced it, the date on which it was issued for the first time, the second time, third time, etc.

Patterns are grouped in compartments in the model shed and bear numbers and letters. In the office is a list, methodically arranged, not only of all the existing patterns having reference to each machine, with their names and distinctive features, but showing, also, in what compartment each of them is to be found. I saw some admirable pattern sheds or houses which were absolutely fireproof.

I was shown administrative offices invested with plenary powers. Among their duties were not only the making of plans, but also the giving of necessary instructions to each department, forge shop, pattern room, foundry, iron and steel store houses, shops, etc. These departments exchange material with each other in accordance with orders direct from this office, and mutually give and take receipts. The office decided on the quantity of iron to be issued to the blacksmith, on the share of work to be done by the carpenter on a pattern, etc. This centralisation certainly prevents many disputes and difficulties.

Almost all concerns have now adopted a centralised system for sharpening and storing lathe tools, planers, drills, bits, mills, etc. This desirable innovation presents great practical advantages over the old system under which each man, leaving his machine, came himself, arbitrarily and according to his own ideas, to sharpen his tool, holding its edge by hand against the grindstone.

The room for the hardening and sharpening of cutters, drills, mills, taps, calipers, and gauges; the room for fine work, such as truing hardened pieces on a grinding machine; and the tool store room, are generally included in one department. This department contains, for example, a universal grinder, for automatically sharpening on any given template and at any clearance angle, planing and turning cutters, etc.;



CUTTING-OFF AND PIPE THREADING MACHINE, MADE BY THE ARMSTRONG MFG. CO., BRIDGEPORT, CONN.

a machine for automatically sharpening American drills; another for milling cutters; special lathes for taps; small universal millers, and others.

The tool room is often admirably arranged. In pigeon holes are grouped, methodically, tools of all kinds, taps, drills, boring tools, mandrels, calipers and gauges, tap wrenches, bits, files, etc. Each workman receives twelve checks or tickets on entering the shop. In exchange for a tool he hands in a check which is hung up in the place of the tool issued. This check bears the workman's number; on leaving the shop he must turn in his twelve checks. For material for current use, such as oil, waste, etc., the tickets are sometimes preserved and a tabular record of them kept.

Measuring instruments of precision, with micrometer screws, and others, are in very general use in America. Their use is so common that the workmen themselves very often have them.

An effort has been made in some establishments to facilitate communications among the different members of the personnel. Sometimes superintendents have a telephone near their table, and I have even seen a shop where the foremen had at their disposition telephones, permitting conversation with the tool room.

In certain establishments an excellent system has been inaugurated for the regulation of the entry and exit of the workmen. The outside door by which all the hands must come in, opens directly into a hall or room completely isolated, which contains basins and hooks or closets, permitting the workmen to wash up and to leave or take, as the case may be, their working clothes or their street clothes. A quarter of an hour before commencing time the outside door is opened and this room is at the disposition of the workmen. A door opens from it into the shops.

At the stroke of the bell, the hands enter by this latter door, ready to begin work. In the same way, at shutting down time, this door is opened on the hour, and as the workman has in the shop neither his clothes nor washing water, this arrangement insures strict keeping of working hours. It eliminates a cause of disorder at each time of beginning and quitting work, which the most active surveillance is often powerless to suppress.

I will devote a moment to two special features noticed at the Westinghouse Machine Company. The first concerns interchangeability of parts; the second, the distribution of the production of motive power among a number of generators. Although at the Westinghouse works as elsewhere, all work is done to 1-20 of a millimetre (.002 inch), it is not all done to gauge. The firm has for each machine a great ledger in which are entered all details of construction, etc. Inscribed in this book are, besides the number of the machine, the date of its order and shipment, name and address of the consignee, the numbers of the tracings that have been used in its construction, all data relative to the test of the machine, etc. Little printed sketches, dimensioned in ink, are added to the brief for pieces likely to require replacing.

The dimensions to 1-20 millimetre, indicated on the sketches, are stamped on the piece before shipment. The perfection of system is such that the purchaser, in case of wear or breakage, is assured that he can order by telegraph, by a single word accompanied by the number of the machine, any new piece, and that it will be shipped from the factory a few hours after the receipt of the telegram. With each machine the company sends a sheet with a drawing of each separate piece and each detail. Underneath the drawing are the names, weight, material, and price of each part and the corresponding cipher code word.

A feature of a great many American shops is the centralisation of steam production, but division of motive power. I was astonished to see in such shops as the Baldwin Locomotive Works and Worthington's, two or even three Westinghouse engines in one shop far removed from the central power plant. The small space occupied by the Westinghouse engines, the absence of necessity for heavy foundations, their moderate and practically constant cost per horse-power, the possibility of installing them on upper floors, and of having one machinist for several machines, explains this practice, which involves a whole series of advantages, such as the reduction of transmission, and the possibility of putting in operation separately and independently any one department.

In conclusion I will say that if the Americans are superior to us in certain respects, we must not always, as is too often the case, exaggerate their merits. In the foregoing pages I have tried to report such interesting and special things as I saw in the shops of the United States, so as to judge and compare the present state of machine construction in Europe and in America. I have described many useful innovations that certain European builders have adopted long since and that others will adopt soon or late; but my visit to the United States and especially to the Machinery Hall of the Chicago Exposition in 1893, has not caused me to forget nor to despise the high degree of perfection to which machine building has been brought in the numerous European shops where the conditions of production are absolutely different from those ruling in America.

Current Topics.

WITH the apparently honest efforts that are now being made in the city of New York towards the introduction of a compressed air street car traction system, to take the place of cable and underground electric trolley, it is worth noting that in France, where compressed air has been carefully studied and tried in a practical way on a large scale for just this kind of work, the electric trolley has scored a complete victory over all rivals. M. Abdank, a French engineer who recently visited the United States on a general inspection tour, has been credited with saying:—"The status of the several systems in France is concisely shown by the fact that, beginning only three years ago, we have built 500 miles of trolley line, while of the compressed air lines there are only forty-one, although the system was introduced in 1881; and a still smaller number of miles of the superheated steam system. There are two main reasons why compressed air traction has gone to the wall and electric traction has come into such wide use,—the greater cheapness of the latter, and its greater simplicity. The compressed air system involves a large number of transformations of energy whereby power is lost and the expense of the operation greatly increased. The compressed air system involves mechanism of a highly complicated order. There are fifty moving parts in an air motor car; in the electric there are only the armature and gear. Whatever is complicated is, upon general principles, objectionable in mechanics; the simpler a thing is, the more desirable and useful. Complicated constructions get out of order easily, and the cost of repairs is great. The repair cost of the air motor cars in France has been something enormous. Since the practicability of the trolley was demonstrated there has not been a single compressed air line added to those already in France. The Compagnie Générale des Omnibus, of Paris, only last year experimented with the compressed air system and discarded it. It also tried the storage battery system, which has met with little favour in France. The underground trolley, while having some objections from which the overhead is free, is essentially the same thing and equally practicable. I think it is not too much to say that all progressive engineers and railway men look upon cable traction as really antiquated and doomed soon to become obsolete. We have tried it in Paris enough to satisfy us that its day is virtually over. Our little cable line in Paris, through Belleville, furnishes our comic journals with perpetual jokes."

AN interesting bit of traction engine history was recently given in the London *Engineer* in the shape of working drawings and general illustrations, as well as data, of an engine whose wheels laid down an endless railway for themselves in the form of flat wooden shoes, attached by suitable links to the tires of the driving wheels. One of the illustrations has been reproduced on this page. The engine had been designed by a Mr. Boydell and was built nearly forty years ago by Messrs. Charles Burrell & Co., of Thetford, England. The great defect of the machine was that it could not be used at any but very moderate speeds, up to about two and one-half miles an hour; beyond this the shoes slapped themselves down on the road with such violence that they were broken, or centrifugal force interfered with their proper action. Mr. Frederick Burrell, writing of this design to *The Engineer*, said that when it was first brought out it attracted a great deal of attention and his firm received orders for such engines from many countries.

AN ENDLESS RAILWAY TRACTION ENGINE.

THE engines were capable of hauling immense loads, being geared very slow and having shoes which could not possibly slip. The usual test load was fifty tons and this was carried in four or five waggons. In the year 1859 a Boydell engine was built by Messrs. Burrell for the British government for presentation to the viceroy of Egypt. As soon as the latter heard that it had arrived, he got up very early in the morning and had his own carriage put behind it, and was thus drawn through the streets of Cairo. Some of the early Boydell engines, Mr. Burrell says, were arranged to be steered by a horse in the shafts, and worked for some years in that way. It was amusing to see the effect that it had on a strange horse in the shafts. The horse would probably refuse to start at the right moment, with the result that he would be gradually pushed forward until he assumed a sitting position, like a dog, and then would be slid along until he realised that such a position was not comfortable, when he would get up and commence to pull as hard as possible. This having, of course, no effect upon the engine behind him, would last until it gradually dawned upon the animal that dragging was unnecessary, when all would go well. The engines afforded good lessons for unruly horses, and generally cured them of all bad habits. On one occasion, in the year 1861, a plowing engine happened to sink down in a meadow near Messrs. Burrell's works and could not extricate itself easily. Having a Boydell engine in the yard, steam was got up, and this engine sent to the rescue of the other one. The Boydell walked easily over the soft meadow, was hooked on to the mired plowing engine, and drew it safely out on to the hard ground. The shoes of the Boydell engine prevented the weight of the latter from making more than a slight impression upon the meadow.

How suggestive the vegetable kingdom is of engineering problems was pointed out in a very interesting manner some time ago by Sir Benjamin Baker in a presidential address to the British Institution of Civil Engineers. "Every tree," he remarked, "is a vegetable pumping engine, but hydraulic engineers would be sorely puzzled to explain how the large quantity of water required to supply the evaporation from the extended leaf surface is raised heights up to 400 feet and above. We know that the source of energy must be the sun's rays, and we know further that, in the production of starch, the leaf stores up less than 1 per cent. of the available energy, so that plenty remains for raising water. Experiments have shown that transpiration at the leaf establishes a draught upon the sap, and there is reason to believe that this pull is transmitted to the root by tensile stress. The idea of a rope of water sustaining a pull of perhaps 150 pounds per square inch may be repugnant to many engineers, but the tensile strength and extensibility of water and other fluids have been proved experimentally by Professor Osborne Reynolds, and by Professor Worthington and others. A liquid, deprived of air, entirely filling a glass vessel, when cooled, pulls on the vessel, and at last lets go with a violent click. Water has been so stretched nearly 1 per cent. of its bulk, and the adhesion of the water to the sides of the vessel and the amount of the tensile strength were found to be quite equal to that of good mortar. With ethyl alcohol the modulus of elasticity, both in tension and compression, was constant up to the ultimate tensile resistance realised of 255 pounds per square inch. Many hydraulic engineers have, no doubt, lived and died without encountering anything in their experience suggesting that water and other fluids were capable of resisting a tensile stress of no insignificant amount; and yet, as long ago as 1663, the fact was known, for the secretary of the Royal Society then wrote to the Governor of Connecticut that 'what puzzleth and perplexith us is that water defecated from air remains suspended and doth not at all subside after the receiver hath been exhausted of air;' and, in the same year, the president was asked 'to entertain His Majesty' Charles II. with the sight of quicksilver sustaining itself by tension at a height of fifty inches when the barometer was at twenty-nine inches, 'something else but equipondency of air being,' it was truly said, 'necessary to explain this odd phenomenon.'"

Gas and oil engines find a constantly widening field of usefulness. Among the latest applications are those to mine hoisting and mine haulage, and for both services designs have been put on the market which will probably help a good deal towards still further popularising engines of this class. For hoisting work particularly, and especially in the case of small mines where the hand windlass or the horse-power machine will no longer give satisfaction, the gas or oil motor offers a number of advantages worth considering, among them the stereotyped, but none the less important, one of fuel convenience. The water supply question, also, is easily disposed of, since the same water,—and a small quantity, too,—can be satisfactorily used over and over again to cool the engine, while its quality needs no consideration so long as it will not badly corrode the iron. With the scarcity of even fairly good water, that is experienced in many mine localities, this feature of the gas or oil engine outfit will be specially appreciated.

In connection with this it is worth noting that for pumping water, gas engines have been employed for at least a dozen years, having been installed in a number of German towns for municipal supply as long ago as 1884. From all that can be learned, these engines have given satisfactory service. In some of the plants they are used as adjuncts to steam engines to supply any emergency demand, but in most of them they do the whole work of providing for the towns. Outside of Germany little, if indeed anything, has been accomplished in this line, and yet it is not unreasonable to expect that in a few years gas, gasoline, and oil engines for water works pumping duty will have lost a good deal of their novelty.

The fire danger lurking in electric flexible cord connections is practically demonstrated every now and then, and with it, too, the need of better cords. In a recent instance, mentioned in a fire underwriters' report, a flexible cord, supporting a lamp, which was not burning at the time, suddenly developed a short circuit and a one-ampère fuse in a rosette opened, cutting off the current. The cord was quite greasy with oil coming from shafts and bearings, and dirty with lint which had accumulated. The risk was a cotton mill. The arc, though almost instantly cut off, was sufficient to set the cord on fire, and several inches of it were burned. The fire was quickly extinguished by an attendant, so that practically no damage was done. A few days before this accident, another cord developed a short circuit under practically the same conditions. In both cases the cords were hanging free in the air and had not been touched for a number of hours. It is the custon at this mill to frequently turn on and off the lamps by the key sockets and also to frequently brush the lint off the cords. During the summer season the cords are wrapped together and tied in a bunch near the ceiling to get them out of the way. The best explanation of the trouble is that a strand of the fine wire broke and pushed its sharp end through the insulation causing the short circuit. Both cords had one or two layers of cotton thread first, then a fairly thick outer covering of silk, but they were not rubber covered. These occurrences show that however quickly currents may be cut off by fuses, the heat generated by the arc is sufficient to set fire to flexible cords, especially if they are at all greasy and covered with lint. A better cord may not mean one having a higher insulation, but rather one which could not be set on fire It seems important that cord should be used which would prevent short circuits occurring under as great a number of conditions as possible, and at the same time prevent the flash produced by a short circuit from doing harm.

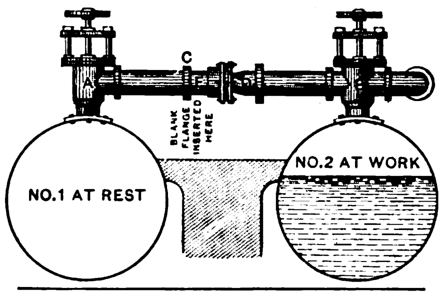
Apropos of the article on "A Modern Saw-mill," which appears in this number, it is interesting to revert to the World's Fair at Chicago, in 1893, and recall to mind the splendid saw-mill exhibits made there by the Stearns Manufacturing Company, of Erie, Pa., and the E. P. Allis Company, of Milwaukee. The exhibits consisted, in each case, of a band mill and a complete set of finishing and conveying machinery, and were in operation for short periods every day during the fair, affording, thus, admirable demonstrations of what can be accomplished in this line in point of working speed. The sawing exhibition was always witnessed by a greatly interested crowd. The rate of sawing the stock boards, usually 12 inches wide and 16 feet long, was from twelve to fourteen boards per minute, once, it is claimed by the Allis men, reaching fifteen boards. This is a speed hitherto unattained with the band saw, sixteen boards per minute being the highest record with the circular saw. The running speeds of the Allis 8-foot band mill and the Stearns mill were about the same, being 400 revolutions per minute, making the speed of the saw 10,000 feet per minute,—the usual speed for white pine. The log carriage, which would weigh, with the log, about two and one-half tons, was propelled in each direction by a steam cylinder of 9 inches bore and 28 feet long. Fourteen boards per minute gives 4.3 seconds to the sawing of each board, the actual sawing time for each board being about 2.3 seconds. This leaves two seconds for gigging, reversing and setting over the log for the next board, thus making the sawing speed about 260 feet per minute, and the gigging speed about 500 feet per minute. This is more like the action of a vegetable cutter slicing up turnips to feed stock, than the old way of sawing boards. The marvel was to see the man remain on the saw carriage, while it was thus shot to and fro. He did his work at the proper time; kept his place as if he were part of the machine; a fly on the wall was not more at home than he.

"READY Made Bridges" is the title of an item which has lately been going the rounds and in which the statement was made that there are a number of establishments now which keep on hand a full stock of ready-made iron bridges of nearly all sizes, ready for shipment at a few hours' notice, to meet emergency demands. It is safe to say that few bridge builders ever before heard of anything like this. In the course of business bridge-building firms are sometimes obliged to take old bridges in exchange, and expediency may occasionally dictate holding back work on account of lack of funds of those who ordered it, but there are no firms, to our knowledge, that make a practice of building bridges to be ready for an emergency. It is rare that the spans of bridges are duplicates, and, besides that, the angles of bridges will always vary.

A RAILROAD without a Morse telegraph instrument in any of its stations or offices, not even the most important, is an uncommon sight, so much so, says the *Railroad Gazette*, that most railroad men would call it a curiosity; but such, it appears, is to be the character of the new Queen Anne's railroad, extending southeastward from Baltimore across Maryland and Delaware, east of Chesapeake bay. This road is about fifty miles long and it is intended to use the telephone for all communications for which a letter by train would be too slow. The use of the telephone for all necessary instantaneous communication is not entirely unknown in the United States. Mr. C. A. Hammond described in the *Railroad Gazette*, several years ago, the practice on the short Boston, Revere Beach and Lynn road, where train orders were sent by telephone and perfectly satisfactory written copies and records were made. The Suffolk and Carolina road, extending forty miles southward from Suffolk, Va., has depended on the telephone for ten years. It is fair to say, however, that the number of train orders issued on that road is not very large. Only two regular trains are shown in the *Official Guide*, and the leeway at the meeting point is eight and one-half hours; that is to say, the north-bound train meets itself at the northern terminus, arriving at 9 A. M., and going back at 5.30 P. M.

BOILER accidents will probably for a long time continue to afford some of the best examples of dangerous carelessness among engine and boiler attendants. Familiarity, we know, breeds contempt, and it is familiarity with the dangers which are always associated with the use of steam apparatus that seems, in numberless cases, to have caused death and destruction around boilers. A new instance of this was recently reported to the Manchester Steam Users' Association, in England. It appears that a boiler was being put into shape for its annual inspection by men who had prepared it for this examination every year for a period of nine years. They blew down the boiler and commenced to remove the manhole cover when the latter was blown off, with injuries resulting from which both attendants died. Evidently there was some pressure in the boiler which they had failed either to relieve or detect, or which, perhaps, they considered so slight as to be not worth taking into account. A pound or half a pound pressure might not show on the gauge, and yet be capable of leading to considerable damage if suddenly relieved through a large opening, like a manhole. It is possible, as was pointed out in this case, that water was fed into the boiler to help in cooling it down, and this may have absorbed enough of the heat still remaining in the brick setting to renew a pressure sufficient to bring about the disaster. Bearing on this, Mr. Lavington Fletcher, of the Manchester Association, has made the following suggestions which men in charge of work like this ought to bear in mind:—"Not only should the safety valve be propped up so as to be held open, but it should be seen that all escape of steam through them has absolutely ceased before the nuts of the manhole covers are removed. The adhesion afforded by the red lead joint may be a trap, and lead to danger. Though there may be no pressure apparently remaining in the boiler, the adhesion of the jointing material holds the lid down for a time, but on being slightly disturbed it allows the lid to be suddenly blown off, when a violent rush of steam ensues, sufficient, as we have seen in the case now reported, to inflict fatal consequences. It would be well also to open the glass water gauge taps, and to note if any steam issues therefrom."

Of the simple oversights in boiler management that may lead to disastrous consequences, another example lies before us. In this case there were two boilers, set side by side, as shown in the annexed sketch, one being at rest while the other was at work. An expansion joint was between them, the end of the pipe D sliding freely in the stuffing box



A DISASTROUS BOILER CONNECTION.

and gland at E. In order to effect some repairs to the stop valve A on boiler No. 1, the valve B was closed and a blank flange was put in at the joint C. After this the valve B was again opened and the man on the job commenced to take out the bolts which secured the valve A to No. 1 boiler. He had taken out two or three of these, when the pressure of the steam, acting on the blank flange at C, shot the expansion joint E, along with the valve A, right off the end of the pipe D, which was drawn out of the gland and stuffing box just like an arm is drawn out of a sleeve. Steam at once rushed out of boiler No. 2 through the open end of the pipe D, which was about 6 inches in diameter, scalded the man to death, and also injured two others who happened to be in the boiler room at the time. The man probably was under the impression that the stuffing box E was in some way connected to the pipe D, for it seems almost incredible to think that a skilled mechanic would willfully commit such a blunder. There can be little doubt that the accident was the result of a kind of easy going indifference for which the poor fellow in this case paid a terrible price.

MISLEADING gauge glass readings, due to defective connections, have also been responsible for many casualties, especially in cases of marine boilers. In a pamphlet issued by the British Board of Trade, Mr. Macfarlane Gray, the chief examiner of engineers, mentions several such instances. One case was that of a passenger steamer in which two of the furnace crowns were discovered to be down just as she was on the point of starting. A Board of Trade surveyor happened to have occasion to visit the steamer at the time, and the chief and second engineers, both certificated men, told him what had occurred, and requested him to note that the gauge glass showed plenty of water in the boiler, and that therefore they were not at fault. Examination proved, however, that the cock on the communication to the steam space of the boiler was shut, this having been done for a survey on the previous day, and forgotten. On opening it the water disappeared out of the glass. The second engineer admitted that he had blown the boiler down to lower the water level, as it was above the top of the glass. Two furnaces were brought down in another steamer at sea owing to the top communication being shut. Other cases, and with more serious results, might be cited, all of them illustrating what serious damage may result from trifling causes which a little thoughtfulness would prevent.

IT may appear as a curious fact that many men who have had years of experience in shops and who are good workmen, seem to be afraid of drawings. While working to them with accuracy, and finishing their jobs satisfactorily, they never seem quite at rest in regard to the meaning of their drawings and frequently remark, "If I had another job of the same kind to do, I could get through it in much less time." This means, practically, that if they had a model before them instead of a drawing, they could turn out their work more easily. It raises the question, too, whether it would not pay to give more attention to making drawings plain and to teaching the men to read them. Shading of parts, and increasing the pictorial effect in general, so as to make one piece stand away from another, would seem to be a good thing, and in this respect some of the older forms of shop drawings might well be taken as examples worth following. To-day many of these out-of-date drawings are considered as having been wasteful of drawing office time, and uselessly elaborate, and yet they had good points. They told their story in a way quite foreign to the modern blue print.

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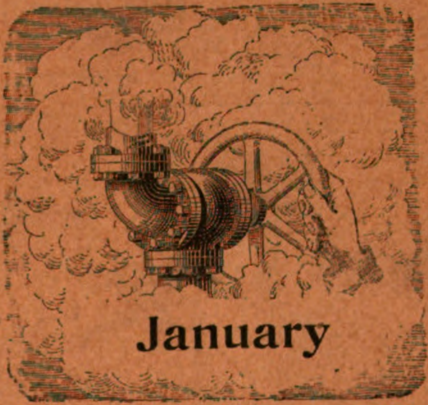

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SMALL REFRIGERATING PLANTS.

By Walter C. Kerr.

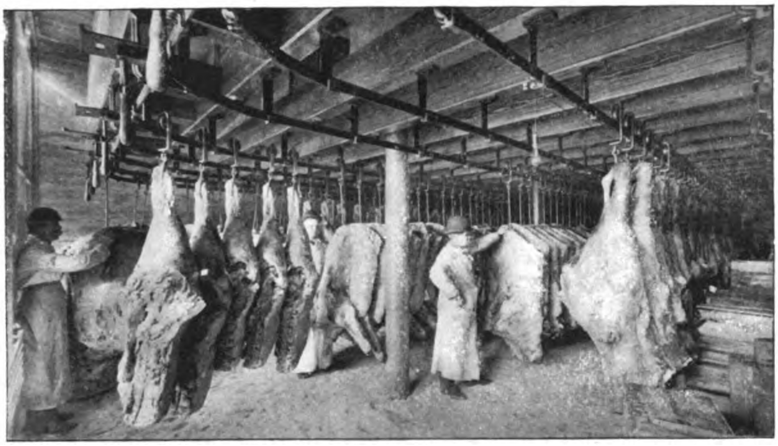
WHILE the art of refrigeration is old, it is probably less understood by the general public, and even by engineers, than any of the applications of heat energy to practical purposes. Locomotives, steamships, electric cars, and other apparatus in which heat energy is in some way transformed into useful effect, are ever present and are subjects of common discussion.

Refrigeration, however, is so completely out of sight, and hence, out of mind, that the public have no knowledge whatever of it. Engineers are, as a rule, less acquainted with refrigeration than with the other engineering arts, because it has always been highly specialised, rather than included in general engineering, and thus the world has come to regard it as a more or less occult science.

Until within the past few years successful refrigeration has been confined chiefly to very large plants, and when attempted on a small scale, it seemed fraught with difficulties which limited its application, but which have proved to be due only to ignorance and to the insufficiency of apparatus. Within five years the increased demand for small refrigerating plants has brought into the field several good designs and stimulated greater attention to the requirements and economies of the smaller class of service. What are known as small refrigerating plants have taken rank with the large ones for quality and all-around commercial efficiency, although, as is common in engineering, the absolute efficiency of the small plant cannot equal that of the larger.

If this article were to undertake a general description of various types of apparatus, and illustrate the different systems, it would suffer from spreading over too much ground. It is, therefore, proposed to illustrate the place which small refrigerating plants occupy in present practice by means of one system which is quite extensively used.

The principles of refrigeration are based on the common laws of heat, and seem strange only because ordinarily attention is directed to something which



A REFRIGERATING ROOM COOLED BY COILS IN OVERHEAD BUNKERS.

gains heat while in refrigerating processes one is caused to consider that which loses heat. This involves such an upsetting of habit of thought as to impair one's logic. Such impairment, however, is not permanent and a little practice enables one to think along cold lines as easily as along hot ones.

To produce a refrigerating effect some medium must be used which shall have considerable capacity for absorbing heat and carrying it away from the object to be cooled, and if this medium is used over and over, its heat must again be transferred from the medium to some other object which may be run to waste. The practice of the world has decided that liquefied anhydrous am-

A MODEL MARKET WITH ARTIFICIAL REFRIGERATION.

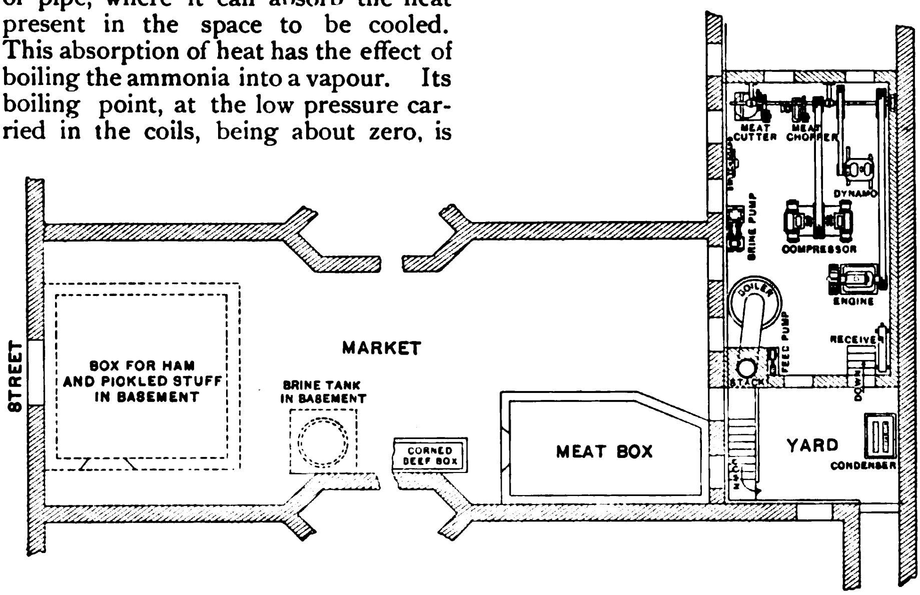
monia is the most convenient medium through which heat shall be abstracted, and water shall be the substance to which this heat shall be eventually transferred to run to waste.

It is not important in the present consideration to discuss why ammonia is almost universally used as a medium, except to say that it is cheap, easily and universally obtainable and has a high heat-carrying power. To perform the act of refrigeration, the ammonia must be pumped as a liquid into coils of pipe, where it can absorb the heat present in the space to be cooled. This absorption of heat has the effect of boiling the ammonia into a vapour. Its boiling point, at the low pressure carried in the coils, being about zero, is quite as low as the temperature to which any space would ever need to be refrigerated.

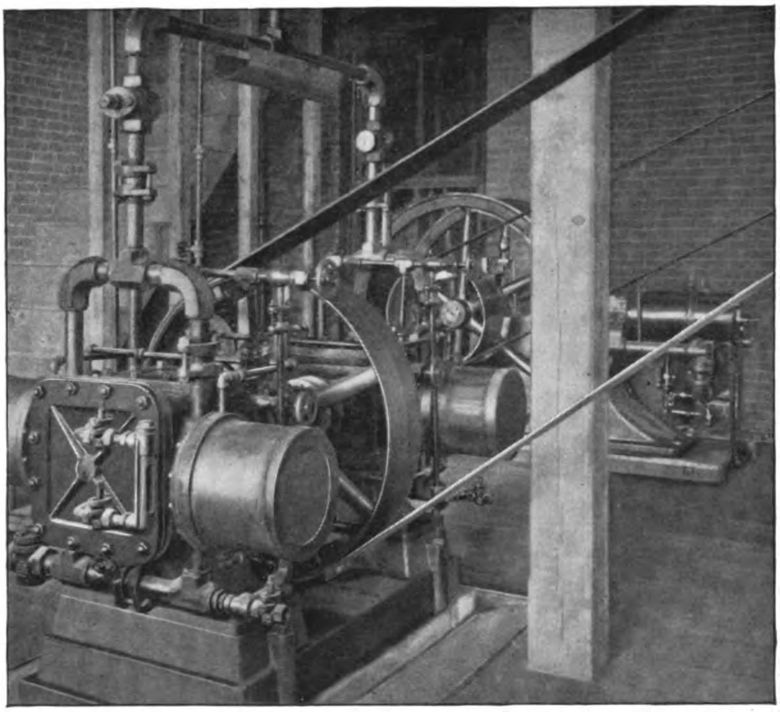
The gas thus formed, carrying the absorbed heat, is piped back to the compressor, which is merely a pump, and is there compressed to about 150 pounds per square inch. Under this pressure it will again liquefy at ordinary temperatures, when the surplus heat has been removed. It is, therefore, led at this pressure into a condenser, composed of coils of pipe over which water flows. By the cooling action the heat is transferred from the ammonia, which condenses to a liquid, and passes to waste with the condensing water. This is where the heat goes which was in the articles refrigerated. The liquid ammonia is again ready to pass through the refrigerating coils, and thus the process is continuous.

Such a simple operation would seem an easy one to apply on any scale, whether large or small, but the limitations surrounding the application to small service are much greater than with large. In a large plant the service is performed on such a scale as to warrant the operation of a substantial efficient steam plant for driving the compressors, and the provision for a cheap and abundant supply of water to flow over the condenser, while skilled operatives can be afforded. In cold storage warehouses, breweries and large ice plants, the problem becomes merely one of good engineering design to provide apparatus of such size and quality as will efficiently perform the service.

In small plants the apparatus must be peculiarly simple and durable. For general adaptability the compressor must be operative from a line shaft, steam engine, gas engine or electric motor, and to this end it must be belt driven and so smooth-running that the



A COMPACT UNDERGROUND REFRIGERATING PLANT AS A MARKET ADJUNCT.



A FOUR-CYLINDER AMMONIA REFRIGERATING COMPRESSOR, DRIVEN BY A GAS ENGINE.

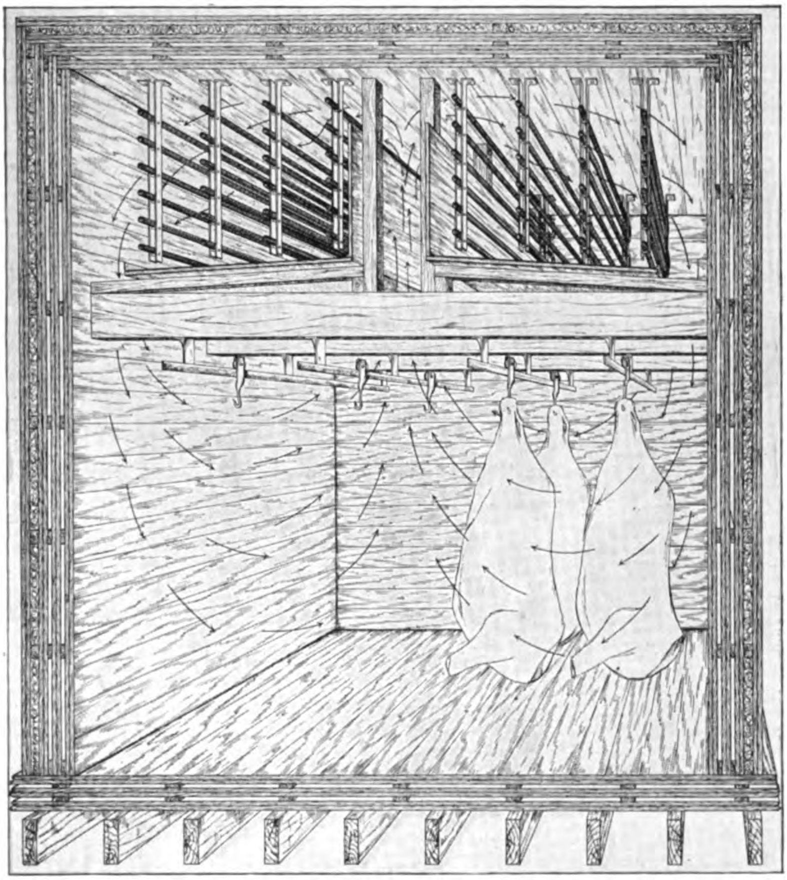
belt will not have the jerky motion which usually attends high-compression machinery.

The condenser must be of a type which shall use a minimum amount of water, for small refrigerating plants are usually situated where an abundant water supply is not obtainable except at a prohibitive cost. The piping and all adjuncts of the plant must be of such character as to stay tight, require but little care and have practically no cost of maintenance. This is the part of the plant where the cheap contractor makes most of his saving, and the customer learns it later.

Of no less importance than suitable apparatus is the skill employed in designing the various adaptations of small refrigerating plants to the service desired. It is only of late years that this skill has been acquired to such a degree as to assure the proper performance of such plants and place them on par with larger work. With small plants, space is usually restricted, surrounding conditions are generally unfavourable, and obstacles which would be small for larger plants, are apparently insurmountable within reasonable cost. The difficulties surrounding small work call for greater resources and ingenuity than the construction of heavy work in which the operations are of such magnitude as to admit of methods otherwise prohibitive.

It is one thing to produce good refrigeration and another to keep it; that is, heat may be removed by refrigerating processes, but unless special precautions are taken, the temperature will again rise. The maintaining of refrigeration depends, in other words, upon insulation. This is a point popularly misunderstood and may be made plain by the followng considerations.

Suppose a box, without openings, were made with thick walls of some absolutely perfect insulator. An ammonia coil in this box could abstract the heat until the temperature was very low,—say, freezing. The temperature of the interior of the box would then stay forever at the freezing point without further refrigeration. Inasmuch, however, as no insulating material can be perfect, some heat will creep through the walls, and it is to remove this heat that the cooling process must continue.



SECTION OF A REFRIGERATING BOX WITH COOLING COILS IN OVERHEAD BUNKERS.

Therefore, the capacity of a refrigerating plant is dependent mainly upon the leakage of heat into the refrigerated space and has but little to do with what is in that space. If, however, doors are opened frequently, permitting inrushes of warm air, or if refrigerated material is constantly being replaced by new, warm material, this also becomes a considerable factor in the required capacity of the plant.

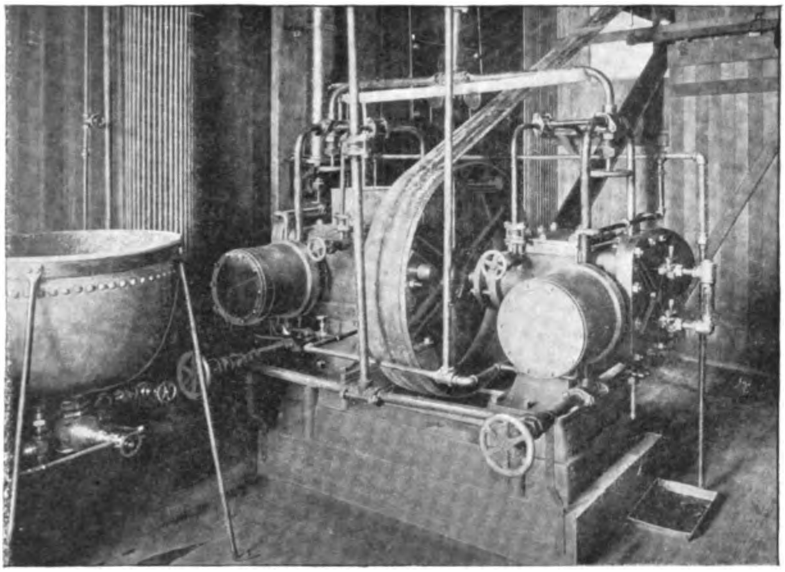
As a general statement, however, the cost of refrigeration is the cost of abstracting the heat which goes through the insulated walls. It is, therefore, obvious that no insulation is too good, and if a plant is to be run at a reasonable expense, the insulation must be good enough to reduce the waste to some moderate amount. The smaller the room or box refrigerated, the larger is its surface in proportion to its cubical contents; for instance, a box, five feet square and high, contains 125 cubic feet and has 150 square feet of wall surface, or more than one square foot of wall for each cubic foot of space, while a room, 50x20x10 feet, contains 10,000 cubic feet and has only 3400 square feet of surface, or about three cubic feet for each square foot of surface; hence, the insulation becomes of constantly increasing importance as the plants decrease in size.

AN ARTIFICIALLY REFRIGERATED MORGUE.

It might be supposed that the ammonia is always circulated directly through the coils in the refrigerated boxes, but as a matter of fact it is often passed through coils in a tank filled with brine, cooling the brine to a low temperature, and this brine is then pumped through coils in the boxes. This, for many reasons, is found the best method for general purposes, especially as a large quantity of cold brine is quite a storehouse of refrigerating effect, which permits the machinery to be shut down more or less without materially affecting the room temperatures. When very low temperatures are desired, custom favours the direct use of ammonia in the coils, without an intervening medium, or a chloride of calcium solution instead of brine.

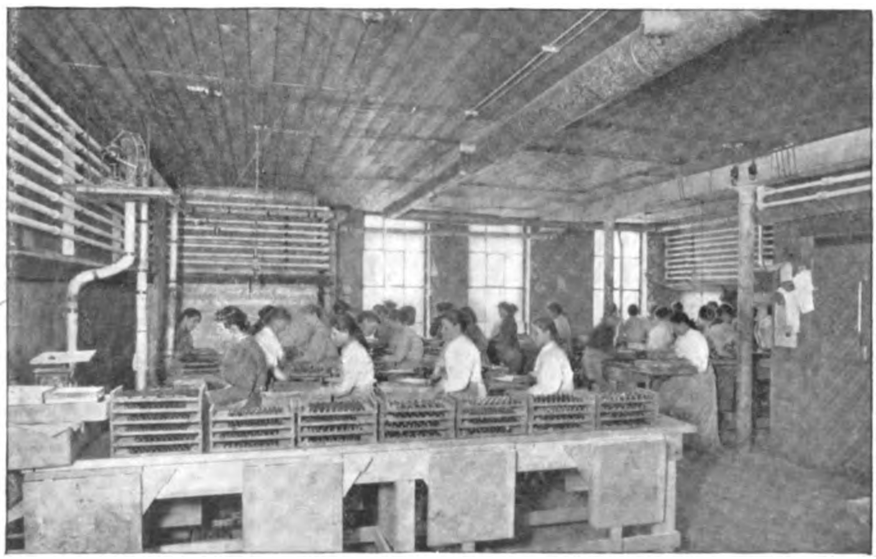
The first, and by no means the simplest, engineering problem connected with the installation of small refrigerating plants is finding suitable room in which to locate them. Many pages might be filled with illustrations of plants squeezed into very narrow quarters, for ingenuity will devise ways of providing necessities even where no space whatever seems available.

An excellent example of this is in a certain market, occupying the cellar and first floor of a building in which the upper floors are used for living apartments. No room was available on the first floor, nor in the basement. A small yard in the rear could not be encroached upon, as the building laws required a stated percentage of yard in the rear of such houses. A rather novel, but simple, method was therefore adopted of excavating the yard and roofing it over, leaving the yard unimpaired, but with an excellent refrigerating plant under it, all of which will be clear from the diagram on page 173.



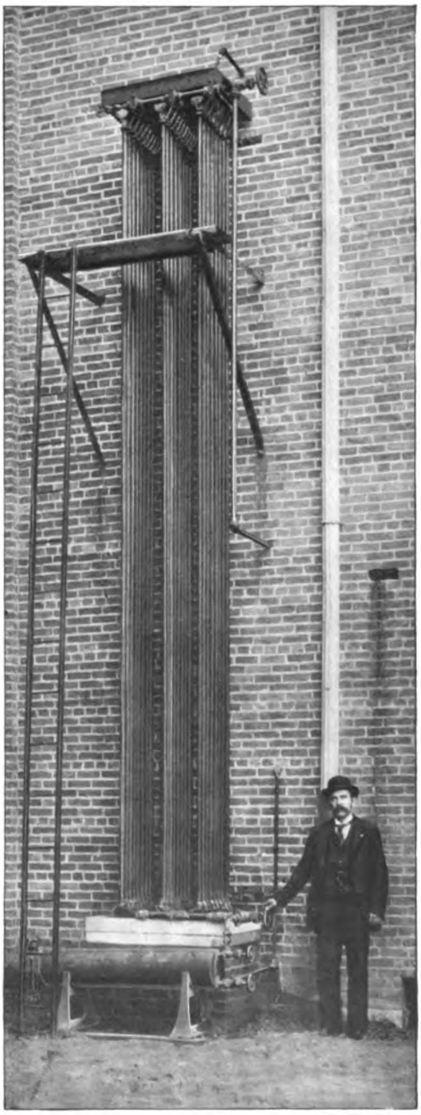
A BELT-DRIVEN AMMONIA COMPRESSOR.

The refrigerating plant in the market illustrated at the bottom of page 172, has several features of importance. The market itself is scrupulously clean, handsomely decorated in white and gold, and fitted with Venetian glass chandeliers. The butter box shown on the left is faced with enamelled brick, and has a plate glass door, while the large box, shown in the background, has plate glass windows through which the meat can be seen by the electric lights within the box in a way so attractive as to be even appetis-



REFRIGERATION IN A CHOCOLATE FACTORY.

ing. Beyond the larger box is a smaller one for freezing game and poultry. The interiors of the boxes are even cleaner and more attractive than the exterior, if that were possible. It is a fancy



AN EXCELLENT FORM OF AMMONIA CONDENSER FOR SMALL PLANTS.

market, serving a fancy trade in the most approved manner.

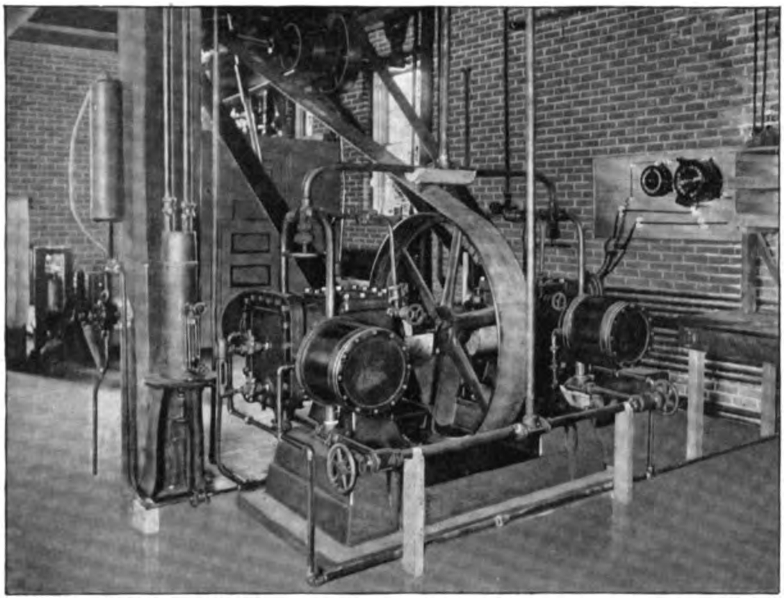
When a refrigerating plant was here first proposed, it seemed as though no place could be found for it. Nevertheless, in a most constricted space, excavated in the rear of the market, was located a gas engine, with shafting to supply power for a compressor, brine pump and dynamo for lighting the market. The dynamo and brine tank are carried on steel beams over the other machinery, while the condenser is placed in the yard.

The most interesting feature of this plant is the record it has made. Its cost of operation is practically the gas for the gas engine, and the gas bills are slightly under what it formerly cost for the electric lighting of the place with the street current. In other words, the refrigeration is performed by the saving effected. It is not often that so good a record as this can be shown, but usually the cost is less than that of ice for equal amounts of refrigeration.

The operation of refrigerating plants by gas engines is of marked importance, owing to the well known efficiency ot such engines even in the smaller sizes and the convenience with which they may be installed and operated. A fair illustration is given on page 174 of a compressor thus driven. The compactness of many most interesting plants unfortunately puts them quite beyond the reach of the camera.

The dryness of artificial refrigeration is of great importance. Ice is wet. It melts into water. The boxes are damp and the contents suffer. Artificial refrigeration is dry. Furthermore, it freezes all the moisture out of the air of the boxes into snow on the pipes, and even though its temperature be zero, and the pipes look like snow-covered rails on a fence, the air within the box is as dry as the hot blast from a furnace. This is one of the great contingent advantages of artificial refrigeration, and has led to its adoption even in cold latitudes where ice is abundant and cheap.

When one enters a cold storage room, it is expected that masses of pipes will be seen around the walls, covered with snow and icicles, giving visible evidence that the refrigerating process is going on. One may, therefore, be surprised to step into a room as cold as the dead of



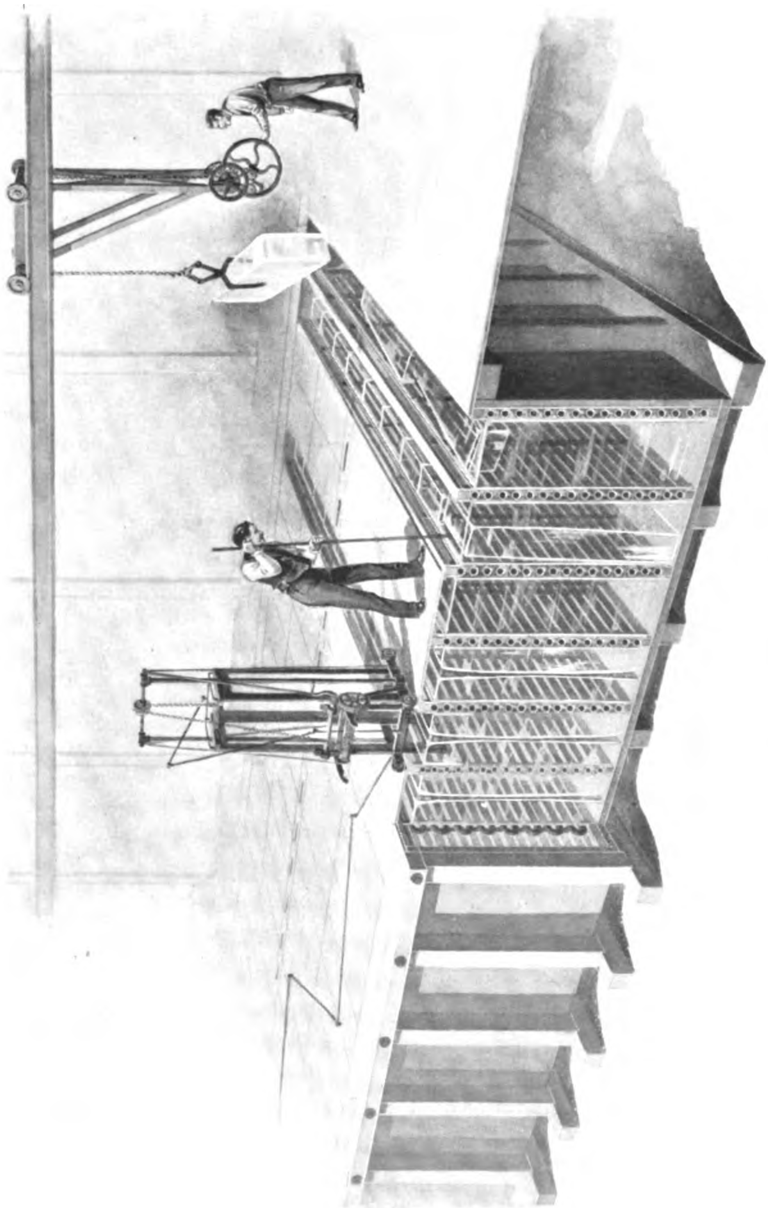
AN ELECTRICALLY-DRIVEN AMMONIA COMPRESSOR.

winter and observe nothing but plain walls and ceiling. The construction is then on the most approved lines, with the ammonia or brine coils concentrated in bunkers above the storage room, and with suitable passages for the circulation of air, which, when cooled in the bunkers, settles to the floor, crowding the warmer air up into the bunkers to be cooled and again descend, thus maintaining a slow circulation. The general appearance of a first-class box of this description is given on page 172, which, although seemingly quite large, is yet within the range of so-called small plants. The cut on page 175 illustrates the arrangement of the bunker coils.

A useful purpose to which refrigeration has, of late, been applied is the lowering of temperature in morgues and hospitals where bodies must be preserved for long periods of time, and obviously in the best condition possible. The process is simple in the main, yet considerable knowledge is required with reference to the requirements of such work to satisfactorily and economically hold the temperatures, especially considering the absorption of heat through the large expanse of glass usually exposed. The view on page 176 shows one of the most complete and accessible morgues ever built.

Numerous special applications of refrigeration have arisen which would scarcely have been suspected until small refrigerating plants were perfected. There are many products, such as oil and chemicals, which are drawn very hot from the stills and retorts, and on which the saving of time by quick cooling, more than pays for the cost of refrigeration. Along these lines of service perhaps one of the most interesting is that of chocolate making. Chocolate was formerly manufactured only in cold weather when the temperature was low enough for it to be worked and hardened.

A working room temperature of 65 degrees is sufficient for the dipping process and insures the setting of the chocolate when put in the chill room at 45 degrees. If the temperature be much above 65 degrees, the chocolate remains sticky and plastic, which is very inconvenient under any circumstances and absolutely fatal to bonbons.



HARVESTING ICE IN A PLATE PLANT.

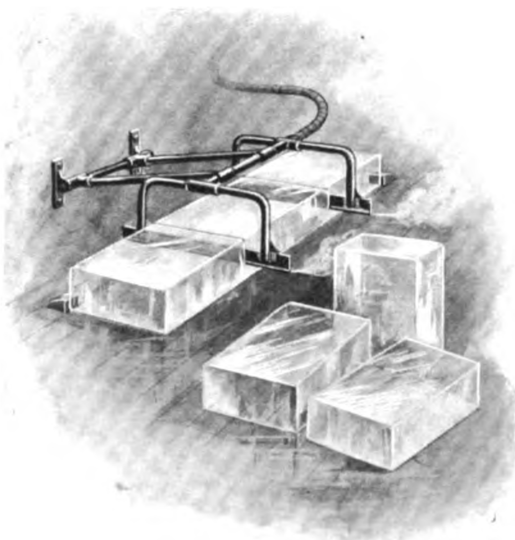
While 65 degrees is not a very low temperature, it is obvious that it cannot be maintained in any room during the greater portion of the summer when in this room is thrown off the bodily heat of a large number of operatives, and the hot chocolate must also be present, giving off heat sufficient to raise the temperature far above the critical degree. Ventilation will assist in modifying the temperature, but only by refrigeration can it be held at a point which will enable the industry to be safely carried on during the warm months.

The interior of such a room is shown on page 177. Cooling coils are placed around the room, like steam pipes, but in addition to this, and of even greater importance, air bunkers are provided, containing ammonia coils over which the air is forced and cooled. It is then delivered to the room through large galvanised pipes, running across the ceiling, thus providing ventilation for the ninety or more operatives, and the requisite coolness to work the chocolate. The chill room is refrigerated to 45 degrees in the usual way and opens off the dipping room.

At the top of page 177 is shown the compressor, located on the third floor and driven from the main shaft of the factory. At the left is seen one of the chocolate boiling kettles, and it is of passing interest to note that such refrigerating machinery can be placed right in the midst of even chocolate kettles without either interfering with the other.

As an illustration of one of the many odd uses of refrigeration may be mentioned that of gelatine working. Every one is familiar with the gelatine capsules in which medicine is administered, and will readily understand that difficulty might be experienced in manufacturing such articles in hot and moist weather. The capsules are formed of sheets of gelatine, pressed over steel pins. The cooling must take place rapidly in order to turn out the product in sufficient quantity; to insure quality, and general evenness of material, a proper temperature must be provided.

In one of these instances the compressor is driven by an electric motor through a countershaft, as shown on page 179, the motor being quite out of sight behind the compressor. This indicates the ease with which such a small plant can be placed without the accompanying annoyance of steam power. The condenser is shown on page 178 and is an

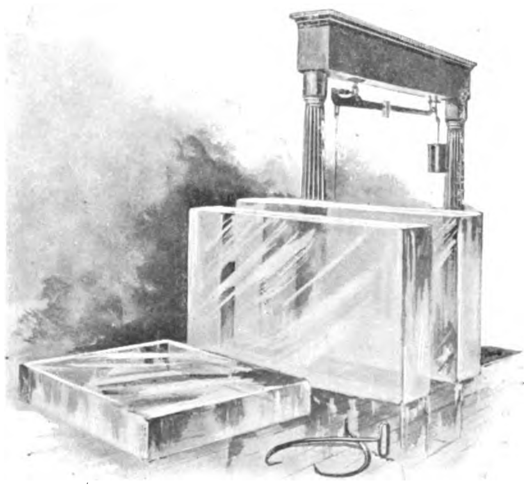


CUTTING BLOCKS INTO CAKES BY MEANS OF STEAM BLADES.

excellent view of the type which is found so well adapted to small plants through its economy in the use of water, and the ease with which it can be put into corners and spaces along the outside of walls where otherwise the room would go to waste.

In this case of capsule manufacture it was found that about 120,000 cubic feet of air had to be cooled per hour in order to insure an even temperature for the gelatine, and about 160,000 pounds of steel pins per working day had to be cooled from about 90 to 75 degrees. By combining the two requirements, and making the blast of cold air cool the pins, both of these results were effected through one operation, requiring only the cooling of sufficient air in bunkers with refrigerating coils. Perfect success was met and probably in no other way could so useful a result have been obtained so cheaply.

In the tempering of steel or the cooling of other articles in a bath of special composition of such cost that it cannot well be run to waste,—as oil or brine,—the necessity arises of removing the heat surrendered by the material cooled, thus keeping a constant temperature in the dipping tank. In the case of saw tempering, a large volume of brine is refrigerated and circulated through the dipping vat. The large reserve volume acts as a fly-wheel, equalising the fluctuations of temperature arising from varying rates of dipping, the compressor running continuously.



"DIAMOND" ICE.

Thus far we have been concerned only with refrigeration without reference to the manufacture of ice, and notwithstanding that refrigeration has so largely taken the place of ice, it is often desirable, even in small plants, to make some ice for table and other purposes. In hotels and restaurants this is particularly true, and nothing but the poor results that have been obtained in the past has prevented this from being done more extensively.

The old method was to put common, filtered, hydrant water into cans and freeze it into white unattractive ice, useful only for cooling purposes and hardly suitable for the table. Distilling and purifying apparatus is found necessary to make acceptable ice by this process, and the manifold duties of the operating engineer usually prevent the giving of proper care and attention to the various purifying devices, with the result that the quality of the product is quite inferior.

There is now developed, however, a practical method of making ice in large or small quantities on the "plate system," freezing outwardly from the refrigerating coils, excluding impurities into the residual water, circulating this water by means of a circulating pump through filters to remove air and impurities, giving clean, pure crystal ice from water of almost any reasonably good quality. The ice is then harvested by a steam cutter which pushes its square nose down in the tank and cuts off a slab of ice whenever required. A tank of this character, added to a refrigerating plant, is a most useful and profitable adjunct, especially considering that the high quality of the product is chiefly a function of the method, rather than the skill of operation.

The limits of this article do not permit of extended description, but the illustration on page 180 will give some idea of such a tank and of the method of harvesting. The cutting out of a cake by means of steam, or the subsequent cutting of the large cake into smaller ones with steam cutters, in addition to saving ice by making no chips, leaves the surface in a most attractive polished form, which has characterized this product as "Diamond" ice, by which it is known wherever such plants are used.

Ice plants of this character may be seen at several prominent hotels, operating as attachments to general refrigeration. In each of these hotels about twenty boxes are refrigerated, each serving some special purpose,—one for oysters, another for butter, others for game,—while eggs, wines, beer and other things, each are given a suitable space, and the temperature in each box is carried at just the point at which its contents are best preserved. Meat is held at a comparatively high temperature, say 38 degrees, while game may be frozen solid. Eggs are almost frozen, and butter, which is carried as low as 20 degrees in permanent storage, runs up to 35 degrees in service boxes. The cook's box, in which the door opens and shuts so frequently that refrigeration seems almost impossible, is simply well chilled, which is quite sufficient, as nothing remains in it long, while the champagnes are almost frappéed at 28 degrees.

The requirements of the market plant, hotel, restaurant and club house; all industrial works requiring the cooling of their products or by-products, including paraffine, tallow, india rubber, photographic films, soap, nitro-glycerine, asphalt, sulphuric acid and condensed milk; the handling of chocolates, gelatine and other pasty materials; the refrigeration of morgues; the blowing of cold air for ventilation, to say nothing of cooling water for drinking purposes in numerous places, from the public library to the department store, are met by small refrigerating plants. Such apparatus is successful to a degree, comparing favourably with the best machinery in any line of service, and it has been the purpose of this article to indicate that such work is an accomplished fact, and, to some degree, point out the requirements of the class of machinery adapted to it.

The reader may have hoped, under the title of "Small Refrigerating Plants," to find a description of something suitable for domestic purposes. This has not yet arrived. It is about the only thing left to be desired in refrigeration. Nothing, however, has yet been produced which combines the necessary elements of quality, cost, ease of operation and reliability for domestic purposes in the hands of ordinary servants. But it should be recognised that in large houses, where considerable refrigerating service is to be performed, and where men of fair intelligence are employed, the smaller refrigerating plants, such as are here described, are entirely applicable.

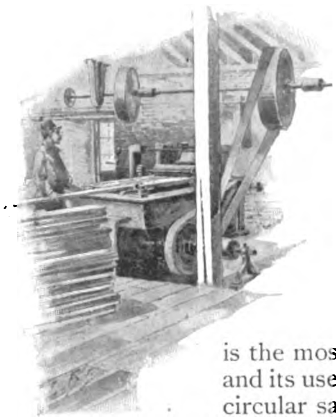
While we speak of artificial refrigeration, it should be remembered that there is nothing essentially artificial about it. The process of refrigeration is merely a loss of heat. Water loses heat to the air, and freezes in winter; cream loses heat to the ice, and freezes in an ice cream freezer; water loses heat to an ammonia coil, and freezes into ice in a tank; meat and vegetables lose heat to cold brine pipes and are preserved. In all cases the process is the same, and one is as natural as the other.

The only part that might truly be called artificial is the method of getting rid of the heat after the process of refrigeration has concentrated it in the circulating medium. No difference therefore exists between refrigeration and the cold of winter, except that the former is constant and under control, while the latter is widely and erratically variable, for which reason the resources of nature have not been able, even in cool latitudes, to compete with the art of man in the useful application of low temperatures to the preservation of perishable material.

THE MODERN SAW MILL.

By W. H. Trout.

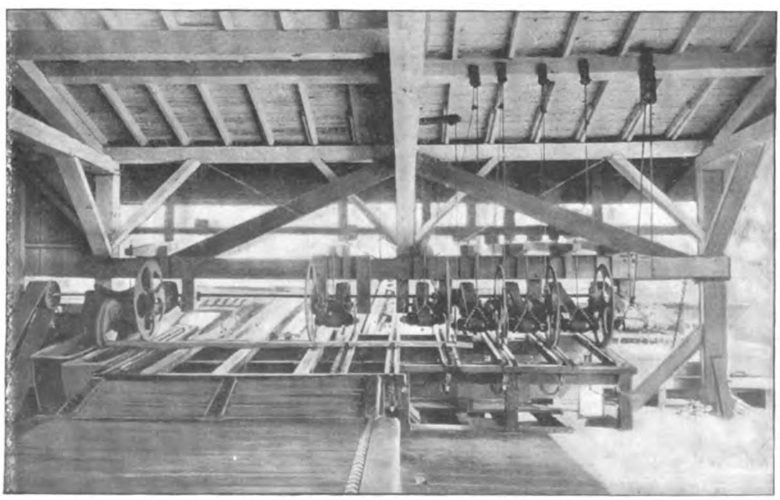
(*Concluded from page 95.*)



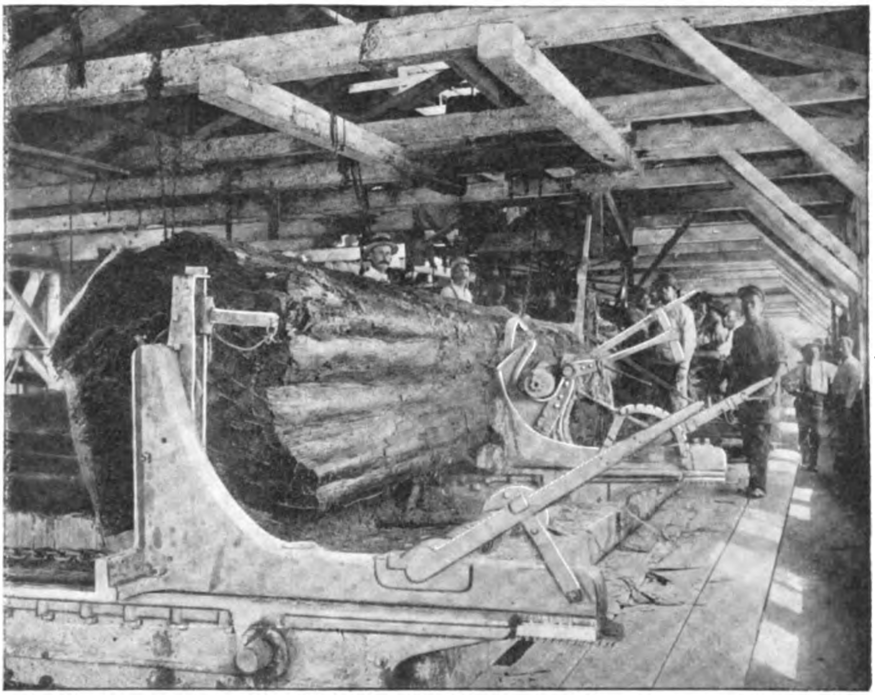
WE have now, in a very general way, completed the latest usual process of converting saw logs into lumber or timber. We have given the band mill the leading place. It is the most modern machine and its use is extending. The circular saw is still useful in small rough logs. It is a cheap, simple machine, requires less skill to run and can do more rough work in a given time than the band saw; but its voracity for sawdust scores it out of the list where economic work must be done.

So far no reference has been made to the gang, which is simply a series of saws set in a vertical frame. This has a reciprocating motion, enabling it to cut a log, or a number of logs, into boards at one time. A summary of the historic processes for lumber making begins with the whip saw, worked by two men; then the English gate and the slabbing and stock gangs, closely followed by the muley mill. Then came the circular saw, and now we have the band mill.

The circular and gang saws still retain a place. As already pointed out, the circular saw is wasteful. Not so, however, with the gang saw. As now made by many firms, it is a good, economic machine, the thickness of gang lumber being more uniform than that of any other sawing, and there is little more waste in sawdust than with the band mill. This refers to the stock gang.



AN AUTOMATIC GANG TRIMMER, MADE BY THE FILER & STOWELL CO., MILWAUKEE, WIS.

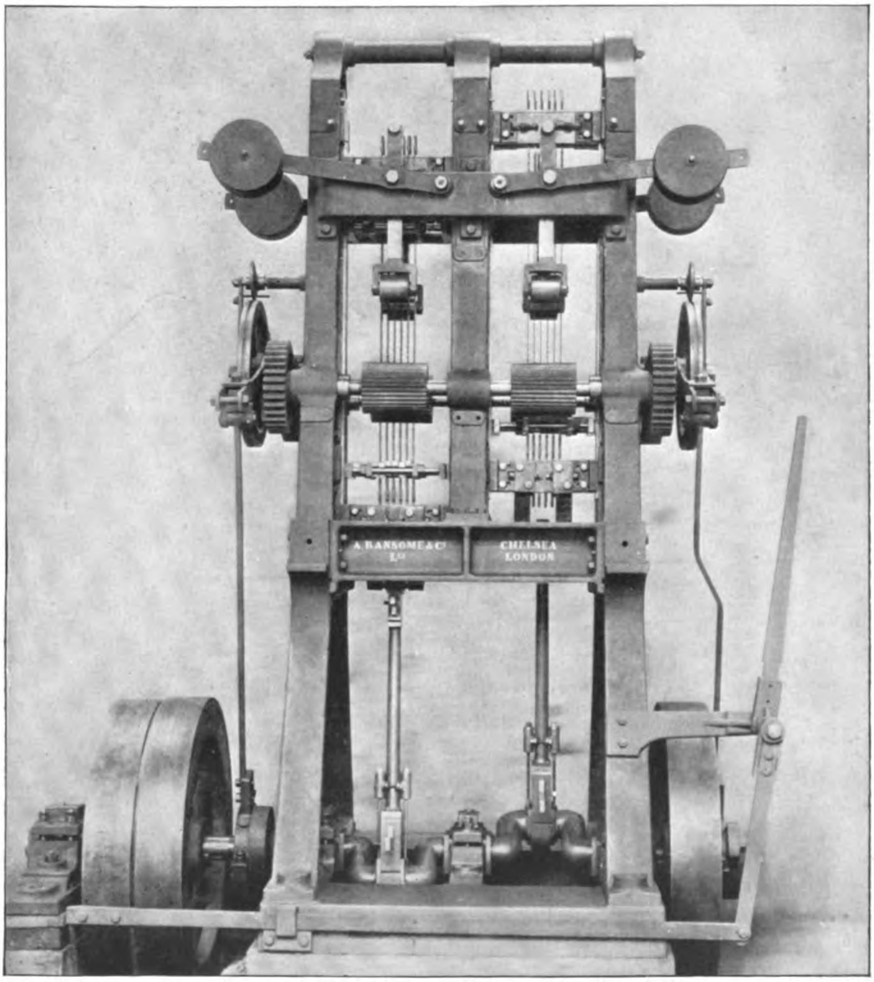


A LOG ON A MILL CARRIAGE.

The slabbing gang is very little in use. The circular saw was an able competitor for its work, and the band saw has crowded it almost entirely out. The gang has this drawback that it does not give the sawyer the opportunity for the exercise of his judgment in getting the best lumber out of the log. The gang must cut the lumber for which it is set. With the band saw, when the sawyer is putting on the log, he sees what part of the log contains the good lumber and places it on the carriage so as to bring this out, and when sawing he sees the face of every board. If he sees clear lumber, he takes off the thickness that commands the highest clear price. In that way he makes the most money out of the log. He can exercise his choice with each particular board. With the gang such choice is impossible.

Saw-mills have their waste products, like all other manufactories. A careful and economical use of these is often the means of placing the manufacturer on the profit side of his account. But direct money profit is not the only consideration; the neatness, comfort and orderly convenience of everything is enhanced by it. The cost of insurance, too, is lowered. In the olden time you could tell every road that led to a saw-mill; sawdust and slabs were everywhere, like finger boards, pointing to the place. Slabtown was a common nickname for the conglomeration of wooden buildings and miil refuse that occupied the valley. Many, though not all, of the modern mills are a direct contrast to this. I have seen beautiful sod growing all around the mill, except where there were roadways. Mill refuse was not to be seen and the lumber yard would be one-eighth of a mile away.

In the city of Ottawa, Canada, I have seen saw-mills which could be entered from the sidewalk like stores on a business street. Neither saw logs nor lumber in quantity were anywhere to be seen. The former came up through the mill floor to be placed on the carriages;



A GANG MILL, BUILT BY MESSRS. A. RANSOME & CO., LTD., LONDON.

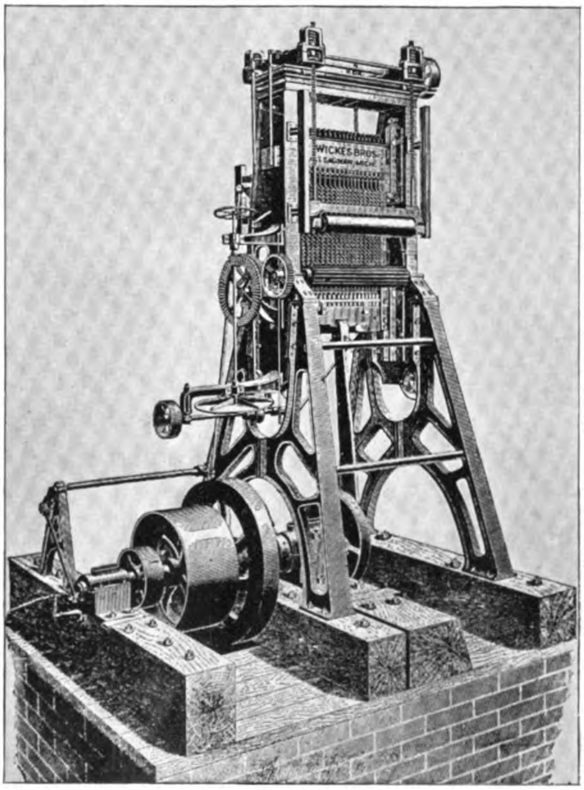
the latter took its exit by the reverse process. Logs came and lumber went by water, out of sight. Refuse took the same course. If the mills were clean, however, the river was fouled. This latter offense, being opposed to legislation and becoming unbearable, the mills had to change their process, which necessitated their complete removal.

Sawdust stands first among the wastes. With a circular saw about one-fifth of the log goes into sawdust; with a band saw it is about one-eighth. This, particularly the circular sawdust, makes good fuel under the boilers. It has the advantage that it can be mechanically supplied to the fires with the result of a fine, uniform combustion, and it is generally more than sufficient for the power demands of the mill. There is often a large percentage to sell for various uses, such as stable requirements, ice houses and packing. The most useful waste is found in the slabs, and in broken and split lumber, the edgings from the edger and the trimmer waste.

The machinery that collects, utilises and finally disposes of this forms a very considerable part of the mill construction. The live rolls carry everything from the saw. Slabs, however, are arrested by a stop opposite the back end of the edger table, and are moved sideways off the rolls and slide down an incline to the floor. There are a number of devices for this purpose, transfer chains, or screw rolls, being the most common; the latter, when well made and mounted, are quite effective and are automatic.

Those slabs land on the floor of the mill, or rather on a smooth hardwood floor, laid on the mill floor, and are drawn sideways by chains under the qack tables of the edgers, and under one line of live rolls to near the outside of mill, where is placed the slasher, of which this floor and chains form a part. The slabs now pass under a line of circular saws, placed 4 feet 1 inch apart, which cut up the slab in lengths suitable for lath or fence pickets, or to be resawn in 16-inch lengths for shingles or firewood.

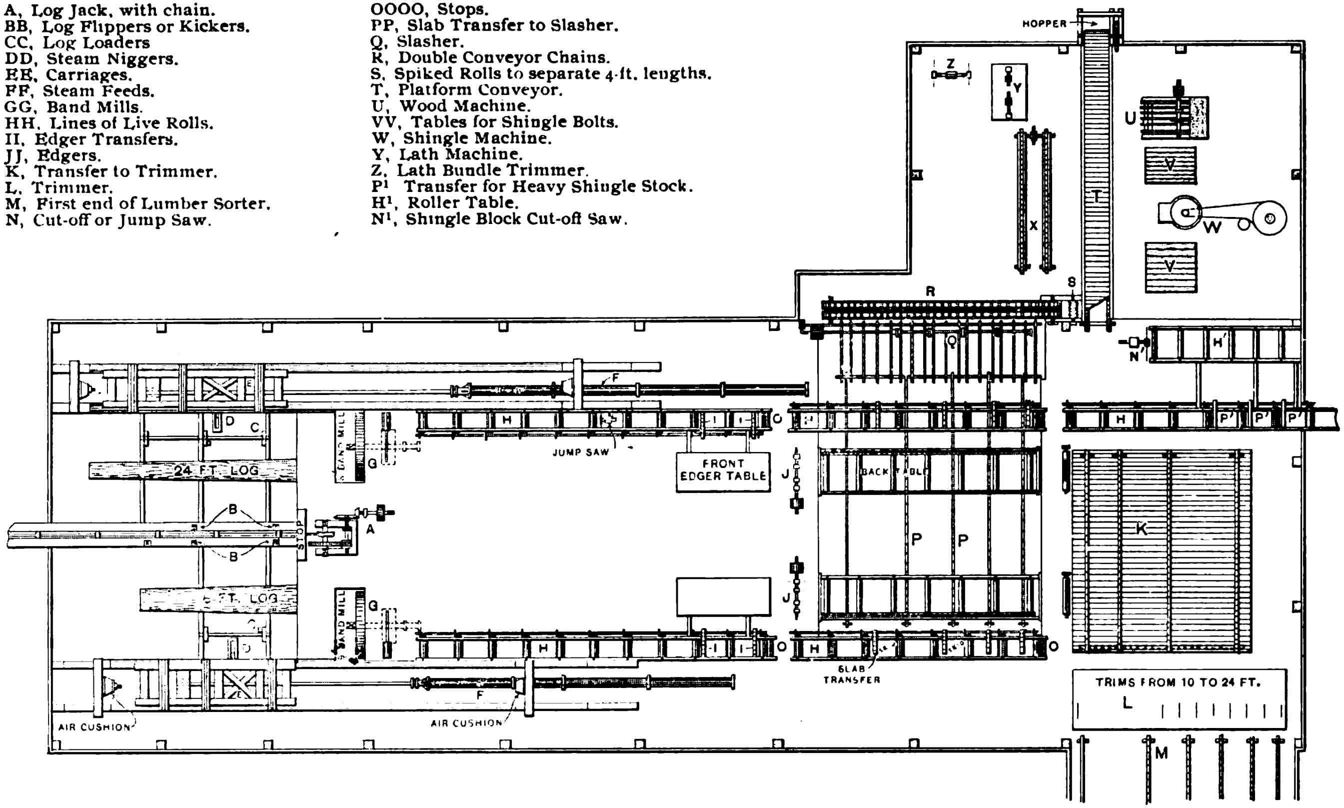
After being thus sawn upon the slasher, the 4-foot lengths are dumped in a trough at the bottom of which runs a wide chain which carries the material toward the burner. At the dump of this chain only the short useless refuse is dumped. Close to the dump are placed a pair of swift-running spike rolls, which catch the 4-foot lengths and shoot them forward against a stop, when they fall on a travelling platform which carries them onward. A boy picks off the pieces suitable for lath, leaving them on a pair of chains, which carry them to the lath machine.



A GANG MILL, BUILT BY MESSRS. WICKES BROS., EAST SAGINAW, MICH., U. S. A.

The laths are counted as sawn, and

A, Log Jack, with chain.
BB, Log Flippers or Kickers.
CC, Log Loaders
DD, Steam Niggers.
EE, Carriages.
FF, Steam Feeds.
GG, Band Mills.
HH, Lines of Live Rolls.
II, Edger Transfers.
JJ, Edgers.
K, Transfer to Trimmer.
L, Trimmer.
M, First end of Lumber Sorter.
N, Cut-off or Jump Saw.
OOOO, Stops.
PP, Slab Transfer to Slasher.
Q, Slasher.
R, Double Conveyor Chains.
S, Spiked Rolls to separate 4-ft. lengths.
T, Platform Conveyor.
U, Wood Machine.
VV, Tables for Shingle Bolts.
W, Shingle Machine.
Y, Lath Machine.
Z, Lath Bundle Trimmer.
P[1] Transfer for Heavy Shingle Stock.
H[1], Roller Table.
N[1], Shingle Block Cut-off Saw.

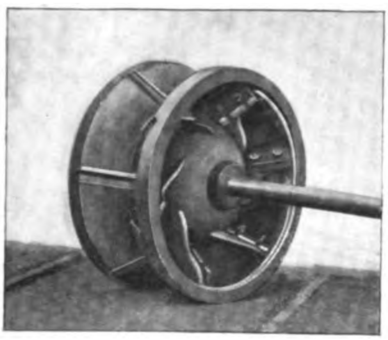


FLOOR PLAN OF A MODERN SAW MILL.

bound in bundles of 100, and are then trimmed to exactly 4 feet in length and sent down a chute to the place for storing. The sawdust and fine refuse from the laths goes to the boiler furnaces, and the coarse to the burner. One or two more boys pick off the pieces suitable for stove wood or shingles. The wood goes into a pocket below, from which it is slid into a cart and taken away.

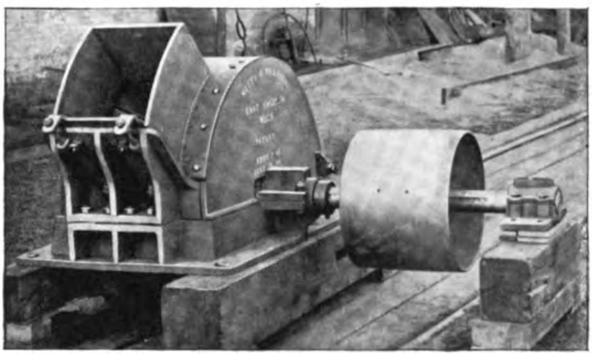
The shingle bolts are laid on a table, convenient to the shingle machine. When the shingles are sawn, they slide down into lower story to be jointed and packed, all the refuse going to the burner. Shingle stock is also furnished from crooked, broken logs, or pieces that are otherwise unfit for making lumber. These are sawn through the middle or slabbed on the band mill, come down the live rolls, and are transferred to the shingle cutoff saw, from which the bolts pass on to the shingle machine.

This concludes the description, in somewhat general terms, of the work floor of a medium sized mill in the northern part of the United States. This style of mill gives as good return for the investment, if not better, than any other.



THE CUTTER WHEEL OF A SLAB GRINDER.

We should not pass over another machine for dealing with refuse situated in the lower story. It is another one of the mill animals, called the "hog" or slab grinder. There are a number of different kinds of mill dogs; all, like good bull dogs, bite hard and hold on But the hog is a literal chewer; he masticates, and his appetite is immense. All kinds of mill refuse go into his mouth and he grinds it up into small chips. The necessity for his existence arises from certain peculiar conditions.

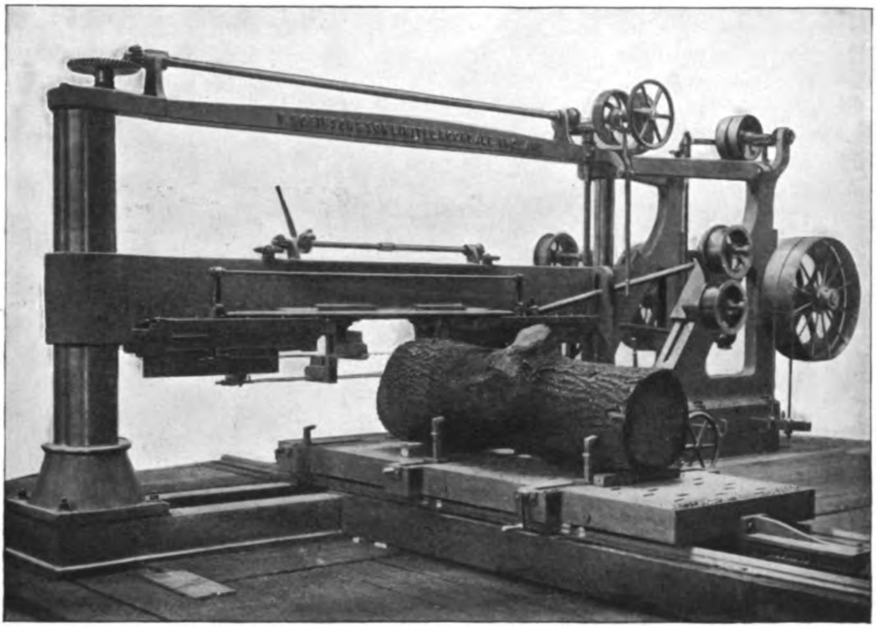


A SLAB GRINDER, OR "HOG," MADE BY MESSRS. MITTS & MERRILL, EAST SAGINAW, MICH.

Band mills furnish but a small amount of sawdust, which is so fine that it is liable to be carried away by the draught in the furnace before complete combustion takes place. It often becomes necessary to supplement it. Steam may be required for other purposes, such as kiln drying, or there may be extra machinery. The hog is, therefore, placed in position and soon grinds up the necessary material for perfect fuel. Whatever is made above the needs of the furnace goes to fill up low land about the mill, or to level up the piling ground.

The problem for the millwright, or mill designer, is to draft or lay out a mill that, while accomplishing its work of sawing the required amount of lumber per day, shall have due regard to the proper relation of first cost, economical working and yearly maintenance for the given time or period in which it is expected to exhaust its available supply of timber.

The main operations of bringing in



DOUBLE HORIZONTAL SAW FRAME, MADE BY MESSRS. THOMAS ROBINSON & SON, LTD., ROCHDALE, ENGLAND.

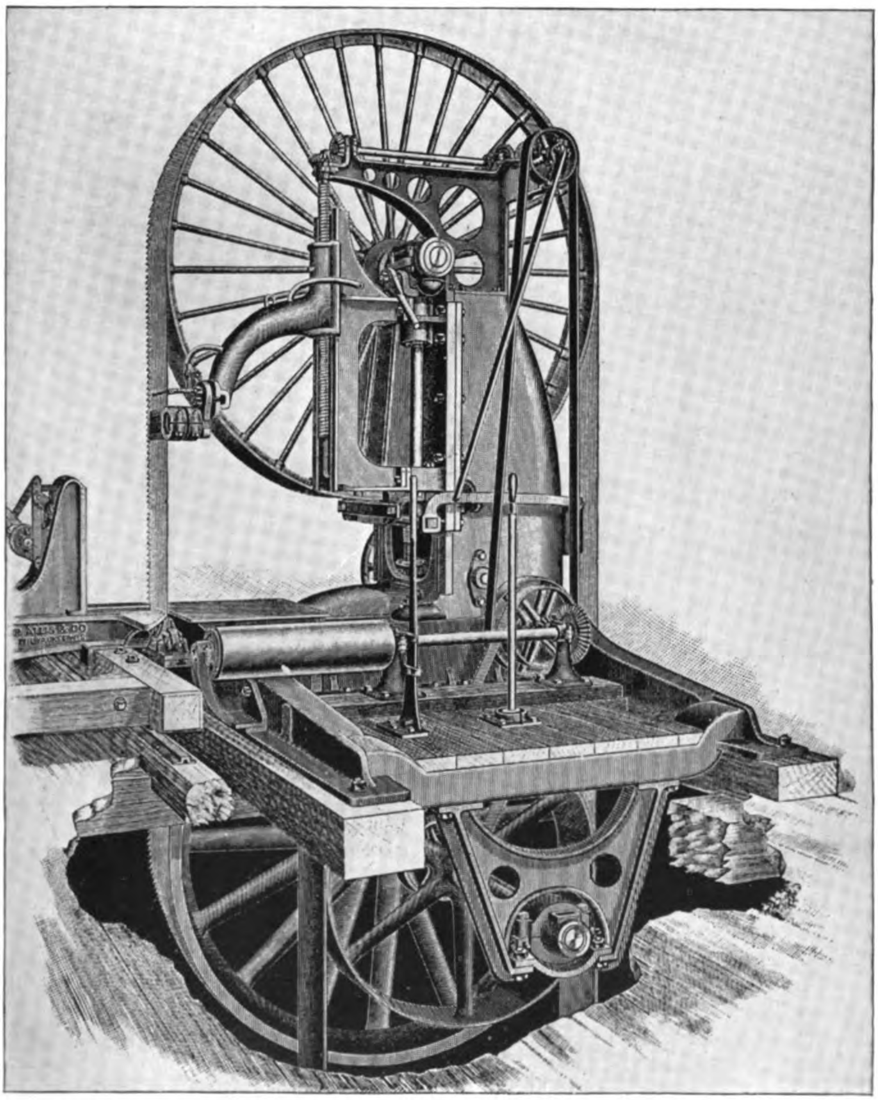
and handling logs, and the processes of converting them into finished lumber are not the test work of the designer. His skill is brought into play when, along with this, he combines the arrangement and economical supply of power, and the neat and clean disposal of the refuse, having in view the convenience and accessibility of all parts of the machinery, along with some regard to architectural design in the style and construction of the building. It is the economical and convenient plan of the whole outlay that brings the designer commendation.

The successful working of a modern mill depends, first of all, upon the superintendent. His ability must be both general and special,—managing men, planning processes of work, and advising in regard to details of repair or change. He is an all-around man. But there are other men who share with the superintendent the responsibilty of insuring success.

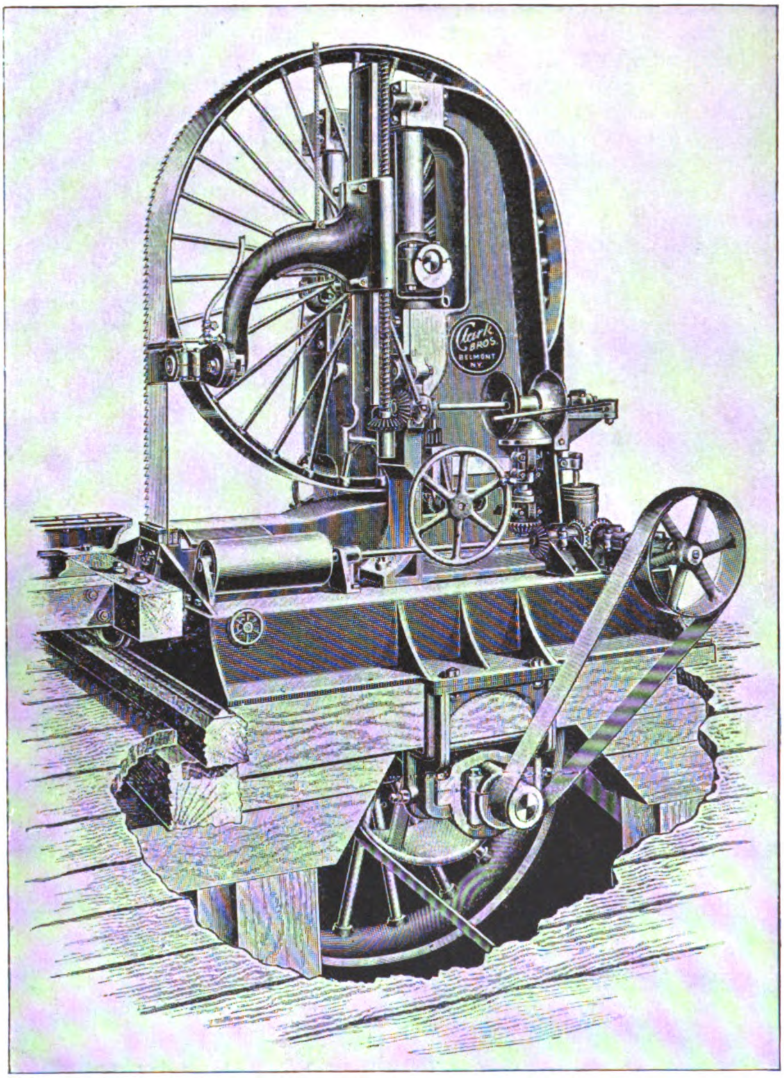
The sawyer is the one who sets the pace of the work throughout every department of the mill, and the effect extends even to the lumber yard. Those in front of the mill must supply him with logs; those behind the band mill must put their work past them or be buried with lumber. Like the lazy convict, he must pump or drown. The sawyer furnishes the brains and nervous impulses for the band mill, the carriage, the steam log roller, steam feed and steam nigger. The levers he uses are but the extensions of his own nervous and muscular system. For eleven hours every day he works unremittingly with mind and muscle with the exactitude of the finest machine, which, in reality, his saw-mill faculties finally become.

Observation and judgment are instantaneous. You may go and talk to him; he will readily maintain a conversation on any familiar subject, while seemingly unconsciously, at its wonted rate, his work goes on. The sawyer is as much an evolution in the human element as is the mill itself in the material element.

But a good sawyer is of little service without a good saw. The best he can do, is to make any given saw cut to the limit of its capability. This limit depends upon the skill and cleverness of the saw filer, who, on this account, takes equal, if not superior, rank to the sawyer. He is not, however, under the continuous strain of the sawyer, who must think so quickly and act so promptly. The filer has more time, observes longer and observes carefully, and generally, at least, concludes correctly. He files, swages, rolls, hammers, gums, joints, or welds, as the case may require. He keeps himself and his saws prepared for all contingencies. He studies character,—the character of saws, knows their temper, and disposition too; and corrects the latter by disciplinary punishment (hammering). His pay is according to his ability to make a saw cut fast and cut straight.



A BAND MILL, BUILT BY THE E. P. ALLIS CO., MILWAUKEE, WIS., U. S. A.



A BAND MILL, MADE BY MESSRS. CLARK BROS., BELMONT, N. Y., U. S. A.

The greatly accelerated speed of modern sawing must be largely attributed to this class of men.

About twenty years ago, the first attempt in the United States to turn out lumber with the band saw, was made in New York,—with what measure of success I am uncertain, but I saw what the same firm attempted at the Centennial Exhibition at Philadelphia, in 1876. That band saw was a success in making serpentine lumber. It was excellent on a beautiful wave line, but scorned the inartistic mechanically straight lines.

The defect was not so much in the machine as in the saw which, I think, was made in France. The French, in fact, have led the way in the manufacture of band saws. However, this one, which was the first of its kind that I ever saw, impressed me as being somewhat crude. It was the expression of an idea,—an idea that gave promise of usefulness, but one that was not then mechanically evolved. The true theory in regard to the nature and treatment of circular saws which were then in well established use, was only beginning to be understood, and ten years elapsed before it was understood in reference to band saws.

The circular saw was treated as a disc of tempered steel, was ground flat on one side and slightly convex on the other. Such a saw did fair work at a low or moderate speed, but an increase of speed resulted in crooked lumber. But some wise filer conceived the idea of treating the circular, not as a flat disc, but as a ring of steel, connected to its centre by an easy filling of the same material, forming, of course, one disc.

It was not absolutely flat when at rest, but, if set up in position, as in the mill, it would be found to be slightly convex on one side and concave on the other, and this convexity and concavity could, by a little pressure, be easily made to change sides, acting the same as when pressure is exerted on the bottom of an old tin pan,—it pops in or out, as required.

A circular saw in this condition, which is obtained by hammering the central part, when placed on its arbor, and set in rapid motion, straightens itself. The centrifugal force of the whole blade is concentrated in the rim, which slightly yields, allowing the saw to run in a beautifully true plane which it has both the disposition and the ability to constantly preserve. In this condition, when suitably dressed for its work, the circular saw is a perfected piece of machinery.

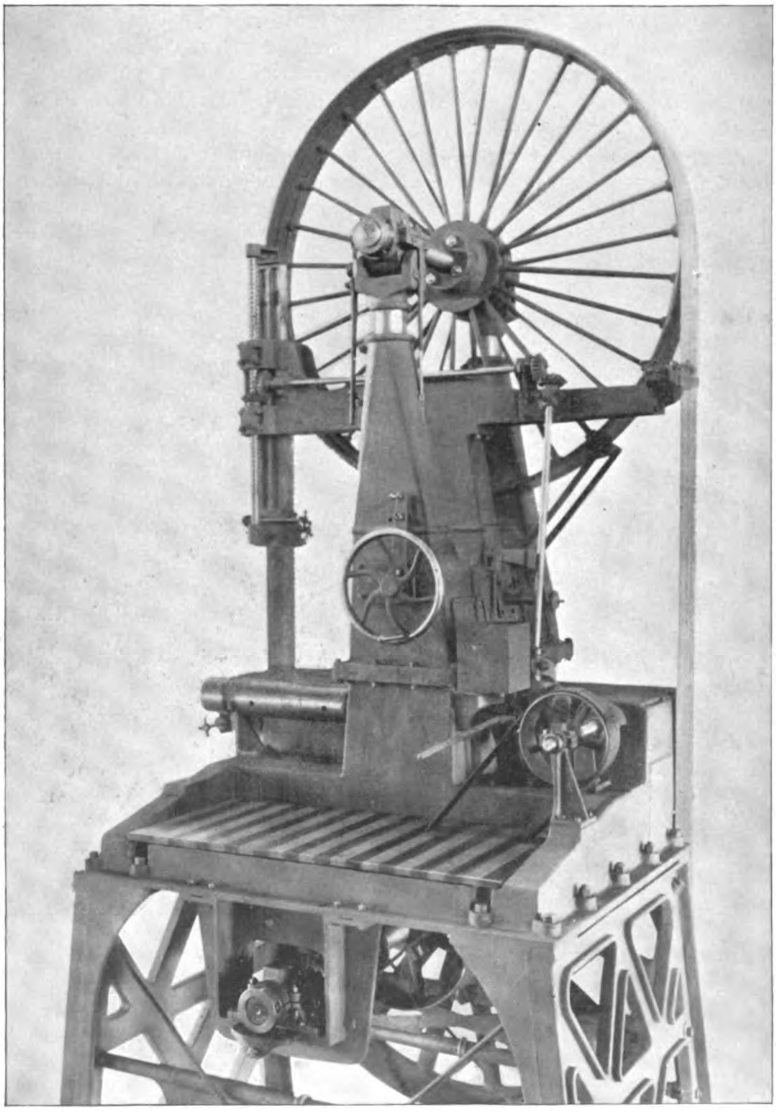
After the first introduction of band mills, many years passed before this constructive principle was applied to them. As soon as this took place, the band saw began to take rank, in speed of lumber making, with its powerful rival, which hitherto held the field. The merit of its great producing power would not make up for its wasteful habits, so it quickly took second place. Now we so seldom build circular sawmills that we are forgetting all about them. The gang holds its place much better, although it, too, is falling out of use.

Tension in the cutting edge of the blade is the principle referred to, which all saws must possess in order to do their best work. In the circular saws this is obtained by hammering the central part of saw. In the band saw it is by rolling the middle portion of the blade,—that is, the saw is passed through a machine between two small steel rollers under heavy pressure which expands the middle portion of the saw throughout its entire length. Applying a straight edge to the side of a saw, either longitudinally or transversely, will show convex and concave places alternating all along the blade. But when placed on the wheels of the mill, under a four-ton strain, all these kinks disappear. It then becomes one straight ribbon of steel, with its edges so tight that there is no chance for deviation in sawing. It cuts straight.

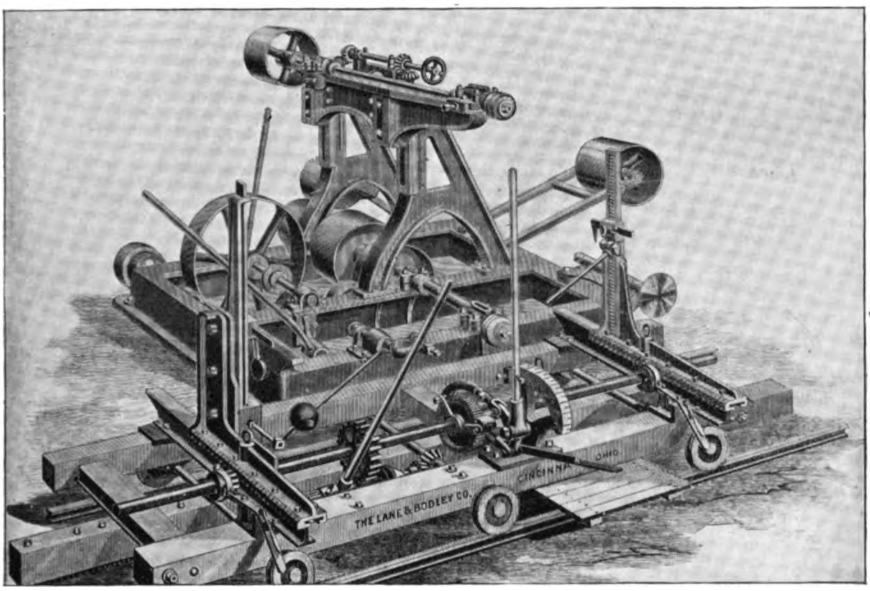
FILING ROOM IN A SAW MILL.

Proper tension of the saw is not, however, by any means all. The amount of swage or the width of teeth, and the angle which the cutting edge presents to the log, are very important and vary with the material to be sawn. When all is just right, or generally so, as the character of logs vary, the saw eats its way into the log with a decided relish, showing an anxiety for more. No amount of feed seems to surfeit it.

We have mentioned the three most important personalities about the mill. There are still others who have important places, such as the caretaking millwright, whose duty is not merely to fix what may be out of order, but to see



A BAND MILL, BUILT BY THE STEARNS MFG. CO., ERIE, PA., U. S. A.



A CIRCULAR SAW-MILL, BUILT BY THE LANE & BODLEY CO., CINCINNATI, O., U. S. A.

that nothing is likely to go wrong. If he knows well how to apply the stitch in time that saves nine, and keeps the mill constantly at work, he may lounge around in the easy cool places and go to sleep; but like the faithful dog who hears the first footfall of a stranger, the first unusual noise that breaks the incessant dim which to him is all harmony, is instantly heard and he is ready and anxious to locate it.

There are others of all grades whose rank and pay is determined by the demand made on brains, rather than muscle,—the same as in every other sphere of the world's labour.

BOILER FEED PUMP EFFICIENCY.

By A. F. Nagle.

THE published circular of a manufacturer of direct-acting steam pumps states that the exhaust steam of said pump is utilised by turning it into the suction of the pump, and that the feed water is raised from 40 to 50 degrees in temperature in this way. This is a very excellent thing to do, wherever practicable, as the only waste heat in that case is that due to radiation, and the cost of pumping the water is only that of doing the necessary work. Should the pump, either the steam or water end, have unnecessary friction, the steam required to do this unnecessary work is all returned to the feed water, barring the small amount of heat transmuted into work. So, also, with any slip of the pump piston or valves, causing needless work by the steam piston, all this heat is thrown back into the suction; hence the rise of temperature of the water delivered is an accurate index of the working of the pump.

At this point let us ascertain what the

rise of temperature of this water should be, if all the conditions were perfect. In that case, the steam displacement is precisely the same as the water displacement. That is, for every cubic foot of water displacement under any boiler pressure there is a corresponding cubic foot of steam consumption under like pressure. This statement of the case makes the calculation for the theoretical rise of temperature of the water very simple.

The accompanying table gives the results of the proper calculation for different boiler pressures.

Boiler Pressure in Lbs. per Sq. In.	Cubic Ft. per Lb. of Steam.	B. T. U. in 1 Cubic Ft. of Steam (Above 62°).	B. T. U. Imparted to 1 Cu. Ft. of Water. Degrees.	Lbs. of Water per I. H. P. per Hour.	Per Cent. of Power Required to Pump Feed Water.
1	2	3	4	5	6
25	10.37	109	2	48.0	.14%
50	6.58	174	3	41.8	.24
75	4.86	237	4	37.8	.33
100	3.86	300	5	35.6	.41
125	3.21	362	6	34.3	.50
150	2.75	424	7	33 4	.58
175	2.41	486	8	32.7	.66
200	2.14	548	9	32.1	.75

Column 1 gives the boiler pressure for which the calculations have been made.

Column 2 gives the number of cubic feet of steam per pound weight of the assumed boiler pressure, taken from Peabody's Tables.

Column 3 gives the heat units (B. T. U.) of a cubic foot of steam. The temperature of water from which the steam is generated is taken at 62 degrees. Deducting this temperature from the total heat of steam above zero and dividing the result by the number of cubic feet in one pound of steam, gives the heat units of one cubic foot.

Column 4 gives the rise of temperature of the water pumped. This is obtained by dividing the heat units in a cubic foot of steam by the weight of a cubic foot of water, or dividing column 3 by 62. In order to free these figures from fractions the nearest whole number only is given.

Columns 5 and 6 are given for further desirable information. Column 5 gives the number of pounds of water per indicated horse-power per hour upon purely theoretical grounds,—that is, no clearance, no condensation, no leakage, no frictions.

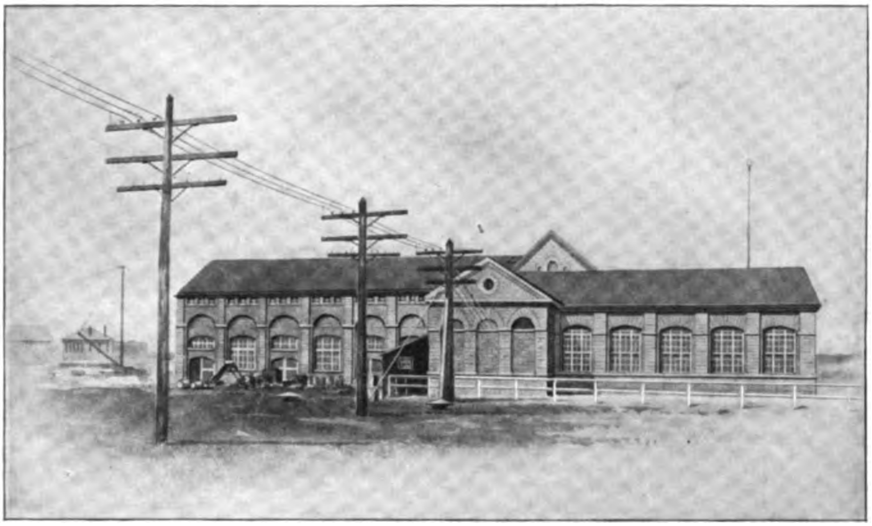
Column 6 gives the power required to force the water given in column 5 into the boiler against the pressure given in column 1, in terms of per cent. of the total power,—that is, per horse-power. For example, with a boiler pressure of 150 pounds and a steam pump using 33.4 pounds of water per I. H. P. per hour, only .58 of 1 per cent. of power is required to force the feed water into the boiler,—under ideal conditions.

It is well enough to point out the theoretical results as given in this table, but what should be realised in good practice? Steam pump manufacturers claim to run on as low as 75 pounds of water per I. H. P. per hour, but it is not uncommon to find it double that amount. Somewhere between two and three times the theoretical heat units, as given in the above table, ought to be a very fair and reasonable expectation.

That is, a boiler feed pump exhaust, working under, say, 100 pounds boiler pressure, while theoretically heating the water it pumps only 5 degrees, should not, in good practice, heat it above 12 or 15 degrees. It may, therefore, be concluded that a pump which heats its water 40 or 50 degrees is not in proper repair.

This manner of ascertaining the efficiency of a feed pump enables us to make an interesting comparison with the injector. I take my data relating to injectors from a work on this subject by Mr. Strickland L. Kneass. The better form of injectors heat the feed water about 90 degrees above the initial temperature. The author also finds that with 125 pounds boiler pressure, the theoretical work of forcing the feed water into the boiler is equivalent to heating the water about 6 degrees,—the same as given in the above table. This would show that, considered purely as a pump, the injector uses fifteen times as much steam as is required for its work, or it has an efficiency of only about 6 per cent.

A steam pump using 75 pounds of steam per I. H. P. per hour for like work would have an efficiency of 34.3—75 = 46 per cent. If we should take the extreme of 150 pounds of steam per I. H. P. per hour the efficiency would be reduced to 23 per cent., which is still nearly four times better than an injector. Or we may put it this way:—If an injector, under certain conditions, heats its water 90 degrees, it corresponds to about 514 pounds of water (34.3 × 15) per I H. P. per hour.



THE NIAGARA-BUFFALO ELECTRIC TRANSMISSION LINE LEAVING THE TRANSFORMER HOUSE AT NIAGARA FALLS.

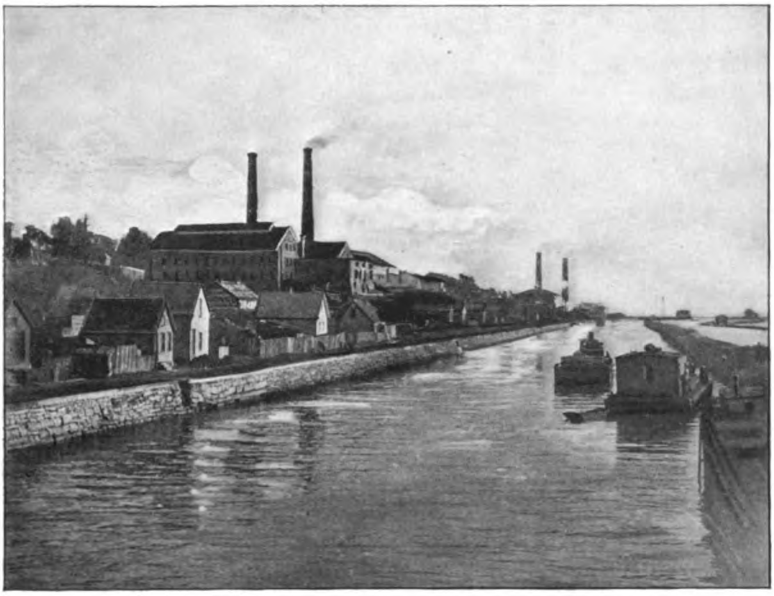
POWER TRANSMISSION FROM NIAGARA FALLS.

By Orrin E. Dunlap.

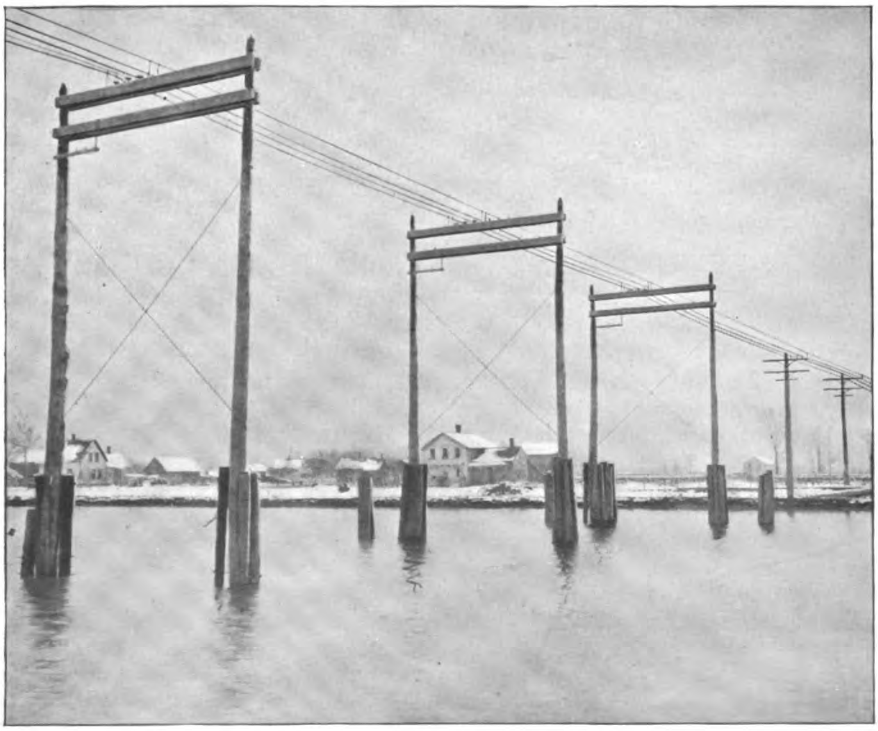
AT midnight on November 14, connection was made at the main power house of the Niagara Falls Power Company at Niagara Falls, between the famous Niagara generators and the transformers in the near-by transformer house, which, in turn, were connected with the city of Buffalo power transmission line, and at the same instant the electric power of Niagara was, for the first time, sent out beyond the confines of its birth-place and on direct to Buffalo, a distance of twenty odd miles. The power is used on the lines of the Buffalo Street Railway Company.

The three-phase system of transmission is used, and as the line is not quite direct and as there are three cables, their combined length is about seventy-eight miles.

It is recognised that this power line is destined to eclipse all others, owing to the market available for the power, and because the amount of power developed, and to be developed, will be an incentive to add to its capacity. The Niagara Falls Power Company are fortunate in more ways than one. Their plant has a practically unlimited water supply by which many thousands of



THE BUFFALO STREET RAILWAY COMPANY'S PLANT. THE DESTINATION OF THE FIRST NIAGARA POWER SENT TO BUFFALO.



CROSSING A CREEK ALONG THE LINE.

horse-power can be developed, and in addition to this their power house is situated in a section of country where there is a great demand for power. The possibility of such wonderful power development is one factor of importance, while the extended demand for their product is another which gives encouragement to the capital invested to accomplish things far beyond what man has ever before attempted.

In the construction of the Niagara-Buffalo line the power company have been governed by their rule to build the best possible work, and for this reason the line is a good example of strength and careful engineering. In no part has any known weakness been allowed to creep in, but in all the contracts the demand has been for perfect material and perfect construction.

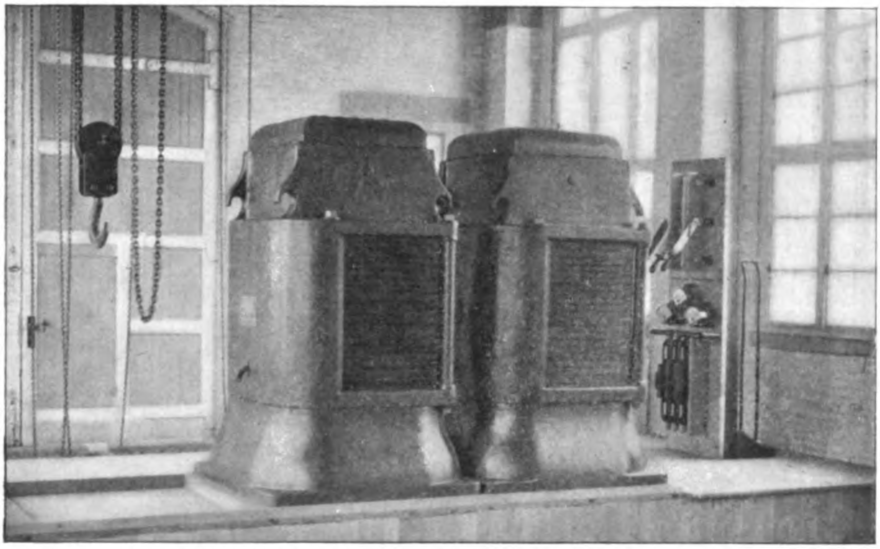
The electrical equipment necessary for the transmission of power to Buffalo was furnished by the General Electric Company, of New York, and comprises, among other things, three air blast transformers with blower motor, switchboards, etc. Any two of these transformers can be used to transform 2500 horsepower in quarter-phase currents at 2200 volts, to three-phase currents at either 11,000 or 22,000 volts. The third transformer will be held in reserve, all being interchangeable. The primary and secondary connections of these transformers are each led to a switch board. The low-tension board is fitted with switches and fuses; the high-tension board is fitted with switches, fuses and indicators. Lightning arresters are also provided where the conductors leave the transformer house.

The transformers are supported on an iron frame work, their bases being eight feet below the floor of the transformer house, and the space below them being practically an air tight enclosure. It is through this enclosure that all connections to the transformers are made, there being ample room for walking about. The connections to the transformers themselves are made so that they can be easily detached, and in case it is found necessary or desirable to substitute the extra transformer for one of those in use, the existing connections can quickly be broken and the transformer removed with the crane in the building, and the extra transformer set in its place.

TURNING A CORNER.

A large blower, which stands in one corner of the room, and is driven by a five horse-power electric motor, delivers air to the enclosure below the transformers and this air passes upward through the spaces between the coils. The amount of air delivered is controlled by valves.

The arrangement of coils is such that exceedingly strong insulation will have



THE STEP-UP TRANSFORMERS AT NIAGARA FALLS.

to be punctured before connection can be made between different coils. At the same time, the air spaces are so placed that the air is brought in close contact with each coil and gives an excellent cooling effect. Naturally, this method of cooling tends to increase the size of the transformers, but it has the advantage of making them clean and accessible, and more convenient to handle.

The Cataract Power and Conduit Company, of Buffalo, was incorporated in July, 1896, for the purpose of becoming the distributing agents of Niagara power in the city of Buffalo. It has George Urban, Jr., as president; Charles R. Huntley as vice-president and general manager; William B. Rankine as secretary and treasurer, while E. D. Adams, Francis Lynde Stetson, D. Ogden Mills, John Jacob Astor, E. A. Wickes and Daniel O'Day are on the board of directors.

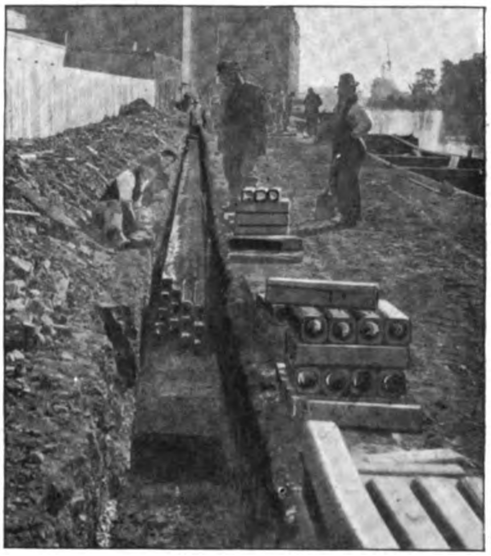
Under the contract made with this company by the General Electric Company, of New York, four 360 horse-power transformers were furnished for reducing the current as it comes from the transmission line to a voltage suitable for connection to 500-volt rotary converters. A special building was erected in connection with the Buffalo Street Railway Company's plant for these transformers at the Buffalo end of the line. The method of cooling and the general construction is very similar to that used in the large transformers at Niagara Falls. This building is also provided with lightning arresters and a switchboard.

It was with the Buffalo Street Railway Company that the General Electric Company made still another contract, and to them they furnished two 500 horse-power rotary converters with switchboards and accompanying instruments. These converters will supply current to the lines of the Buffalo Street Railway Company in parallel with the generators now in their power house. The machines have six poles and operate at a speed of 500 revolutions per minute. They are so installed as to make it possible to start them either from the alternating current, or by direct current from the lines to which they are connected.

It is probable that no pole line was ever better constructed than that from Niagara Falls to Buffalo. Work was commenced on August 14, 1896, and on November 14 the line was turned over to the Cataract Construction Company, practically finished. In this period the poles had been obtained, set, painted, and the insulators placed and cables strung. In height the poles vary from thirty-five to sixty-five feet. They are all of white cedar and are shaved. They are set from sixty to seventy-five feet apart, the distance being varied in order to overcome any possible vibration of the spans during the high winds which frequently prevail in that locality. All the poles are painted with two coats of pure white lead and boiled linseed oil.

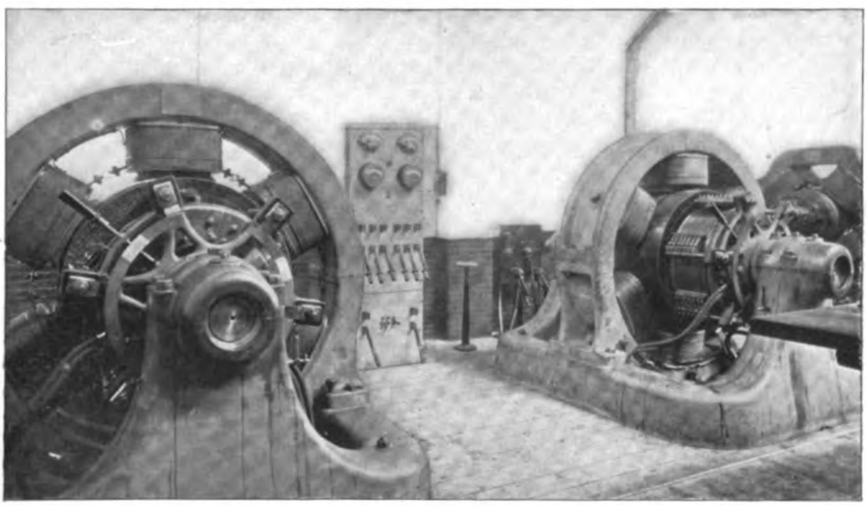
In turning sharp angles, as at corners, six poles are used instead of three, and these are braced by poles extending from the bottom of the opposite poles, as will be seen by the illustration on page 199. Where the double-pole construction is employed, double cross arms are also used. These double cross arms are 24 feet long and measure 6x12 inches.

All single poles have three cross arms, the two upper arms being used for power cables, and the lower arm to carry a telephone wire. The upper cross arms are of the same size, 12 feet long by 4¾x5¾ inches, and are of yellow pine. They are supported by solid braces of 2x2-inch angle iron. The lower cross arms are 6 feet long by 3¼x4¼ inches, and are supported by 1½x¼-inch angle iron braces.

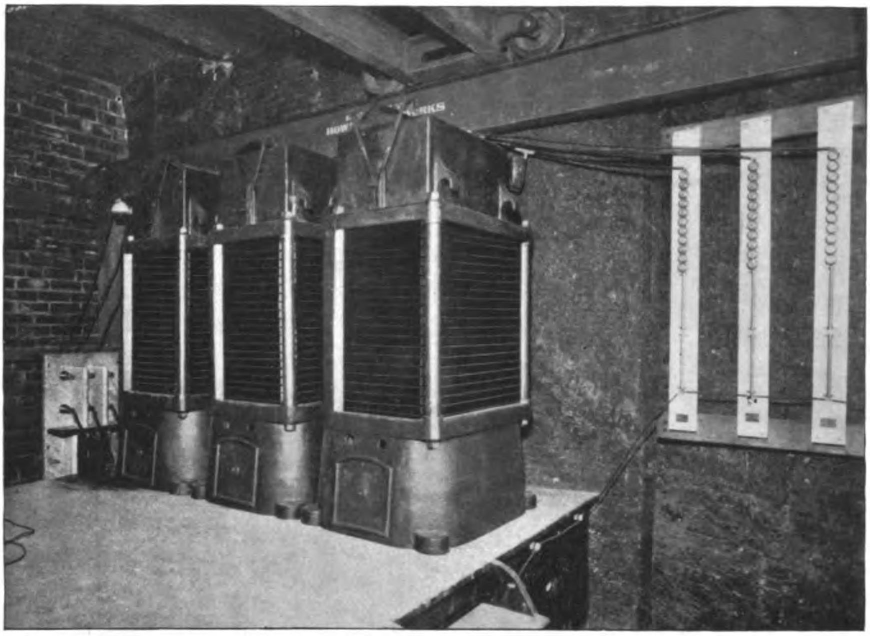


AN OPEN SECTION OF THE CONDUIT IN BUFFALO.

All the cross arms are staggered, and the gains are painted before the arms are set. The upper cross arms carry pins on which a line of galvanised iron fence wire is strung as a lightning pro-



THE ROTARY CONVERTERS IN THE DYNAMO ROOM OF THE BUFFALO POWER HOUSE.



IN THE STEP-DOWN TRANSFORMER HOUSE AT BUFFALO.

tector, and another line of this wire is strung along the apex of the poles for a similar purpose. These lightning protectors are grounded at frequent intervals along the pole line. The pinholes in the cross arms have a depth of four inches, and all have drainage holes. The pins were not nailed in position until after the insulators were placed.

Two styles of insulators are in use on the line,—one made by the General Electric Company, and one by the Imperial Porcelain Works, of Trenton, N. J. This latter insulator is known as the "Niagara type." In shape it is oval, and it has a projecting rim around the bottom to aid in throwing off water. This insulator is nearly as large as a derby hat, and of goodly weight. The other insulator is round in shape.

THE "NIAGARA TYPE" INSULATOR.

In the transmission, transposition is effected every five miles, and at these points two poles five feet higher than the adjoining poles are placed. The cable strung on the pole line is one of bare copper having nineteen strands.

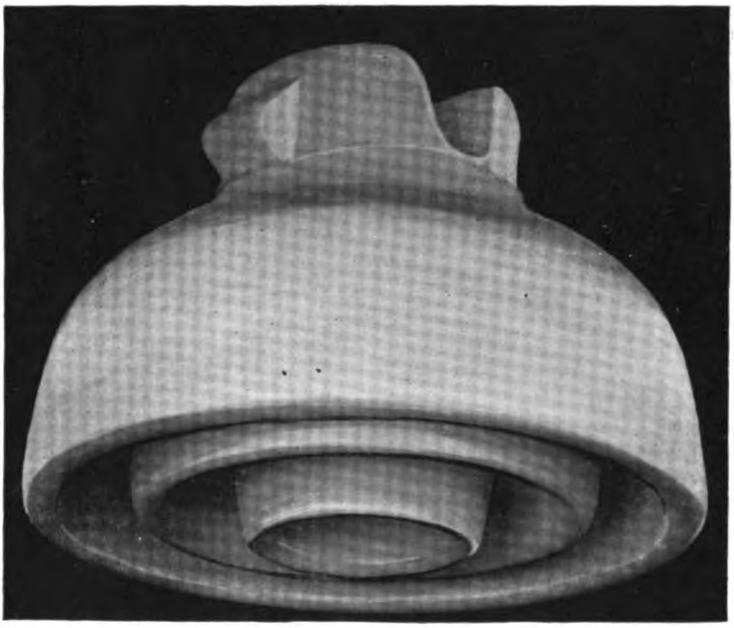
About seventy-five miles of this are used in the three lines, forming one three-phase system. The cable was shipped to the work on large reels, each carrying about a half-mile length. These reels were loaded on to a reel cart and horses drew this heavy load along the line as the cable was paid out, a simple movement of a lever bringing the cable up taut on the arms.

At the Buffalo end of the line, for about 4200 feet, the cables are laid in a conduit made of twelve vitrified tile ducts, each of which has a diameter of three inches in the clear. These tiles are laid in concrete with four inches as the minimum protection on all sides. The trench to accommodate them was excavated to a depth of about forty inches, but this was governed by the locality. The average depth of soil over the conduit is eighteen inches. The conduit is laid along the Erie Canal bank, but in no place does it approach the edge nearer than fourteen feet, holding close to the sixteen-foot mark on the inside line. About sixteen manholes, octagonal in shape, are located along the conduit. They are surrounded by a brick wall twelve inches thick, the bottom being formed by six inches of concrete and one layer of brick.

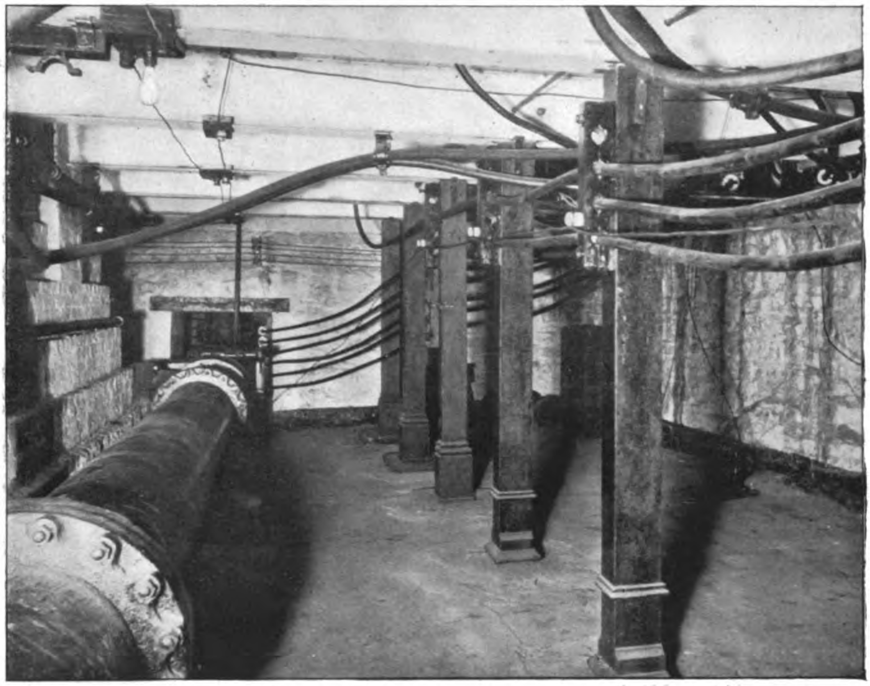
The terminal of the pole line at Buffalo is a brick house, twenty-two feet high, and its interior dimensions are 16x9 feet. A short tunnel leads from the last manhole in the conduit to the house. The cable laid in the conduit aggregates 12,345 feet in length for the three circuits. The rubber insulation is 9-32 inch thick and is covered with rubber tape. The lead sheath is 7-64 inch thick. Samples of the cable have withstood 40,000 volts successfully.

The cable, after entering the terminal house through the short tunnel above referred to, is carried up inside on a trestle and the ends are sealed. A rubber-insulated cable without lead is carried out to the first pole, and there connected with the bare copper cable of the pole line. The terminal house is fitted with lightning protectors.

It is already apparent that the transmission line is to be an important factor in building up the section of country between Niagara Falls and Buffalo. For about eighteen miles of the distance to Buffalo the transmission line runs through private property, the right of way over which was purchased by the Niagara Falls Power Company. This strip of land is thirty feet wide, and in the construction of this first line the poles have been set to the east side of the centre, the outside boundary of the strip being one foot beyond the outside end of the large cross arms. This method was adopted



THE GENERAL ELECTRIC CO.'S DOUBLE-PETTICOATED INSULATOR.



THREE-PHASE CIRCUITS FROM THE STEP-DOWN TRANSFORMERS TO THE ROTARY CONVERTERS.

so that another line can be constructed along the west side of the strip when occasion demands. The ownership of the land also makes it possible for the owners of the line to pass along it without trespass, and affords them excellent facilities for guarding it. The poles are set at a depth of from six to eight feet, and where soft soil was met they were set in concrete.

Power was first transmitted over the line early on the morning of Monday, November 16. In the power house at Niagara Falls Mr. William B. Rankine, secretary of the Niagara Falls Power Company, threw the feeder switch and this let the current pass from the house to the transformer room adjoining. Beside Mr. Rankine, when he did this memorable act, stood Paul M. Lincoln, electrical superintendent of the power plant, and Mr. William A. Brackenridge, resident engineer of the Cataract Construction Company, under whose personal supervision the transmission line had been constructed and the electrical equipment installed.

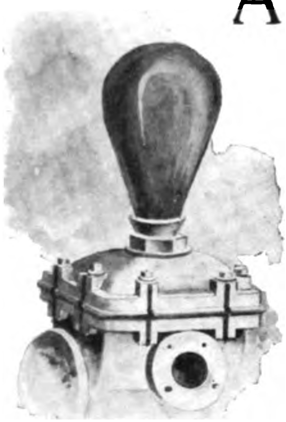
Over in the transformer house was Mr. I. R. Edmonds, of the General Electric Company, who threw the low-tension and high-tension switches of the installation there, letting the current pass into and through the transformers and out over the line to Buffalo, where it was successfully received, and its arrival heralded by the booming of cannon, even though the hour was midnight.

At the Buffalo end of the line there was a notable gathering of prominent men. Mr. W. L. R. Emmet, of the General Electric Company, was in charge of the apparatus on behalf of his company. The mayor of Buffalo, leading editors and officers of the Cataract Power and Conduit Company and the Buffalo Street Railway Company were also there to welcome the coming of Niagara energy.

The product of the big generators at the Falls is now being daily transmitted to Buffalo at a voltage of 11,000, and 1000 horse-power is being used in that city for the propulsion of trolley cars.

CONDENSATION WITHOUT WATER SUPPLY.

By Louis R. Alberger.



A LARGE amount of time and energy has been expended during recent years in the refinement of the steam engine. The endeavours of the best engineers have been stimulated in this direction by the demand for cheap power in connection with the application of electricity to seemingly unlimited fields. The installation of many new and large power plants has afforded excellent opportunities to ascertain the practical value of high-pressure steam, the influence of steam jackets on cylinders, the relation of clearance space to speed, and other points that assume importance as the development increases.

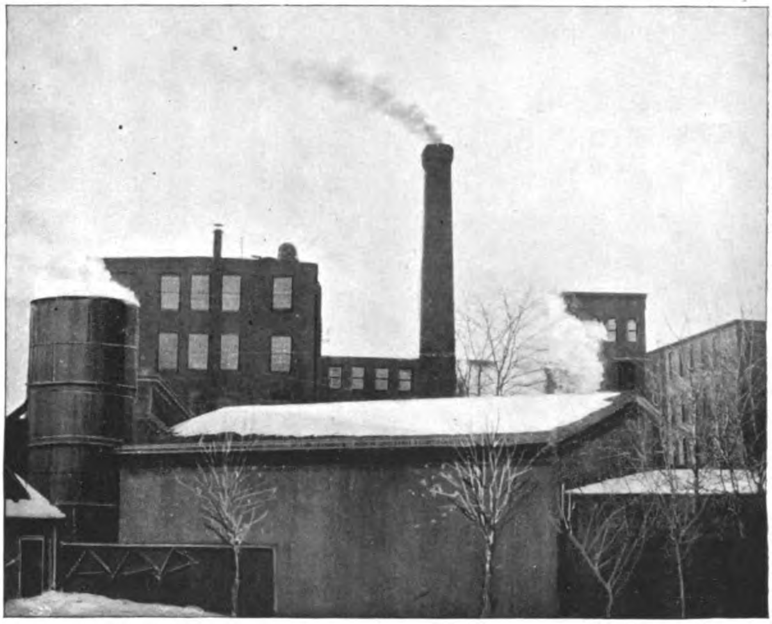
Such progress has been made, and the possibilities have become so narrowed down, that for any great stride we must look to some new form of heat engine which does not depend alone upon the expansive force of steam. Methods and devices that have added but a few per cent. to the economy of the steam engine, we are ready to consider great achievements.

It is at this time that our interest is attracted by an apparatus that will, if used, affect most materially the economy of a great number of steam engines, and to an extent that makes it of more than usual importance,—an apparatus that enables an engine to be run condensing where a supply of water, such as is necessary for condensation by the ordinary method, is not available. When we consider that by far the larger number of stationary engines are so situated, and that condensation brings with it an enhanced economy of from 20 to 30 per cent., we must believe that a great advance is given to the ultimate economy of steam engines as a whole.

The adoption of this machine will give to all users of steam power a means of economy heretofore commercially unavailable, save to those whose engines are in close proximity to an abundant natural water supply. Non-condensing engines, in any locality, can be run condensing, with all the benefits that accrue, by the use of a vacuum. In the construction of new steam power plants, the highest types of compound and triple-expansion condensing engines can be used, without reference to the quantity of water available, except to provide a sufficient amount for boiler feeding purposes.

Aside from the actual gain resulting from a reduction of steam consumption, these possibilities influence most particularly electric light and railway enterprises, in the matters of location of the stations and the method of distribution. Many electric generating stations are placed away from a natural water supply in order to be near the centre of distribution, and are severely handicapped in cost of power by competitors who have been more fortunate in the location selected, and who, by means of condensation, are able to produce power at very much less expense.

On the other hand, we are well aware that sites along water fronts in large cities are expensive, and are found usually at a long distance from the centres



A COOLING TOWER CONDENSING PLANT AT THE WORKS OF THE OVERMAN WHEEL CO., CHICOPEE FALLS, MASS., U. S. A., INSTALLED BY H. R. WORTHINGTON NEW YORK.

of distribution, necessitating the use of lengthy and costly conductors to transmit the current. By the use of this improved condensing apparatus, the advantages of condensation can be added to those of central and perhaps already determined location, and the plant placed nearly, if not fully, on a par with the best and most recent practice of condensing engines with natural water privileges.

Before describing this apparatus it may be interesting to state briefly what has previously been done in the direction of condensation without natural water supply. It is not claimed that the broad idea as embodied in this machine is distinctly new, but that it is the first practical and reliable device for the purpose that has been offered to engineers and users of steam power.

Many methods have been proposed to cool the heated water from the condensers of steam engines, so that it could be used again, and several of them have been described in this magazine. In some cases the heated discharge water is delivered into a pond and allowed to cool to as low a temperature as possible before being used again. Open pans, placed in the yard adjoining the engine house, or on the roof of a building, have been found fairly serviceable in a few instances where the structures were of sufficient expanse and strong enough to support the weight. Both of these methods of cooling water are slow, and, as only the surface exposed to the air is active to any great extent, very large areas are required. Furthermore, they are uncertain, as they rely upon the favourable conditions of the wind and atmosphere for anything like satisfactory results.

In Europe the heated water is sometimes pumped upon a pile of brush or fagots, and in that way caused to expose a large surface to the air. Modified and somewhat improved forms of this plan have been used for a long time on the island of Cuba, in connection with vacuum pans, in the manufacture of sugar, at places where water is scarce, the prevalence of trade winds adding much to the reliability and effectiveness of these contrivances.

Rilleaux, who is credited as being the inventor of multiple effect evaporating apparatus, many years ago suggested the use of gunny bags, suspended by one edge and arranged in a series with a space for the circulation of the air, and a device for supplying the heated water along the upper edge of the bags. He found, however, that the cloth, subjected to the combined action of heat, moisture, and air, decayed very rapidly, and its use was soon abandoned. In Hungary and Germany expensive constructions, quite like Rilleaux's, are in use, wooden plates or partitions being substituted for the gunny bags. The plates are hung in a parallel series a few inches apart. It is very desirable, and at the same time difficult, to maintain an even distribution of the heated water along the edges of the plates, so that each plate will present a thoroughly wetted surface to the air, and elaborate means are adopted to secure that result.

As distinguished from the above methods, in which the exhaust steam is brought in contact with the water, numerous forms of so-called air or evaporative condensers have been devised and used with varying success. They consist of a series of tubes or hollow plates, exposed to the atmosphere, into which the steam from the engine is exhausted, the steam being condensed, and the water resulting from the condensation, after being freed of the lubricating oil from the engine, is fed to the boiler. The surface required merely to condense the steam, without producing even a moderate degree of vacuum, is very large, and the machine, to be of full effect, must be bulky and expensive. The efficiency of this style of condenser can be increased by continually wetting the surface of the tubes exposed to the

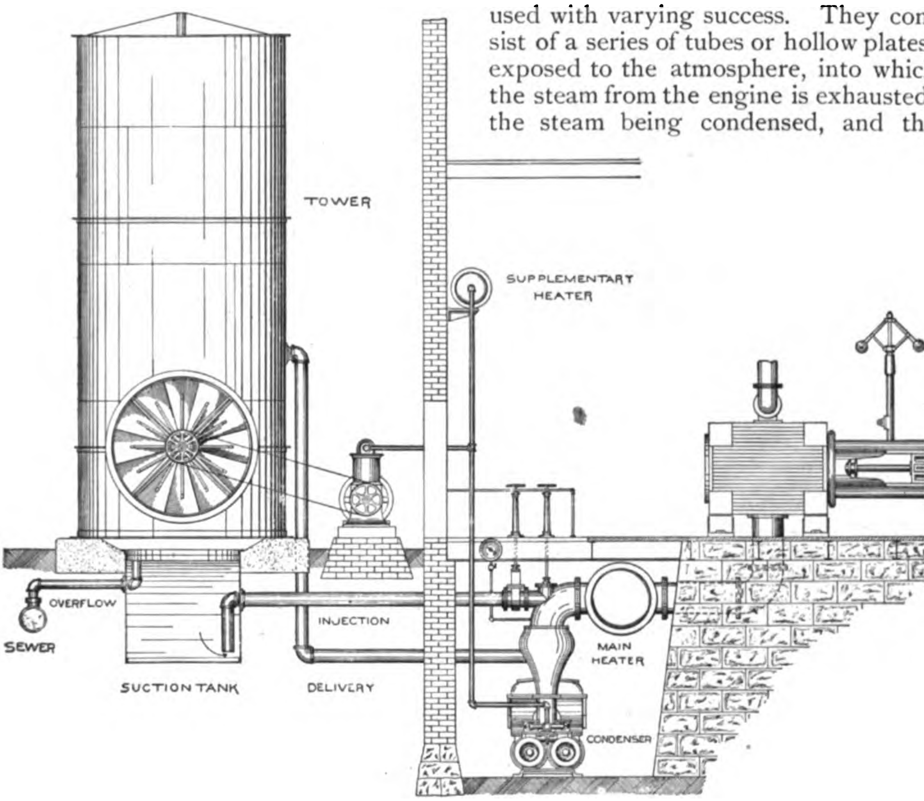
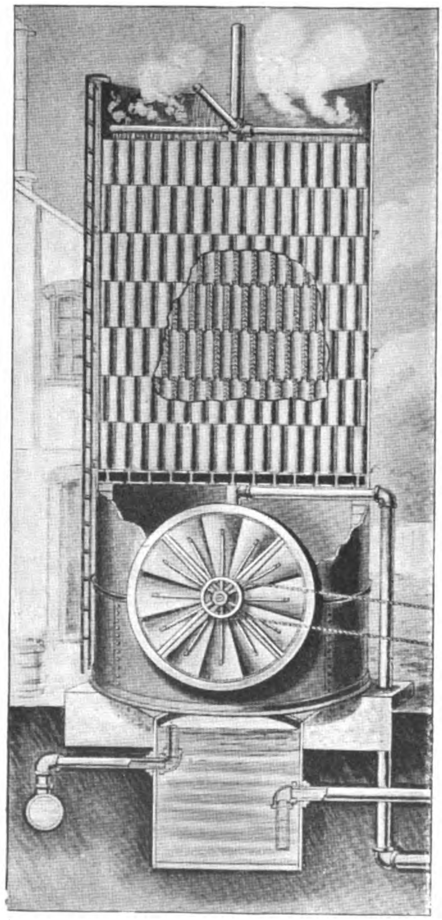


DIAGRAM SHOWING CONNECTIONS OF A WORTHINGTON SELF-COOLING CONDENSER, WITH TOWER IN YARD.

air. Aside from the cost, which prevents its commercial use, it possesses a very great practical disadvantage in that the whole structure, including the tubes, with their fastening devices arranged to accommodate expansion and contraction, requires to be air tight against atmospheric pressure.

It is obvious that such methods and constructions, while interesting and, in a limited way, operative, would not be applicable to the large majority of steam plants of considerable capacity with which we are familiar, and which have become so necessary for modern mill, electric light, and railway purposes.



BY COURTESY OF "POWER."

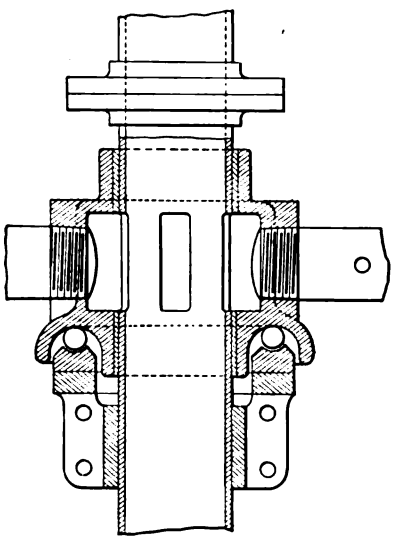
A VERTICAL SECTION OF A COOLING TOWER.

An apparatus for this purpose, and one which can be safely employed as a reliable portion of a steam power plant, must be simple and compact in construction, thoroughly durable, and so completely under control as to be practically independent of changes of wind and weather. The one which it is the intention of this article to describe, is so far beyond the stage of experiment that it may be confidently said to embody these features. It is illustrated in section on page 207. It consists of two parts,—a condenser, in which the exhaust steam of the main engine or engines is condensed, and a tower in which the heated discharge from the condenser is cooled to a proper temperature to be used again for the further condensation of exhaust steam.

The tower consists of a cylindrical steel shell, open at the top, supported upon a suitable foundation, and having fitted at one side a fan for circulating a current of air through the tower and its filling. This filling consists of layers of cylindrical tubular tiling, which rest upon a grating supported by an interior brick wall extending around the circumference of the tower. The heated discharge water from the condenser enters the tower at the side, passes up a central pipe, is delivered on the upper layer of tiling and over the whole cross section of the tower by a distributing device which rotates about the central water pipe by the reaction of the jets of heated water issuing from one side of each pipe after the manner of a Barker mill.

The water, thus delivered, spreads over the outside and inside surfaces of the walls of the tiling, and forms continuous sheets of large extent which are presented to the action of the air. The tiling is placed on end in horizontal layers, one upon the other, and packed as closely as possible, the walls of each individual tile of each successive layer being disposed so as to come opposite the air spaces of the next lower layer, breaking joints, as it were.

The cuts on the opposite page show the cellular arrangement of the tiling, the object being in this distribution to break up both the currents of air and water, so that the most thorough and extended contact will take place. If there are ten layers of tiling in a tower, then there are nine places, in addition to the original spreading at the top, at which there is a complete redistribution of the water. It will be seen that each tile must rest on at least two, and possibly three, in the next lower layer. Assuming, however, that each tile rests on only two others, a given quantity of water, placed on any one tile in the top layer, will be divided over at least two tiles in the second layer, three in the third, four in the fourth, and so on, until it becomes spread over fifty-four in the lowest layer on the grating. The air is distributed in an equally effective manner, and there is a large free area with equal facility for its passage up-

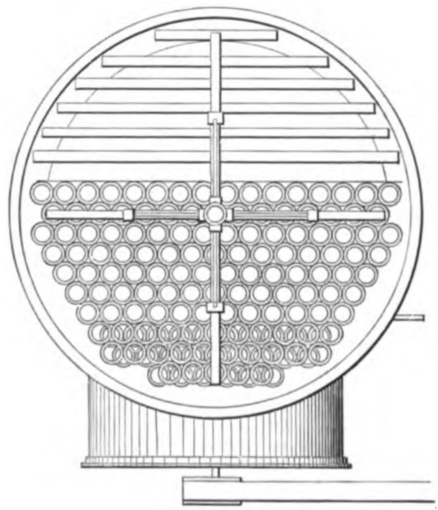


THE REVOLVING DISTRIBUTOR.

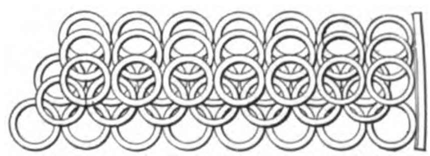
ward over the entire cross section of the tower.

The heated water, falling through the tower, is cooled by three processes:—First, radiation from the sides of the tower; second, the contact of cooled air; and third, evaporation. This latter is by far the most important, as the evaporation of a pound of water in this way carries off about 1000 units of heat, and indirectly enables a pound of steam to be condensed in the condenser.

As quite a proportion of the cooling is done by the first two processes, the evaporation of water in the tower must



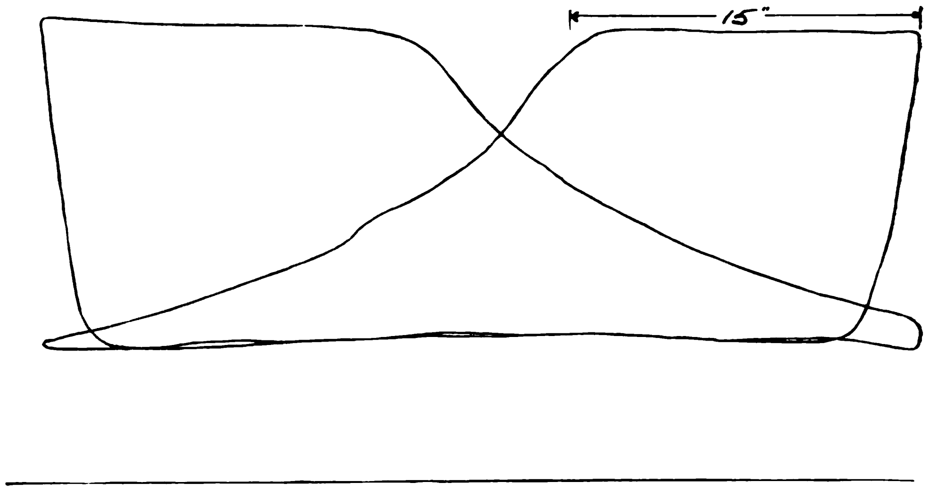
A PLAN OF A TOWER.



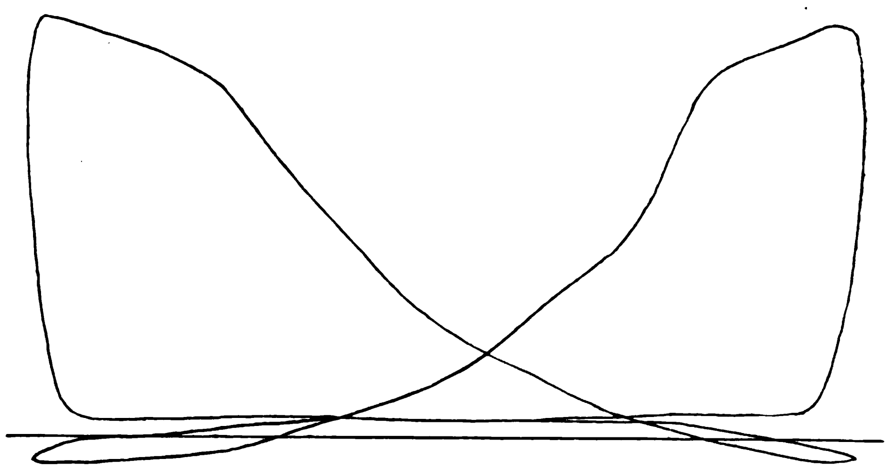
THE ARRANGEMENT OF THE TILES.

be less than the water formed by steam condensed in the condenser. Consequently, the supply of circulating water is constantly augmented and requires no replenishing, while the slight overflow from the suction tank carries off the oil and grease which come from the engine with the exhaust steam, and which would otherwise accumulate in the suction tank. The heated water falls from the grating to the subsiding tank at the bottom, and is from there drawn by the condenser to again assist in condensation.

In situations where the water to be had for boiler feeding is so impure as to form objectionable scale in the boilers, a modification of the apparatus is used to great advantage. This modification



HIGH-PRESSURE CYLINDER DIAGRAMS FROM HARRIS–CORLISS COMPOUND ENGINE AT THE OVERMAN WHEEL CO.'S WORKS, RUNNING NON-CONDENSING. DIAMETER OF CYL., 16 IN. STROKE, 36 IN. REV. PER MIN., 80. BOILER GAUGE, 100 LBS RECEIVER GAUGE, 28½ LBS. SCALE OF SPRING, 40.

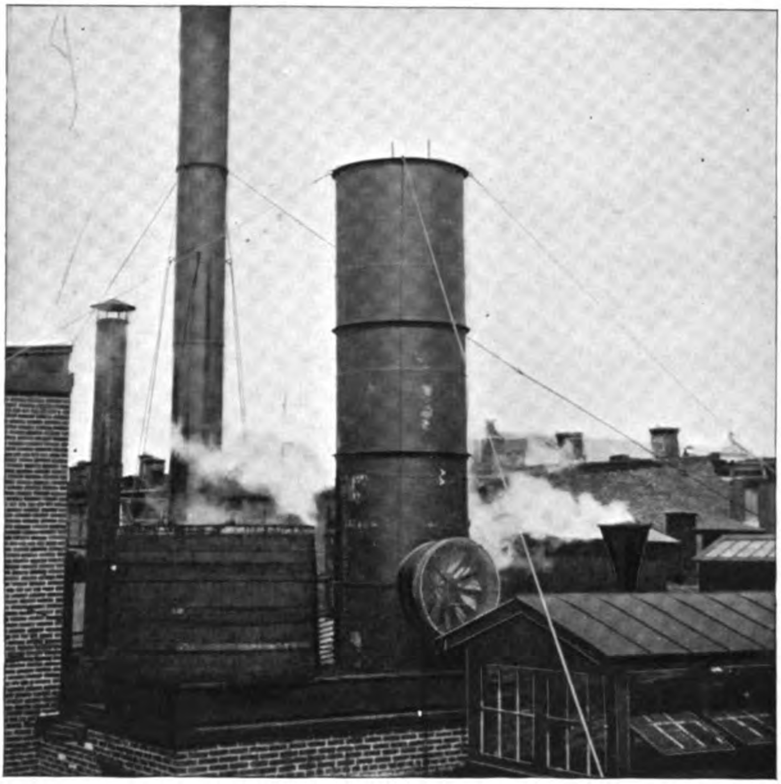


LOW-PRESSURE CYLINDER DIAGRAMS. DIAMETER OF CYL., 30 IN. STROKE, 36 IN. SCALE OF SPRING, 10.

consists in a substitution of a surface condenser with air and circulating pumps for the jet condenser and pump. The circulating pump draws the cool water from the suction tank, passes it through the tubes of the surface condenser and the tower, and back again in a continuous circuit to the suction tank. The exhaust steam from the main engine, brought in contact with the outside surface of the tubes, is condensed. The pure water thus formed, together with the air and uncondensable vapour, is removed by the air pump and delivered to the hot well, whence the water is fed to the boilers. The loss to the circulating water by evaporation in the tower must needs be made up from the source of water supply.

On account of the peculiar open construction of the filling of the tower, the fan for the circulation of the air requires very little power for its operation, being designed to deliver large quantities under slight pressure. Careful and extended tests have shown it to use less than one horse-power for every thousand pounds of steam condensed, or about 2 per cent. of the power of the main engine during the maximum requirements of summer, while the average for the year in a temperate climate does not exceed 1¼ per cent. The fan may be driven by an electric motor, belting from the main shafting, or by a small steam engine, as the conditions of the situation may render most desirable.

The apparatus is adapted to almost any situation, as the floor space occupied by the tower is quite moderate considering the objects attained. This will be appreciated when it is understood that an apparatus suitable for 1000 horse-power is only 15 feet in diameter and 30 feet high. The suction tank, which is placed directly under the tower and in the foundation, is 8 feet in diameter and 7 feet deep, and contains about 2000 gallons of circulating water, this being a sufficient quantity to fill the condenser pump, pipes, and tower on starting up, and to carry on continuously the transfer of heat from the exhaust steam to the atmospheric air.

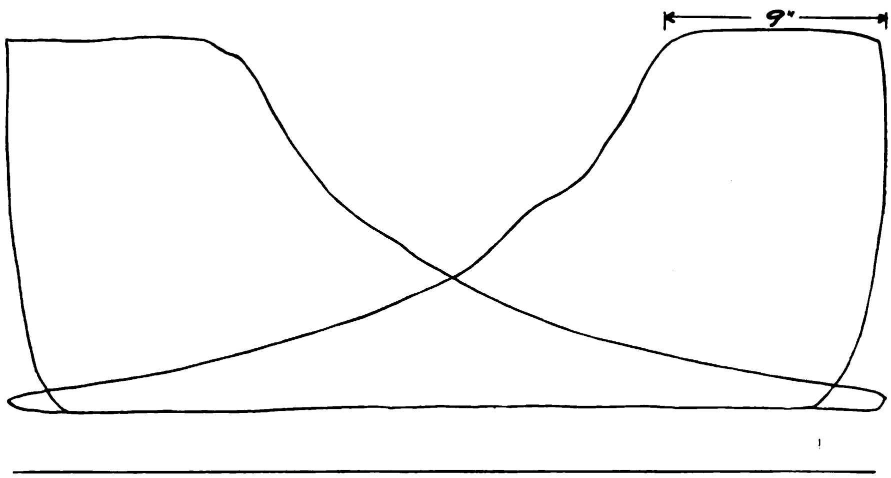


A COOLING TOWER PLANT AT THE PACKING ESTABLISHMENT OF MESSRS. C. HOHMAN & SONS. BALTIMORE, MD., U. S. A.

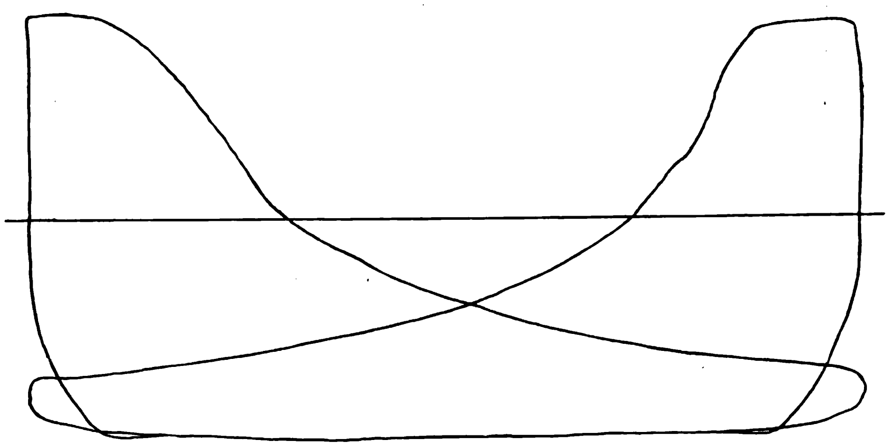
The location of the tower may be on the engine room floor, on the top of the building, or in the yard, the latter place being well adapted. It may be at any reasonable distance from the engine and the condenser, and connected to the latter by one pipe for the heated and one for the cooled circulating water.

The distance is limited only by the friction of the water, which depends, of course, upon the size and directness of the pipes.

The illustration on page 206 is from a photograph of one of these machines at



HIGH-PRESSURE CYLINDER DIAGRAMS FROM ENGINE AT THE OVERMAN CO.'S WORKS, RUNNING CONDENSING. BOILER GAUGE, 97 LBS. RECEIVER GAUGE, 9½ LBS. REV. PER MIN., 80. SCALE OF SPRING, 40.



LOW-PRESSURE CYLINDER DIAGRAMS. VACUUM GAUGE, 26½ INS. SCALE OF SPRING, 10.

the factory of the Overman Wheel Company at Chicopee Falls, Mass. The engine with which it is used is a Harris-Corliss, cross-compound engine, having a 16x36-inch high-pressure steam cylinder, and a 30x36-inch low-pressure steam cylinder, making 80 revolutions per minute with 100 pounds boiler pressure. This engine was run non-condensing for several years. The indicator cards on page 210 show the behaviour of the steam in the cylinders, and the difficulties encountered under the existing conditions. While it may be said that these cards could have been improved by certain modifications of the valve motion and setting, they are, nevertheless, not widely different from many others taken from non-condensing compound Corliss engines, and certainly better than when the latter are worked under light and varying loads.

The change to condensing was made during the summer of 1895. The condenser is placed in the basement of the engine room and the method of pipe connections employed is similar to that shown by the outline cut on page 207. The cooling tower is in the yard near one of the wings of the building, and at a distance of 150 feet from the condenser, the air circulating fan of the former being driven by an extension of the line shaft of the factory, so that the fan is put in operation at the same time that the main engine is started. Means are provided to change the speed of the fan under extreme conditions of winter and summer weather, and also to throw it out of commission if at any time desirable.

The diagrams given on the page opposite are of the same engine when condensing, and were taken during the month of July. They show the effect of the vacuum and the beneficial result, not only in earlier cut-off, under nearly the same load and steam pressure, but also in the better division of the load between the high and the low-pressure cylinders. It will be seen that initial steam pressure is carried only nine inches of the stroke, instead of fifteen, as was the case when the engine was non-condensing. This is a difference of six inches, and represents, roughly, a saving in steam consumption of 40 per cent. Some allowance should, of course, be made for slightly increased cylinder condensation in the high pressure cylinder, due to the reduction of the terminal pressure from twenty-nine to ten pounds (gauge).

The power used in driving the fan is not over 2 per cent. under the most severe conditions of weather and season. The actual work done by the air pump in the production of the vacuum and the elevation of the heated discharge water to the tower is 5.7 horse-power, or less than 3 per cent. of the total horse-power of the main engine. This amount, added to that required by the fan, makes the total cost of production of the vacuum practically 5 per cent., thus leaving a very satisfactory net gain to the plant by condensation.

It should be mentioned that in the application of this system to such a plant in which the engines have been previously run non-condensing, no change is made in the method of feed water supply. The feed pump and the ordinary main exhaust heater are left in position, and the exhaust steam from the main engine is passed through the latter on the way to the condenser. The steam exhausted by the condenser pump, boiler feed pump, and the small engine which runs the fan (if a separate engine be used), is conveyed to a second heater of moderate size. This supplementary heater receives the feed water, which has already been heated nearly to the temperature of the exhaust steam, say to 110 degrees Fahr., with a vacuum of twenty-six inches, by the main heater between the engine and the condenser. The exhaust from the auxiliaries being entirely condensed in the supplementary heater, its latent and sensible heat is transferred to the feed water and by this means returned to the boiler.

The temperature of the feed water will approximate that obtained when the same plant is run non-condensing, and was, in this instance, 200 degrees Fahr. It is evident that as that portion of the heat in the steam supplied to the auxiliaries, and not converted into useful work nor lost by radiation and leakage, is completely returned to the boilers, the efficiency of these machines is very high, and the air pump can be charged only with the heat equivalent of the actual work done, no matter what may be the amount of steam passed through its steam cylinders.

As before stated, the cooling tower can be placed in any convenient place upon the ground, when ground space is available, or in the centres of cities it can equally well be located on an elevated structure or roof of a building. The cut on page 211 shows the apparatus supported upon the main walls of the engine house, the condenser and fan engine being in the room below.

These two plants have been selected for illustration because they have had long and severe trial during all periods of the year. Many other installations, however, are in operation, giving excellent results. They vary in capacity from 200 to 5000 horse-power each, and include almost all classes of service,—electric lighting, electric railway, blast furnace, cotton mills and refrigerating plants.

In conclusion it may be interesting to consider a feature of superiority that the self-cooling condenser has over a condenser dependent upon a natural water supply such as is usually to be had, especially when used in connection with steam engines subject to great variations of load, as are found in electric railway, rolling mill, and similar irregular work. It is substantially correct to say that not less than half of the condensing apparatus in use in connection with stationary engines are located so as to be compelled to lift the injection water at least sixteen feet, and some as high as twenty to twenty-two feet. This is caused by the fact that the stations or mills, if they are alongside of a river, are usually placed upon moderately high and firm ground. The result of this arrangement is that in case of a sudden overload of the engine, by which steam may be carried three-fourths of the stroke instead of one-fourth of the stroke as normally, the condenser is not capable of maintaining the full degree of vacuum; and when the vacuum falls, as it must necessarily, unless a very large and extravagant amount of water is being passed through the condenser, to a point below that due to the suction lift plus the friction in the pipe, say to twenty inches, then the water is lost entirely, and the engine must either be run non-condensing, or the condenser cooled off and started by means of a forced injection from some outside source.

This is a very undesirable occurrence in an electric railway station, as can readily be understood. With the self-cooling condenser, however, having the suction lift reduced to a few feet, and a supply of water on hand, entirely free from debris or foreign material, such as would cause the stoppage of the injection supply, an overload may come to the condenser and the vacuum may temporarily fall to a point as low as ten inches without becoming entirely lost. Just as soon as the cut-off again takes place at an earlier point, the vacuum will return to the normal degree without the annoyance of shutting down or of cooling and priming the condenser.

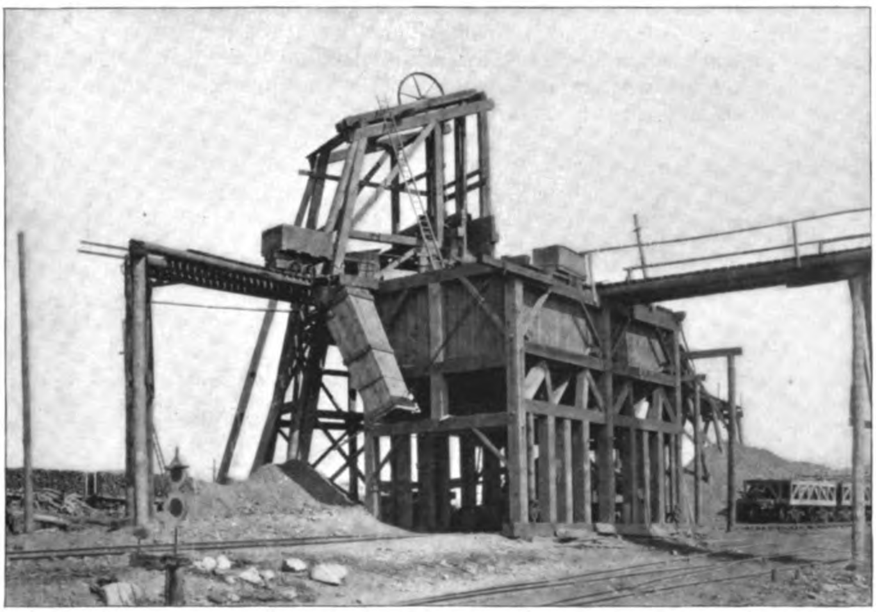
COPPER MINING IN THE UNITED STATES.

By William P. Kibbee.

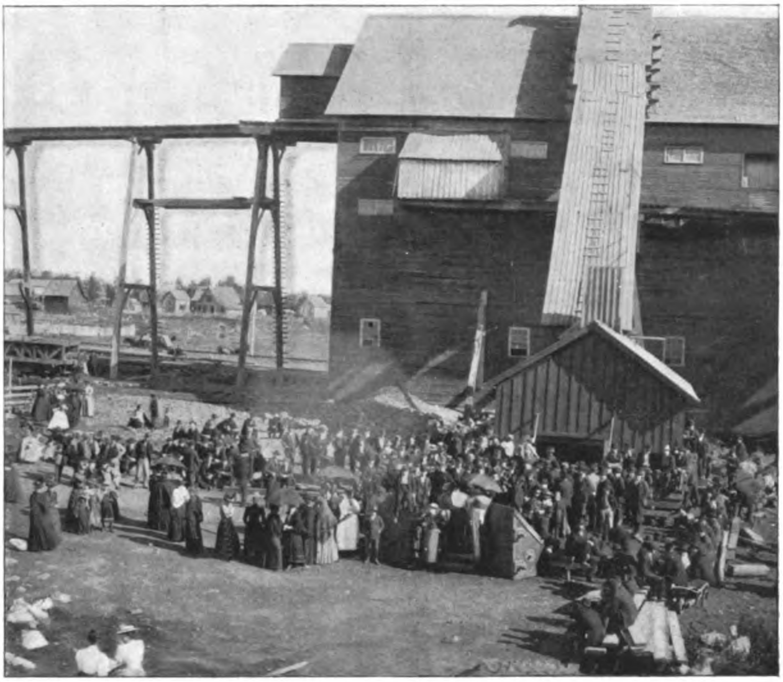
ONE afternoon, as the golden orb was making its majestic march down behind the rock-ribbed hills of Opechee township, in Michigan, and the night was casting its mantle of darkness over the earth, John Daniell, of Tamarack fame, sat in his little office at the Osceola mine, racking his brain of science. Many figures he made upon paper, and many a line he drew, when finally he conceived the idea of going three-quarters of a mile to the northwest of the famous Calumet and Hecla mine, and there sinking a vertical shaft 2500 feet into the bowels of the earth, with an ultimate purpose of intersecting the great Calumet conglomerate copper lode, whose width and richness surpasses that of any copper-bearing formation anywhere.

From a careful study of the inclinations of the copper-bearing portions of this extraordinary lode, it was reasonably conjectured that beneath the surface of the land of the Tamarack Company it possessed a degree of richness that would amply compensate for all expenditure and risk incurred in the effort to reach it.

Imbued with this faith, Daniell, with a powerful syndicate behind him, did not hesitate in the endeavour to accom-



THE HEADWORKS AT A MINE.



AWAITING THE BODIES AFTER A MINE ACCIDENT.

plish it, and so well did they succeed that the great lode was pierced, rich in copper, at a depth of 2468 feet below the surface, thus marking the initial perpendicular shaft sunk in the Lake Superior district.

The Tamarack Company have at the present time four vertical shafts producing copper from the conglomerate, and a fifth, which is destined to become the deepest mining shaft in the world, is now being sunk, and will take about five years, at the present rate of sinking, before the conglomerate will be pierced and the shaft completed.

Of course, it is a matter of speculation whether the conglomerate will be found at so great depth—viz., about 6000 feet, and even, in that event, whether the lode will be found to retain its average characteristics,—about 3 per cent. copper. The expense of sinking and equipping this shaft will reach nearly three million dollars; still this is not considered large in these days of modern mining.

Within walking distance from the Tamarack proper we have the Red Jacket vertical shaft, belonging to the famous Calumet and Hecla mine. This shaft is now the deepest and most modern mining shaft in the world. It is so constructed that in case of fire in the Calumet mine, the men can make their exit through this shaft when escape would be cut off at all the others. It is 4900 feet deep, and was started in the fall of 1889 after the two great mine fires, since which year work has been vigorously carried on night and day. The greatest number of feet sunk in a month was sixty-nine, and in one week thirty-seven. The least number of feet in one month was thirty-nine. Power drills were used in the bottom. The drill holes averaged five feet, and two blasts of 100 holes each were made each day.

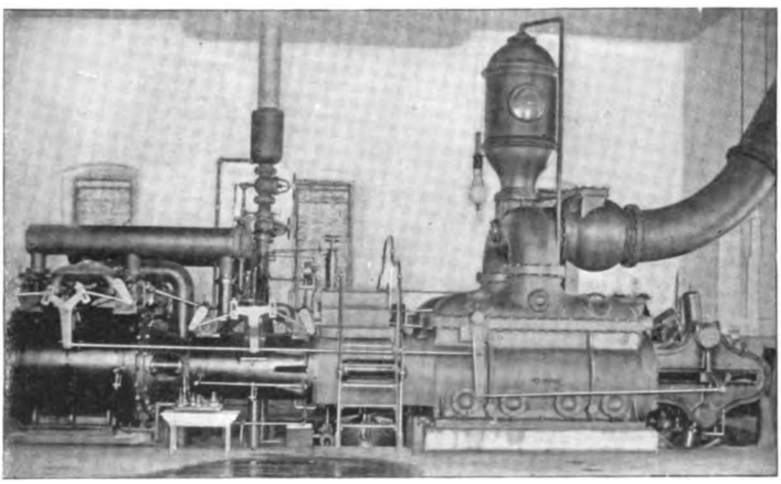
Connections are made with the Calumet mine, No. 4 shaft, in the following manner:—The first cross-cut, which was connected with the mine in 1890, is at a depth of 2106 feet, has a length of 1573 feet and intersects No. 4 shaft at the 36th level. The second cross cut, at a depth of 2296 feet, intersects the lode at the 39th level, while the third cross-cut, at a depth of 2463 feet, connects at the 42nd level. From each level three openings are made at the shaft, the main entrance being on the east side of the shaft, while on the north and south sides the openings are made with a curve, until they meet the main or east drift about 178 feet from the shaft.

The inside dimensions of this shaft are 14x22½ feet. It is divided into six compartments, and timbered throughout with Georgia pine. President Agassiz, in one of his reports, stated that the Red Jacket vertical shaft was planned after the two mine fires in 1887, in order to insure against the loss of the northern extremity of the mine in the event of a similar disaster in the future, and to afford access to the extreme lower levels of the mine.

Hoisting in this shaft has been brought to a degree of simplicity. A twin compound condensing engine, Leavitt pattern, 16x32 inches by 48 inches stroke, drives two grooved drums of 7 feet diameter, with three grooves on each drum. The rope measures 1¼ inches. Soft maple blocks compose the grooves of the drums, and the runway of the tension carriage is 650 feet long. The average pressure employed is about 120 pounds, while the speed of hoisting is between 1200 and 1500 feet per minute, with a load of ten tons.

The machinery at this shaft is not only the finest in the United States, but presents elements of novelty that will repay any person interested in mining machinery the cost of a visit of inspection.

The twin engines,—the Minong and Siscowit, as also the Mesnard and Pontiac,—are the finest engines on the mine. The two latter are held in reserve in case of accident, and right here it might be said that the Calumet and Hecla have duplicated every engine on the mine. Some idea of the size of the engines at the Red Jacket shaft may be gained from the weight of some of their parts:—Engine bed, 76,100 pounds; main pedestal bed plate, 150,722 pounds; end piece for bed plate, 19,466 pounds; cylinder, 25,500 pounds; engine beam (steel), 64,920 pounds.



A MODERN MINE PUMPING ENGINE.

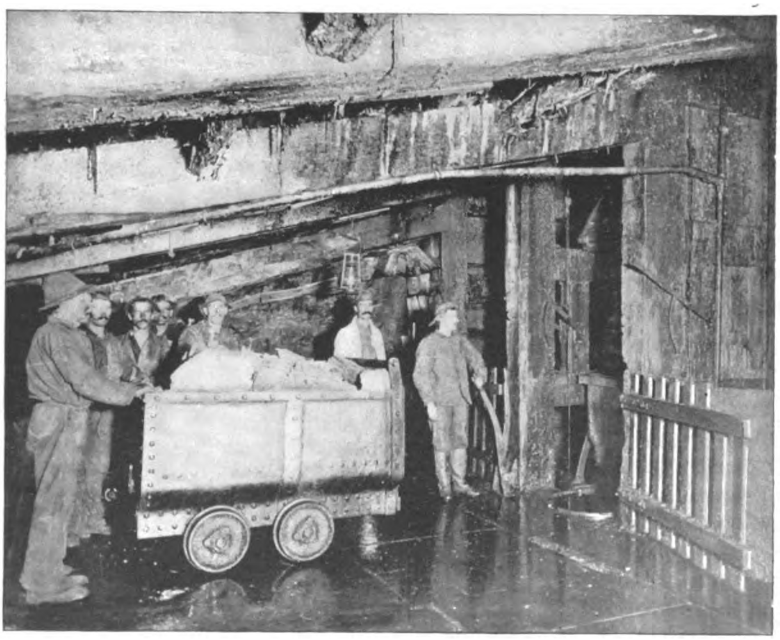
No one nowadays expects to open a copper mine on Lake Superior without a large preliminary expenditure of capital. It is frequently only by a large outlay that one can hope to succeed at all. The less the amount of copper in the rock, the more rock must be mined and stamped in order to secure a product that shall insure the requisite income. A copper-bearing lode that yields only twenty pounds or less of ingot copper to the ton of rock must be so worked that the cost of obtaining these twenty or less pounds shall at least not exceed the market value of the copper.

But this difficult problem has been successfully solved. It is wonderful how thoroughly every factor which enters into it is considered, and the exact relation to the other elements understood and defined. Nowhere in the world is mining work in advance of that done in the copper region of Lake Superior. No improvement is lost sight of, every advantage is seized upon and rendered available. The crude methods of early days have been discarded, and the mines of this district are in the vanguard of the world's mining industry.

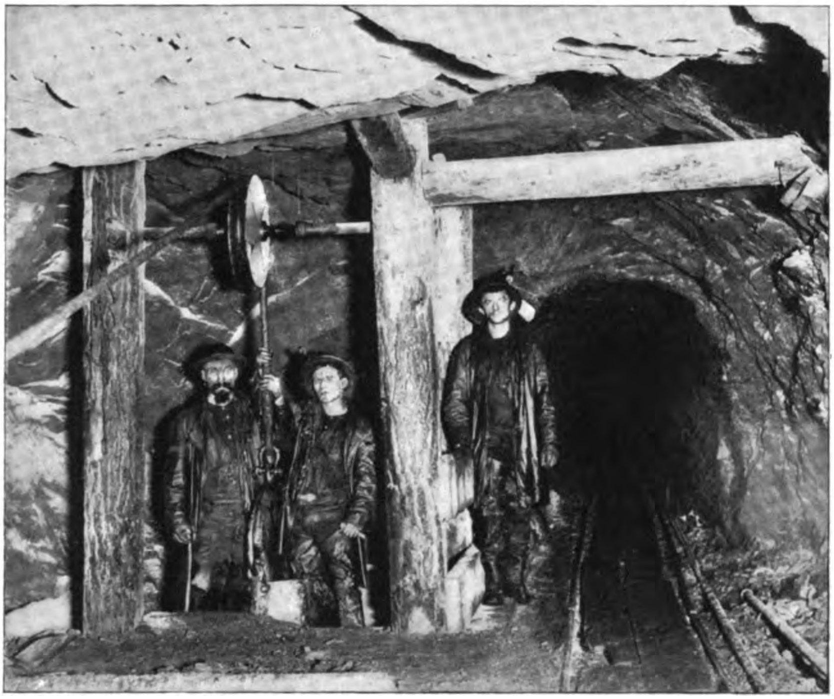
Comment is unnecessary when we consider that mining work is so conducted, as in the case of the Atlantic mine, that a deposit which yields only about 12 pounds of copper to the ton of rock is made to defray all expenditure connected therewith, in addition to laying up a substantial surplus every year. This result is accomplished by daily mining and working up 750 tons of rock and doing it at an almost incredibly low cost.

The Atlantic mine is more like the Calumet and Hecla than any other mine on the lake, as regards the uniformity of the lode. In both mines all the vein rock goes to the mill. It is all taken down except the pillars, and even these stand at the opposite end of the list.

The Atlantic rock averages the lowest in copper of any mine on the lake, while the Calumet and Hecla averages the highest. The Atlantic is noted throughout the world's mining circles for the fact that it yields such a low percentage of copper to the ton of rock and still is able to prosper. The reason of this is due to several circumstances,—first, the uniformity of the lode, of which even the most minute



AT THE BOTTOM OF THE 4000-FOOT TAMARACK SHAFT.



IN THE TAMARACK MINE, 3580 FEET UNDERGROUND.

particles are taken to the stamp mill. It is a soft amygdaloid trap, that gives easily to the drill, neither wearing on the latter or the stamp heads; the width and dip are the most advantageous on the range, the averages of the former being 15 feet and the latter 45 degrees. At such a pitch the rock requires no extra handling; it rolls down of itself against the stulls, and at the same time it is not so steep as to require staging. The openings are carried very little in advance of the stoping; in fact, the lode is taken down and trammed away as fast as it is reached, the drift and stopes being carried along together.

The Calumet conglomerate lode is generally from eight to ten feet in width, is very uniform, and, like the Atlantic, is all taken down except what is left for the pillars at the shafts. The levels are uniformly the same distance apart, and are in all respects precisely similar. The men are lowered into the mine by a system of man cars and steel cages. There are ten working shafts, and the levels are ninety feet apart. Steel skips are used, carrying two tons to the load, varying with the size of the rock.

No other corporation in the world offers so many advantages to the student of mining affairs as the Calumet and Hecla. The surface workings, which extend over two miles of territory, are equipped with the most powerful machinery known to the art of mining. The great Superior engine, devised by Leavitt, and a score more, towering up like church steeples, their brass mountings shining like glittering gold, make the sight an impressive one.

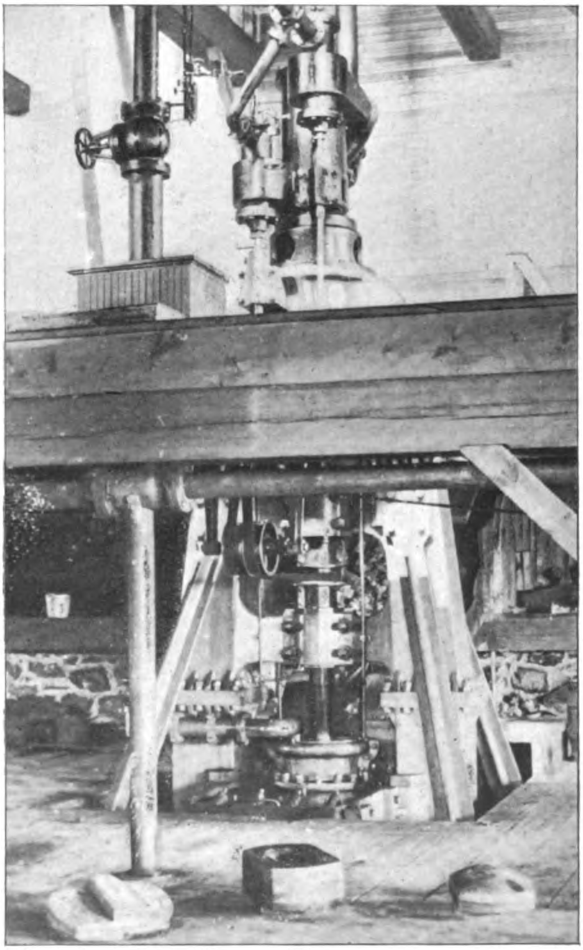
Improvements are continuously going on. Old trestle roads and wooden pump rods that formerly obscured the view have gone; old shaft houses and rock houses that stood like weather beaten sentinels for three decades, have disappeared, and new combination shaft and rock houses have taken their places. The latter are monster buildings, 25x45 feet, built straight up from the ground, and three stories high. Altogether there are eleven of these buildings, extending over two miles in length.

The difference between the two systems is mainly that in the old the rock was conveyed from the several shafts by trestle roads,—an endless rope system,—to one or more centrally located rock houses, from which the rock was conveyed to the mill by rail, whereas in the combination rock house the rock is dumped almost directly into the crushers and thence goes into the cars in which it is carried to the mill to be treated after the usual manner.

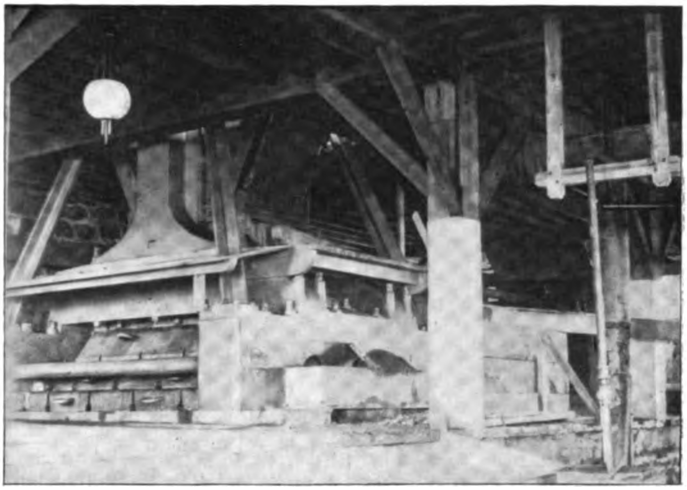
In the history of mining on Lake Superior there have been many successes, as well as some extraordinary failures. A party of Philadelphia men came to the country, not many years ago, and purchased large tracts of land in the Keweenaw mineral peninsula, Lake Superior. They had conceived the idea that beneath the surface of their land

> "There was a mine of wealth untold,
> In a hundred fathoms deep."

Operations were begun for one of the greatest mining campaigns of the time. Huge shafts were sunk into Mother Earth. Great stone buildings



AT THE HEAD OF A STEAM STAMP.



THE GROUND FLOOR OF A STAMP.

were erected, behind whose four walls was installed the most modern machinery of the age. A stamp mill,—one of the best in the Michigan copper region,—was built on the shores of Lake Superior, while a railroad, leading from the mine to the mill, was constructed and equipped with rolling stock shipped from the Far East. And the company built a canal leading to the open waters of the Great Gitchigamme—Lake Superior.

Row after row of substantial dwellings were erected upon the ground, and finally, when all was in readiness, the great mogul whistle awoke a peaceful hamlet from the dead. The powerful engines began to turn. The tall stacks vomited forth their torrents of black smoke and steam. Down, down, down, went the multitude of miners into the bowels of the earth, and up, up, came the great steel skips, loaded with barren conglomerate. There was a mine there, it is true, but it was in the minds of originators.

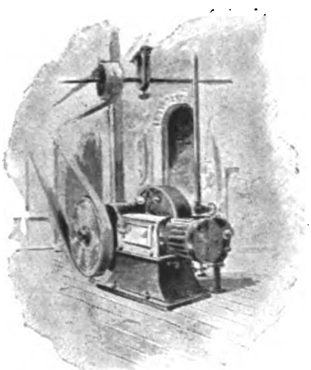
And there to-day stands the deserted village, the fine machinery reeking in rust, and the massive buildings, bleaching in the sun and rotting in the rain.

An evening's stay at Lac La Belle can never be regretted. Here also was once a Hudson Bay Company trading post, while a little further up the shore one may see the ruins of an old government fort, standing picturesquely on the slope overlooking the lake. The place is peculiar in itself, there being nothing to break the presence of solitude except the splashing of waves on the rock beaten shore. The tall shaft houses stand out in dark relief against the heavens, like funeral monuments in some vast church yard, while black shadows of adjoining buildings drape their walls like funeral velvet.

VICTOR DWELSHAUVERS-DERY.

A Biographical Sketch.

By Dr. R. H. Thurston.



IT is interesting to observe that there always may be discovered a kind of lineal descent in the intellectual as well as in the physical succession of any order of men. Galton, in his famous work, "Hereditary Genius," traces the connection between the genius of to-day and the genius of yesterday and the relationships existing between men of genius of a stated time, and indicates a fact of which his own case is an illustration,—that genuis is apt to develop in genealogical lines and to pervade certain families.

He was himself the grandson of Erasmus Darwin and a cousin of Charles Darwin, and evidently an heir to that peculiar genius which distinguished that great family. In invention, similarly, Newcomen, the originator of the modern steam engine, was succeeded by Watt, its greatest improver, and the latter by Sickels, and Sickels, in turn, by Corliss and Greene, each intellectually inheriting from his predecessor that knowledge which furnished basis for his own later work. The order of improvement was that of intellectual succession.

Again, Watt was the spiritual progenitor of many great men in another line, that of scientific investigation of the principles upon which are based all modern advances in the development of the world's motor and supporter, the steam engine. Watt inaugurated the method now familiar to all members of his great profession and pioneered every advance upon scientific research. This line comprehends the names of Daniel Kinnear Clark, of G. A. Hirn, and the subject of this sketch. Hirn founded the "Alsacian School," and Dwelshauvers-Dery is his surviving successor.

This series of great engineers has supplied us with the material for the modern and, so far as yet developed, most complete theory of the steam engine, combining the thermodynamic theory of Rankine and Clausius with the physical theory of our own time to furnish a scientific method of tracing all energy entering that machine in its various dividing streams, and of securing a final balance sheet on which are exhibited, in any given case, the details of utilisation and waste, in such manner that the sources of loss and the magnitude of their effects may be traced and separately studied with a view to reduction of the wastes to a minimum, and the securing of maximum possible efficiency of heat conversion.

The writer of this sketch, as an acquaintance and personal friend of, now, nearly a quarter of a century, and as one who has had occasion to closely follow and to take some small part in this, perhaps the greatest scientific series of researches of our century, has been asked to supply an account of the life and work of the most famous and most productive of the surviving investigators, inheriting their task and their methods from Watt and through Hirn.

Victor Dwelshauvers-Dery is of aristocratic descent, especially through his mother's family. He was born at Dinant, Belgium, the third of five brothers, on April 25, 1836. His earliest education was received from his mother, and partook of the severity and austerity characteristic of her race and time. Nevertheless, it inculcated strongly democratic principles and imbued the youth with an intense love of liberty, a desire to make duty a first thought and to accomplish all that natural powers and environing circumstances might permit.

At the age of seventeen he was sent out to complete his studies in the "old world of Europe," as he himself expressed it, to make his way, later, as best he might. His only capital, aside from his collegiate education, was the good wishes of his family, the excellent advice of his father, and the benediction of both parents. He was counselled by his father after a manner which exhibits well the serious aspect of the world to the people of his country in his early days:—

"You are now to go out into the world to prepare to earn a living. Do your work well. But seek always to augment the wisdom that comes with experience that you may become a useful citizen. You will meet with many obstacles; you may make enemies; you will be subject to frequent injustices. Be patient and persevering, seeking always the right and the good. Tarnish your character by no misdeeds, however tempted or apparently justified. Remember that in your father you always have a disinterested friend, but also a judge."

The young student found, in the succeeding four years of study with M. Dupuich, of Brussels, in the institute then well known by that name, in its principal, a mentor whose teachings had a large influence upon his career. While his ideas were enlarged, his sentiments were developed in all admirable ways. His tasks were lightened and his progress accelerated by wise counsels and a well-planned course of instruction.

The course was extended into the higher mathematics and the youth acquired a profound distaste for all advanced work in which he could not see promise of a practically useful result. His positive and aggressive spirit "sought to see things as they are and not as they should be, according to the views of speculative philosophers," as he himself said, and quoting in illustration:—

> "*Dans sa science profonde,*
> *Le modeste G——t*
> *Se defend d'avoir fait le monde*
> *Disant qu' il l'aurait mieux fait.*"

He came to the decision that his place was in the École des Mines, and entered the school at Liége to pursue studies having immediately practical value and "founded upon fundamental truth." He was admitted to the section for "Mécaniciens," in 1858, and received his diploma as Mechanical Engineer (Ingénieur Mécanicien) in 1861. He at once received appointment as "répétiteur" in mechanics in the University of Liége, later attaining the chair of a full professor, which chair he still retains.

At that period, at the École des Mines of Liége, as in all other technical institutions of the time, while excellent instruction was given in many branches of mining and of metallurgy, very little could be offered that had special value for the mechanical engineer. Our modern instruction in resistance of materials, graphostatics, thermodynamics, the theory of the steam engine, steam distribution, and other now well established divisions of the course assigned to students in that department of engineering, were then untaught; but they were promptly introduced by Dwelshauvers-Dery, as the sciences upon which they were based and as the results of scientific research embodied in their respective fields of work were developed.

The young professor had enjoyed the exceptional good fortune of study under Brasseur, a great and famous professor of applied mechanics, who was able, despite his slight facilities for such work, to bring into the profession many distinguished men, who, later, contributed effectively to the industrial progress of Belgium. His mind was of that synthetic character which enables its possessor to condense into the fewest words the clearest ideas and to present a formidable theory in a manner readily appealing to the student's mind. His motto was *non multa, sed multum.*

Dwelshauvers-Dery, whose powers and inclinations led him rather to work independently than to follow the leading strings of a teacher, became enthusiastically charmed by the instruction of Brasseur and the master and pupil became at once warm friends. The pupil became, later, the répétiteur, and still later, the successor, of Brasseur.

But Brasseur was a pure mathematician and cared comparatively little for practical applications of his science, and not at all for the reconciliation of his computed results with practical experience. The outcome of a computation was to him positive knowledge and quite sufficient for his purposes. Precisely the opposite were the characteristics of his pupil. The latter desired, above all things, to compare theory with experience, to experiment and to investigate in the realms of physical science and of engineering practice.

Facts, *la vérité réelle*, were sought by him with avidity. This disposition led him to the detection of many defects in the then practiced methods of instruction in applied mechanics and in engineering, which topics were peculiarly subject to these defects as then taught. So-called principles, written, inaccurately, by one writer, and repeated, parrot-like, by his successors, constituted too largely the code of applied mechanics then in vogue. Thermodynamics, as a science, was then in its infancy and had not found its place in the theory of steam and other heat engines.

Fortunately, the courses of instruction of those days were not as overloaded with work as those of to-day, and the young professor made full use of his opportunity to take up his chosen line of original work. He desired, above all things, to experiment, to investigate; and he lost no time in carrying into practice his ideas of the engineer's task in his department.

Visiting the London Exhibition of 1862, he was greatly impressed by the Porter-Allen engine,—there for the first time exhibited to the engineers of Europe,—and also with its Porter governor, and with the Richards indicator attached to the engine,—the first of all indicators adapted for use on "high-speed engines."

He at once bought the latter, and the first Richards indicator going upon the continent of Europe thus found its way into the collections of the École des Mines of Liége. The instrument is still in use and is regularly employed in the laboratory of M. Dwelshauvers; but it was, as he says, "a long time mute." He could only show it as an interesting, but as yet practically inapplicable, piece of apparatus.

By 1870, the views of M. Dwelshauvers-Dery became well formed, and he saw clearly the necessity of establishing a mechanical and engineering laboratory in which the students of the school could be given practical instruction relating to the materials of engineering, its processes, and its special apparatus and machinery.

He sought to secure such a laboratory for his own students, but for a long time without avail. It finally came; but he was nineteen years getting his steam engine laboratory. He taught the Zeuner theory of steam distribution, the Rankine theory of thermodynamics, the Culmann methods of graphostatics. He reduced all subjects, as far as possible, to a form which permitted laboratory illustration and investigation. In his experimental study of the steam engine, he soon discovered a discrepancy between the theory which he had been accustomed to teach and the practical results of his researches in heat conversion.

In 1873, he was made a member of the International Jury at the Vienna Exposition, and it was here that both he and the writer,—then one of his colleagues on the jury,—in the discussion of these problems began to see light breaking in this field.

Dwelshauvers visited Messrs. Hirn and Hallauer at Colmar, in Alsace, for the special purpose of continuing his investigation of the extent and the causes of the discrepancy between the pure thermodynamic, and a correct, applied theory of the steam engine, so clearly illustrated by the earlier experiments of Watt, as well as of Clark, of Isherwood, and of Hirn himself, in later years.*

After a brief conversation, Hirn proposed that his visitor should make use of the steam engine already employed by the former in his now famous researches, to verify those results. The offer was as promptly accepted, and Dwelshauvers joined MM. Grossteste and Hallauer in further investigations, in the establishment, and under the eye, of that great master to whom the young man was now instinctively attracted; and thus originated a friendship which became stronger and more permanent as time went on. The project of a steam engine laboratory, in which such researches could be satisfactorily prosecuted, took shape in the mind of the new disciple of Hirn and he at once entered upon a discussion of his plans with his new friend and teacher.

In 1876, Hirn prefaced the report on the work of Hallauer relative to these investigations with the following statement:—

"M. Dwelshauvers-Dery expressed to me a desire to aid and co-operate in experiments on the steam engine, following the method which I have described in my recent work on 'Thermodynamics.' He came, not simply as a friend and as a savant, but also brought official authority, and came charged with a mission, in the name of his minister. * * * Convinced, on his part, that many and systematic researches on the motors generally, and on the steam engine in particular, must lead to real progress, he had, further, conceived an idea both grand and useful,—that of founding at the university in which he was professor, a physical and mechanical laboratory where young men could study, and could also produce results of real utility while studying."

* For details see "The History of the Growth of the Steam Engine," New York, D. Appleton & Co., and the historical portion of the writer's "Manual of the Steam Engine," New York, John Wiley & Sons.

The young investigator had taken charge of a course which included the discussion of the steam boiler, but not of the condenser. The facts that the one was the complement of the other, and that vaporisation and condensation take place in the steam cylinder of the engine itself, and play an important part in modifying the thermodynamic theory of the machine, were not then recognised by scientific men.

He introduced a new treatment of both phenomena into a course in applied thermodynamics, experimentally illustrating its applications. Many other improvements were effected in the course, and higher mathematics, graphical statics, and mathematical physics, with courses in the description and design of machinery, were, after a time, offered to all the students of the institution.

Still the authorities lent a deaf ear to the constant calls of the new incumbent of the chair of engineering for laboratories and experimental apparatus. It was not until 1879 that he was able to make a real beginning, receiving, at first, but 10,000 francs, later small sums from time to time, and thus gradually building up his long-hoped-for laboratory.

His first endeavour was to provide for experimental steam engineering, and he purchased an "Experimental Engine." This engine was first exhibited at the National Exposition of Belgium in 1880, but was not then set up at the University of Liége. No place was provided for it by the university. M. Beer, its builder, generously provided a location within his own works, without charge, and supplied steam from his own boilers. There, at a distance of six miles from the university, Dwelshauvers carried on his work until able to transfer the machine to his own college laboratory. Vainly appealing to the university and the State for aid, he determined to draw upon his own limited resources rather than surrender the opportunity to enter upon the magnificent work now opening before him.

The professor and his pupils gained an instructive experience in the operation of this embryo laboratory, and yet were unable to secure results, following Hirn's method of analysis, that were satisfactory. Steam leaks at every point, at one time or another, invalidated their work, and only a Job-like patience was finally rewarded.

During this period of struggle and suspense, other steam laboratories were organised. As early as 1876, Linde, at Munich, had set up an experimental steam engine; and Dwelshauvers' example was followed by many of the principal European, and later by some of the American, schools of engineering. But it was ten years before the value of this method of practical instruction was fully recognised.

The school at Liége, which should have been first in the list, was, of necessity, late in its date of complete organisation. Dwelshauvers proclaimed his needs and the promise of his great plans to his students in 1887, and re-enforced himself by opinions obtained by correspondence with men like Zeuner, Haton de la Goupillière, Collignon, Colombo, Hirsch, Schroeter, de Comberousse, Schmidt, Doerfel, Fliegner, Unwin, Kennedy, Donkin, Willans and Davey and a number of American workers in the same field, who were thought to be authoritative advisers in this matter. He published their opinions, and was supported loyally by M. Ollivier in the *Revue Générale des Sciences*.

Weiler, a well known engineer and friend of the mover and of the movement, instituted a "referendum" among engineers with a similar purpose, and every class of scientific and professional men was appealed to. Nearly every one consulted declared in favour of the modern method; the minority was insignificant. Even all this pressure upon the officials holding the power to inaugurate the work would have been insufficient to secure official action, except for the influence of M. Frère-Orban, who had, from the first, favoured it.

After twenty years of this unimaginable and indescribable toil, in 1893, the University of Liége finally gave this patient and persistant pleader his mechanical laboratory, including his steam engine and all the accessories for which he had laboured so long and at such disadvantage. From 1894, students were enabled to take part in the work of this laboratory regularly, and as a part of the scheduled course of instruction in mechanical engineering.

The outcome of that year's work was published in the *Revue Universelle des Mines** of the university, and that work has since steadily continued. It included, in that year, the study of the economic effect of the steam-jacket when the engine was operated with saturated, and also with superheated, steam, and at ratios of expansion ranging from 1 to 10. It was found that, contrary to the earlier belief of the investigator, the use of superheated steam and of the steam-jacket together might prove, in some cases, useful.

The work of 1896 is already published, and the results of an attempt to determine anew the mechanical equivalent of heat by the use of the friction brake, those of the study of the economy of the steam-jacket at a ratio of expansion of 10, and the effect of draining the valve chest, are among these new determinations.†

The outcome of these experiments and researches was the proof that thorough separation of moisture from the steam, at the entrance of the latter into the steam chest of the engine, was an element of real importance. This fact has special interest for the engineer, as it had, earlier, under peculiar circumstances, been apparently controverted, and the desirability of supplying dry steam to the engine has been denied by some practitioners. It was found that the reduction of the moisture in the steam from 5 to 8 per cent. to 1.5 and 1.8 per cent. yielded a gain of 9 per cent. in the unjacketed, and of 12 per cent. in the jacketed engine. The jackets gave gains of 26.5 per cent. with the wet, and of 28.75 per cent. with the dry, steam. But the greatest work, recently performed by Dwelshauvers-Dery, related to a vastly more impressive physical research.

* Vol. xxxiii, 1895.
† Ibidem, vol. xxxiv, 1896, p. 141.

The most striking and, in the view of men of science, most important, of these researches was that of determining, anew, and on an actual heat engine of commercial size, the value of the mechanical equivalent of heat. This engine, by its peculiarly delicate adjustments, and its complete adaptation to work in research, was well suited to furnish the required data.

The result of a series of six very carefully and exceedingly skillfully conducted experiments, was the computation of the value of Joule's equivalent as $J = 426.2$ kilograms, per calorie, or $J = 778$ feet pounds per B.T.U., Rowland's figure being, in metric measure, 426.8 under similar thermal conditions. The larger work of Dwelshauvers-Dery was within one-tenth of one per cent. of the generally accepted figure of the great physicist. There can henceforth be no hesitation on the part of either engineer or physicist in accepting this value as sensibly accurate.

A singular fact,—predicted, however, by Hirn,—was proven by these experiments:—The mass of steam in the engine is not homogeneous. Water was drained from the steam chest when the steam pipe contained steam superheated to the extent of 35 degrees or 40 degrees C. (63 degrees to 81 degrees F.) and the thermometer showed superheating at the entrance into the steam cylinder. Collating the work of other investigators, Dwelshauvers enunciated the following principle, since sufficiently confirmed by direct experiments:—"The most economical operation of the steam engine is secured when, by any efficient means, whether jacketing, superheating, or other, the cylinder wall is brought to a condition of perfect dryness at the beginning of the exhaust period."

The familiarity of M. Dwelshauvers-Dery with the work of Hirn, his own researches, and the work accomplished elsewhere on both sides the Atlantic, rendered him a suitable historian of these latest developments in this great field of engineering research and he was urged by his friends and by scientific men among his correspondents to undertake the task of putting on record such a history. This was done and, at the same time, the talented writer, for the first time, constructed an algebraic theory of the case, of the Hirn analysis.

He constructed the equations for each phase of the cycle of the steam engine and thus completed the work of Hirn by reducing it to consistent and exact theoretical form. Zeuner reproduced these equations with some modifications which, in the opinion of their originator, restrict their application and their value. This "Étude Calorimétrique de la Machine à Vapeur" is published in one of the volumes of the *Encyclopédie de Léauté*. The seven equations, finally developed, constitute the existing calorimetric theory of the steam engine. They are, in this last publication, supplemented by a new enunciation of the principle above stated, thus:—

"The less the quantity of water remaining on the surface of the metal of the cylinder wall at the instant of opening the exhaust passage, the less the consumption of steam by the engine. When the ratio of expansion is varied from one to another extreme of values, it will be found that the measure of steam consumption and of efficiency will pass through a series of values also, giving a minimum cost of power and maximum efficiency of steam employed at a point which corresponds to that at which this condition of final dryness of the cylinder wall is secured."

Since 1867, M. Dwelshauvers-Dery has been present at nearly all international expositions, and has served upon the International Jury. These opportunities have been most thoroughly utilised as affording a means of studying the work of the world of mechanics, the methods of the great builders of all nations, and the latest and most advanced developments in science, pure and applied.

In 1888, the British Institution of Civil Engineers awarded him their Watt medal and the Telford prize for his discussion of the steam engine governor, in which he brought out a new and practical method of study of that accessory. In 1889, he shared with

Donkin a prize for successfully investigating the thermal action of the interior of the cylinder wall. The American Society of Mechanical Engineers had, in 1886, made him an honorary member of that great organisation, and, in the same year, he was made corresponding member of the Société Industrielle de Mulhouse. In 1890, two other great associations, the Société d'Encouragement pour l'Industrie Nationale de France and the British Association for Advancement of Science, conferred upon him the same high distinction.

These are undoubtedly great and well deserved distinctions and honours. But other qualities than those which appear in professional work distinguish the man and are not the less worthy of recognition that they are concealed from the great world to whom these scientific and professional works are patent. The man is greater than the practitioner and expert. Those personal qualities which make the real man may certainly be touched upon within the limits of a biographical sketch without exceeding its proper bounds. Personally, the subject of this notice is as magnetically attractive as admirable.

A personal acquaintance of nearly a quarter of a century,—with direct intercourse, often and long interrupted by intervals of space and time, but continuously maintained by a never failing exchange of correspondence,—has revealed to the writer qualities that have excited as much esteem as admiration. However imposing the work of the brain, it is the heart, after all, that makes the man.

With Newtonian characteristics of mind are here combined all those qualities of character and of soul which, only, can constitute the real man an attractive and lovable personality. He who makes close friends, who never forgets a friend, who may be relied, upon, in life and death, in sickness and in health, to prove loyal and honourable and honest, absent or present, whatever may be his magnitude of intellect, proves himself vastly greater for his higher quality of heart.

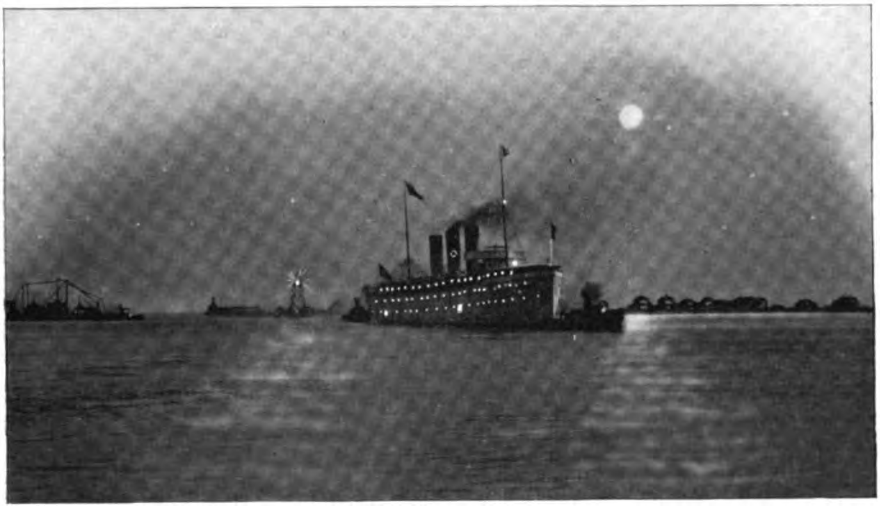
Serving with Dwelshauvers-Dery on more than one International Jury, at great "expositions," the writer long ago learned to recognise his breadth of view, his extended knowledge, his familiarity with his subject, and, none the less, his absolute impartiality and delicate sense of justice. No one of the distinguished and able men who served on those great juries ever showed more absolute freedom from jealousy of the work of other countries than his own. He proved himself an ideal juror, and a jurist as well.

Daily intercourse, for months together, brought into high relief his admirable qualities of head and of heart, and the happy fortune of a visit to his home, and an opportunity of seeing the husband and father in his own house, gave similarly satisfactory inside views of those characteristic features of domestic life which can exist only in the presence of a generous and happy disposition, of a noble soul.

This modest, but none the less great and justly distinguished, man is a great admirer of the political institutions which it is the blessing of the American citizen to enjoy. He attributes the wonderfully prolific inventive faculty of the inhabitants of the United States largely to the political freedom which gives unlimited latitude of choice of vocation and unrestricted action in that field of choice.

In Europe, thousands of men find themselves confined to the vocations of their fathers; in the United States thousands of men distribute themselves wherever their inclinations and their personal attributes best fit them to succeed. The consequence is that the thousands in the United States find opportunities to display such inventive powers as they may possess precisely in those departments of industry in which their genius finds best play and largest recompense. In Europe not one man in a thousand is an inventor; in the United States many in a thousand men are nearly all more or less occupied in invention. It is this, in his opinion, which largely constitutes the difference in the outcome of invention on the opposite sides of the Atlantic, and which gives the United States such marvellous power of advancement in all that makes modern life.

In Europe, Dwelshauvers-Dery is one of the still comparatively rare but now rapidly increasing number of men whose instincts for freedom, social and political, theological and intellectual, scientific and professional, compel constant activity and insure wide range of thought and work. It is this characteristically American character that, reinforcing a fortunate cast of mind and structure of brain, has made him one of the recognised leaders of Europe and of the world in his department of scientific work.



THE LAKE STEAMER "NORTHWEST" COMING INTO PORT AT NIGHT.

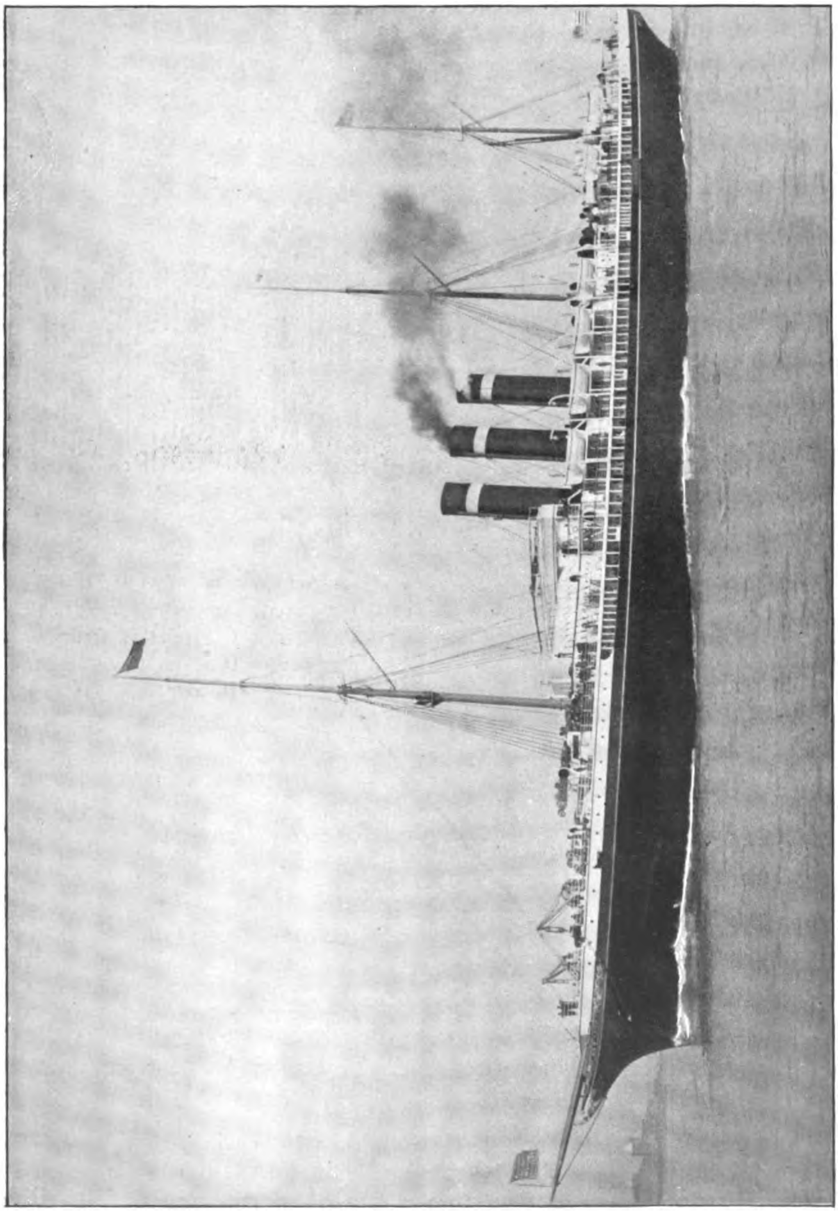
AMERICAN LAKE AND OCEAN STEAMSHIP MODELS.

By Joseph R. Oldham, N. A., M. E.

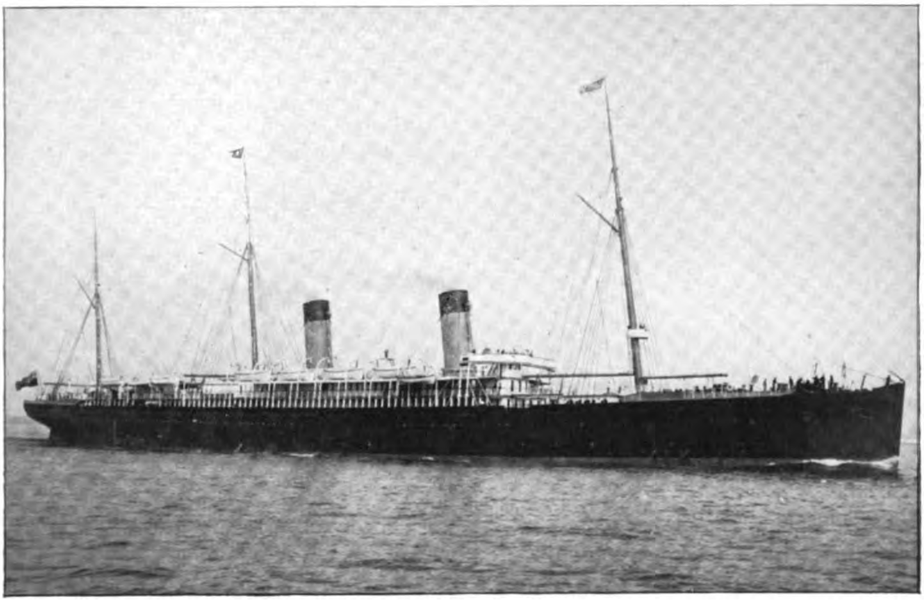
SEVERAL years ago the late Mr. Froude pointed out the now well known fact that it was possible by increasing the moulded breadth, and by fining the entrance and run, to design a ship model, which, at high speeds, would have considerably less resistance than the common merchant ship form, with about ten breadths in length.

Recently Mr. Archibald Denny, the eminent Scotch shipbuilder, in referring to very valuable information, obtained by experiments in a model tank, showed that for high speed a certain increase of beam, when associated with increased fineness in the ends, resulted in largely augmented efficiency.

As regards breadth, he stated that according to experiment, the beam of a certain type of side wheel steamer might be increased from thirty-five to thirty-eight feet with a gain of fully one knot an hour with the same horse-power, and on the same displacement. I have illustrated this in the diagrams on page 231, which show that though the breadth be increased about 8½ per cent., the angle of entrance and of run are largely fined, other features remaining the same.



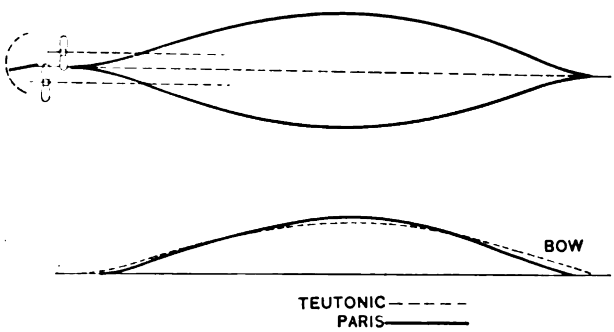
THE AMERICAN LINE STEAMER "PARIS." LENGTH, 575 FEET. BEAM, 63 FEET. TWIN SCREW, TRIPLE EXPANSION ENGINES. 20,000 HORSE-POWER.



THE WHITE STAR LINE STEAMER "TEUTONIC." LENGTH, 565 FEET. BREADTH, 57 FEET. DEPTH, 39 FEET. GROSS TONNAGE 9984.

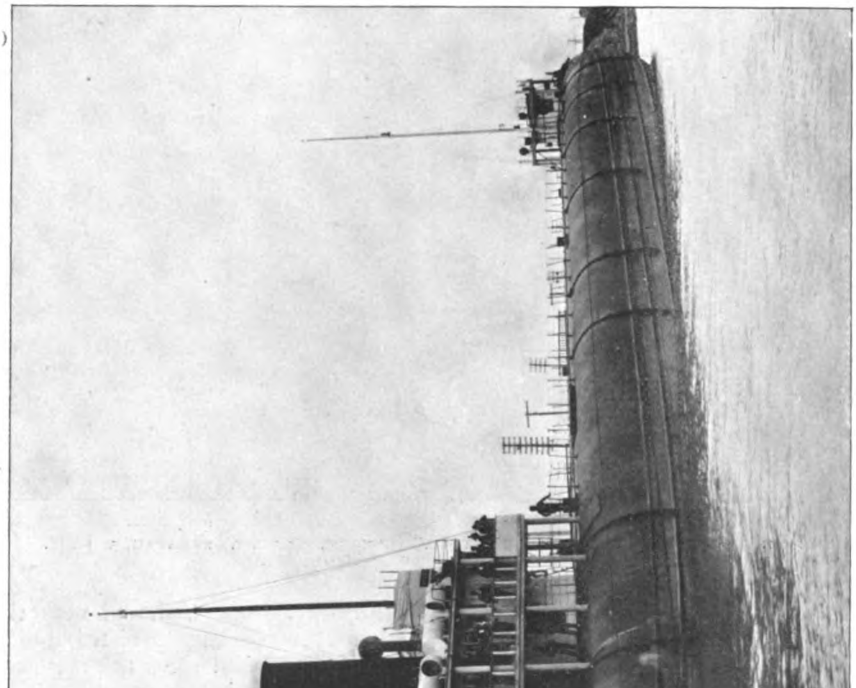
As to seaworthiness, consider the *Teutonic* and the *Paris*. The length of the former equals 9¾ times the breadth, that of the latter, 8⅓ times. The broader vessel is quite as speedy as the *Teutonic* and is a superior sea boat. This, however, may be partly due to her bow projecting above the water.

As reduced resistance with a large increase of beam can be obtained only by fining the ends, I may say that for ocean steamers a limit, beyond which the ends should not be fined, is soon reached. It is well known that ships with very fine ends, and which have their displacement abnormally concentrated near mid-length, are inferior as sea boats to ships with fuller bows and sterns. From this it should seem that high speed river steamers or smooth water lake steamers may be made comparatively full amidships, with fine ends, whilst steamers engaged in a generally rough water voyage, should have their buoyancy more largely distributed toward the bow and stern to prevent excessive pitching in a seaway.



THE WATER LINES OF THE ATLANTIC STEAMERS "TEUTONIC" AND "PARIS." THE UPPER DIAGRAM REPRESENTS THE "TEUTONIC" ALONE.

The great importance of good breadth is, however, to secure stability of form in merchant steamers subject to be loaded with homogeneous cargoes, such as grain or coal. I thus refer to the merits of ample breadth in proportion to depth, because broad ships are the most expensive to build; deep narrow vessels are much cheaper as regards



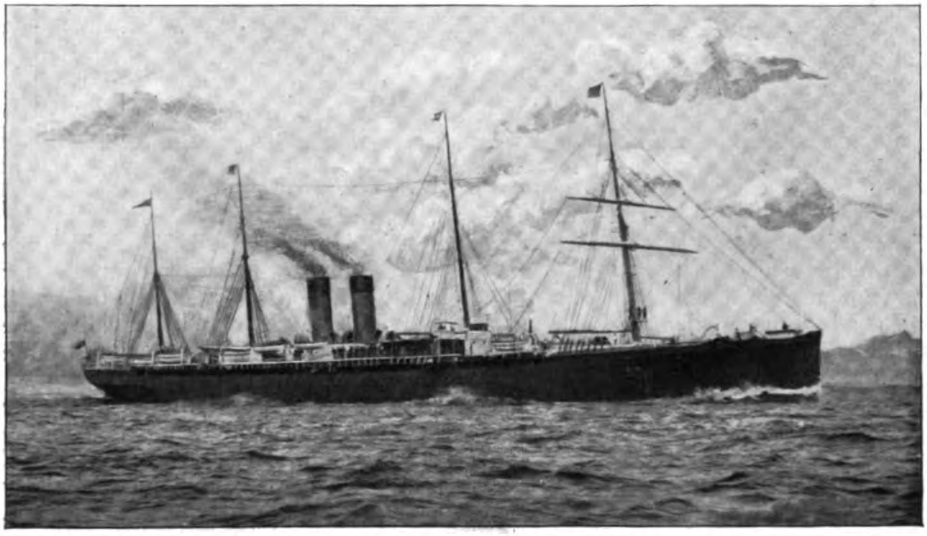
AN AMERICAN WHALEBACK STEAMER.

construction in proportion to dead weight.

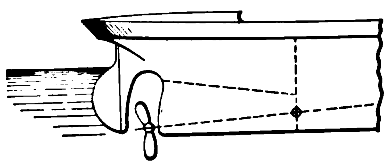
It is difficult to make comparisons, having any great claim to accuracy, as to the relative speed-efficiency in proportion to power expended in vessels of very diverse proportions and speed; but if a class of vessels be selected, of fairly high to very high speeds, a useful comparison may be made by using the familiar expression,—

$$\frac{\text{Dis.}^{2/3} \times \text{Speed}^3}{\text{I. H. P.}}$$

to ascertain the co-efficients. It may be taken for granted, that the performance is high if the co-efficient largely exceeds 250.



THE WHITE STAR LINE STEAMER "BRITANNIC." LENGTH, 455 FEET. BREADTH, 45 FEET. DEPTH, 33 FEET. GROSS TONNAGE, 3004.



THE LOWERING PROPELLER, AS ORIGINALLY FITTED, ON THE STEAMER "BRITANNIC."

Dealing with such steamers, it may be shown that a certain angle of entrance and run is a necessary factor to insure high efficiency. In illustration of this I annex diagrams, on pages 234 and 235, of several typical steamers, on which are shown the elements of entrance and run.

Let me compare an efficient twin screw steamer with some single screw ships of the same class. The Hamburg-American Steamship Company's steamer *Columbia* has a displacement of 10,106 tons, mean speed 18.95 knots, and indicated horse-power 12,850.

Then for this vessel we have

$$\frac{10,106^{2/3} \times 18.95^3}{12,850} = 248.$$

Though the efficiency of this twin screw steamer is extremely high, it is surpassed by some single screw passenger steamers, as the following figures will show:—

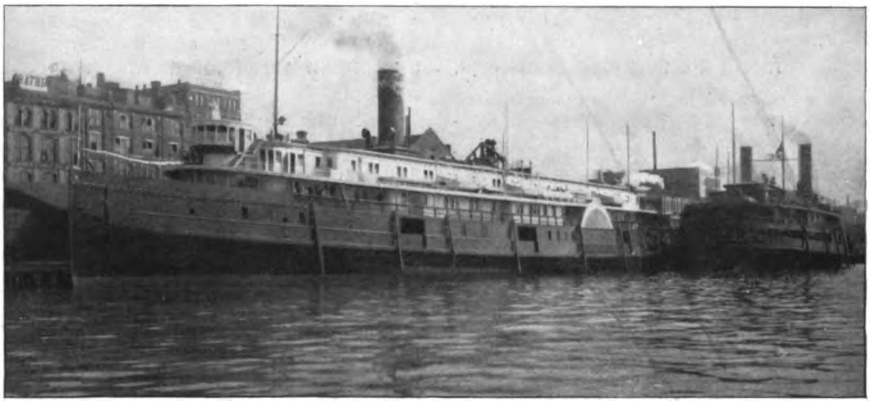
S. S. Sterling Castle...... $\frac{7600^{2/3} \times 18.4^3}{8396} = 286.8$

S. S. Furnessia $\frac{8578^{2/3} \times 14^3}{4045} = 284.$

S. S. Aller.... $\frac{7447^{2/3} \times 17.9^3}{7974} = 277$

S. S. Umbria.. $\frac{9862^{2/3} \times 20.18^3}{14,321} = 260$

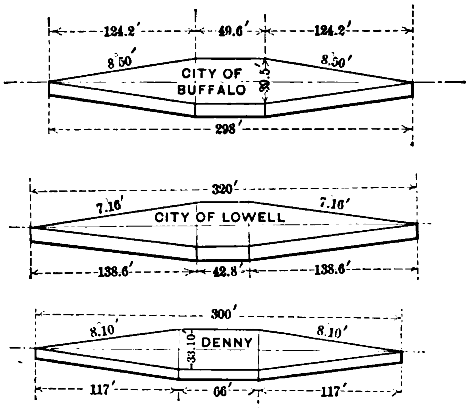
S. S. Ems.... $\frac{7030^{2/3} \times 17.55^3}{7251} = 273$



THE LAKE STEAMER "CITY OF BUFFALO."

From this it appears that single screws are much more efficient as a propelling instrument than double screws.

In addition to this comparison I would refer to diagrams on this and the opposite pages, which represent, in a general way, several typical steamers as they appear when delineated according to Kirk's analysis. I may explain that Mr. Kirk proposed to reduce al



BLOCK MODELS OF SOME TYPICAL STEAMERS.

ships to a definite and simple form, so that they could readily be compared. A block model is delineated, having the same length on water line, and the same mean draft of water as the ships under comparison.

The form consists of a middle body which is a rectangular parallellopiped, and the fore and after bodies, which are prisms having isosceles triangles for bases. The main breadth of the block model is determined by dividing the immersed area of mid-section by the mean draft of water.

As rectangles and triangles are the simplest forms of figures, and are more easily compared than surfaces enclosed by curves, so the model adopted by Mr. Kirk is bounded by triangles and right angles. The wetted surface, as calculated by the block model, in very fine hulls exceeds that of the actual surface by about 5 per cent., and for full steamers by about 2 per cent. For all purposes of comparison between merchant steamers it is safe to take the surface of the block model.

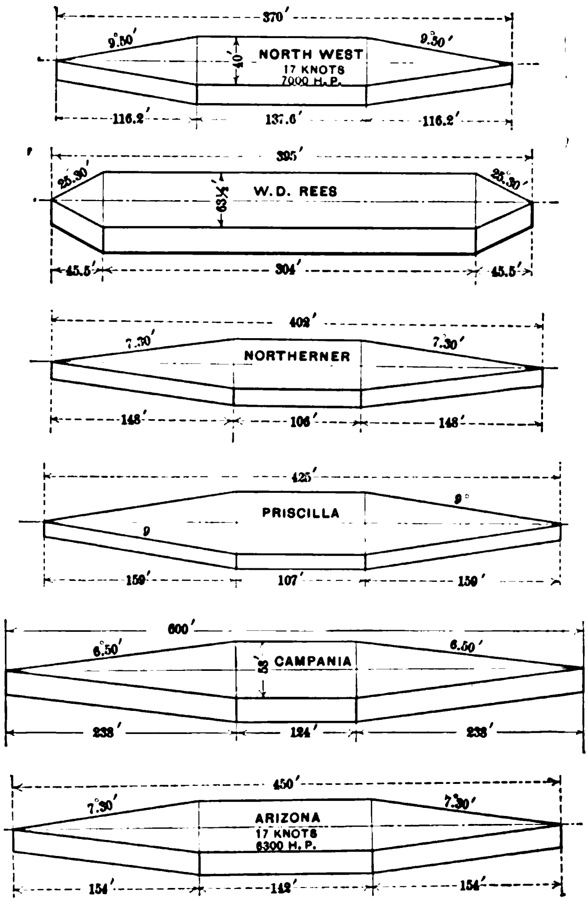
The most potent factor in favour of double screws for deep-draft merchant steamers of limited horse-power is the economy of duplication. The great advocates for this system are Messrs. Harland & Woolf, of Belfast, Ireland, but they were not always so. When they built the first White Star steamers, they had to pay George Forrester, or Messrs. Maudslay, Son & Field, Ltd., of Lambeth, Eng., for each set of engines, and in those days higher efficiency was sought by adopting a lowering screw propeller, attached to an inclined shaft, which caused the screw to be deeply immersed. But such a device was removed from the steamship *Brittanic* after working for a short time, and the screw was re-arranged in the ordinary manner.

Since the great Irish firm began to make their own engines, however, they would seem to recommend duplicate screws and machinery for vessels of all dimensions and speeds, and though such practice may not result in the highest mechanical efficiency, except for the largest high speed steamers, it has a tendency towards high commercial efficiency in the offices of marine engineers.

Too much stress is commonly placed on the benefits of deep or even total immersion of screw propellers. Such an enterprising and discriminating class of people as the British East coast shipbuilders and steamship owners would hardly continue a wasteful and extravagant practice in connection with the working of their screw colliers, which invariably make half the voyage on a draft of water that does not cover the screw propeller in still water by two or three feet, if the result of such arrangements ended in loss.

If this is still the rule after a quarter of a century's experience, and that in the face of available information concerning the efficiency of similar vessels working with the screw totally submerged, it may be accepted as a fair proof that the efficiency of propulsion is not seriously impaired if the screw propeller is partly above the surface in still water. The idea of gaining in general efficiency by largely increasing the depth of immersion of the propeller was erroneous, for Mr. Renni showed that after a depth of four or five feet was reached, increased immersion had practically no effect.

With regard to American lake steamers, it appears to me that the problem facing the designer of a passenger steamer for service is by no means easy of solution. The most suitable type of steamer for a great part of the voyage would be that of an enlarged *City of Buffalo* or one similar to the new Fall River Line steamer *Priscilla*, whilst for

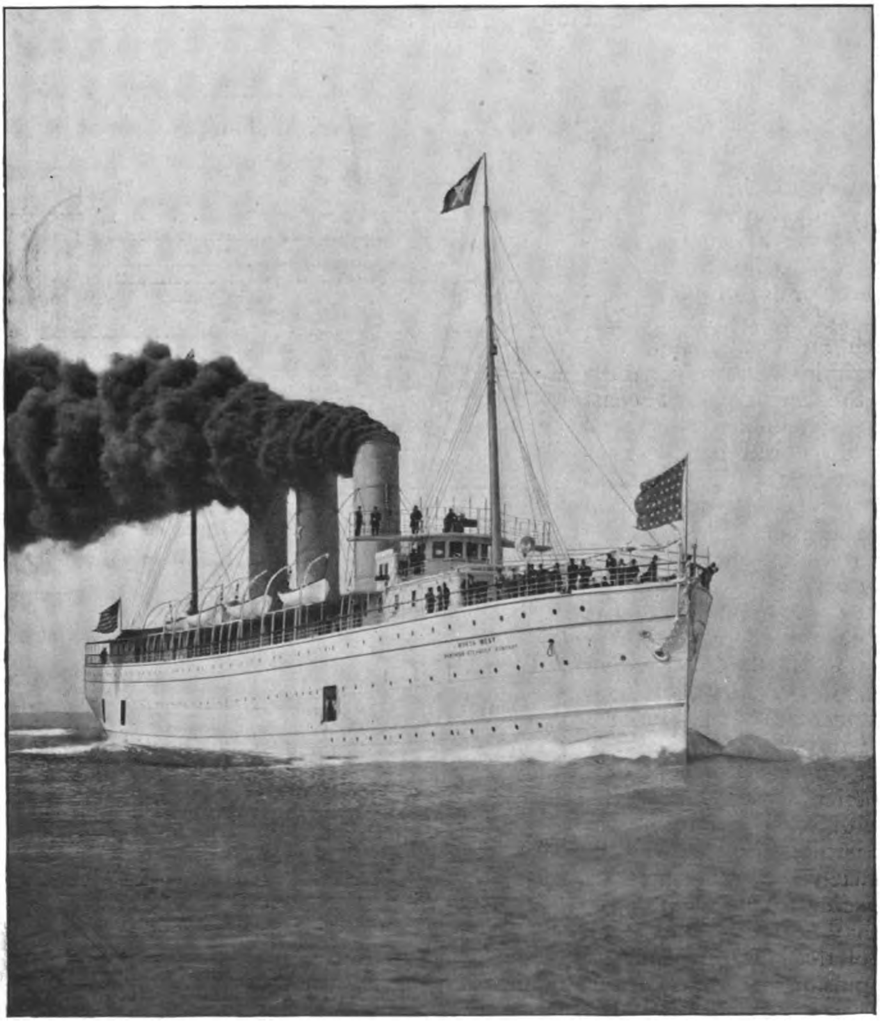


BLOCK MODELS OF SOME TYPICAL STEAMERS.

the fall trade over Lake Superior a P. and O. steamer would not be too strong nor too well protected.

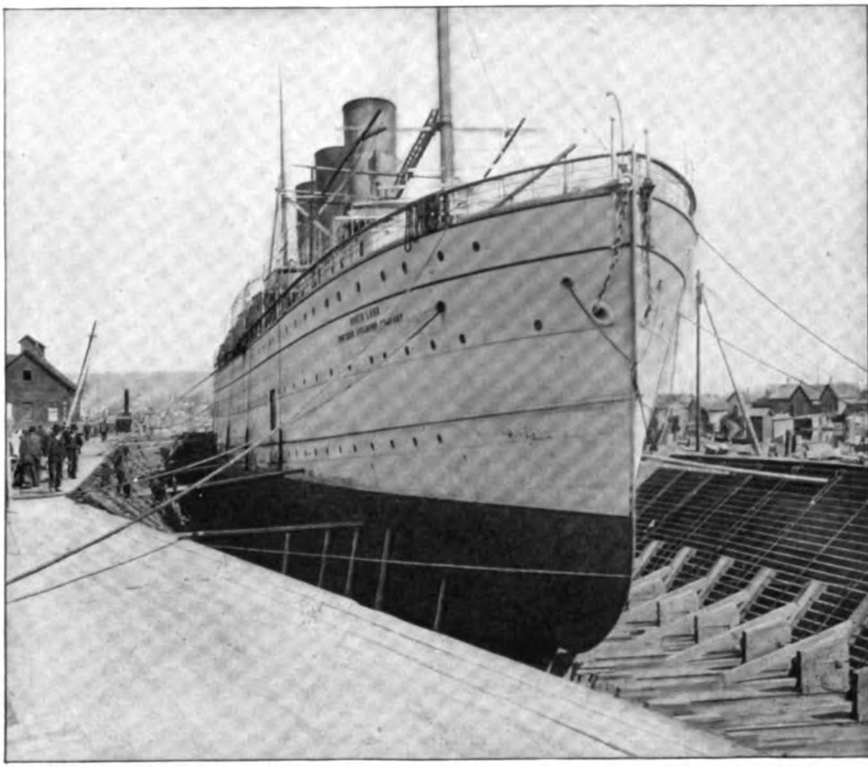
Economy in coal consumption is by no means the most important factor contributing to success in a short passenger trade when the vessels composing the fleet are few. This was the view taken by the Flushing & Queensboro Company, of Flushing, Holland, who have after many years of experience adopted side wheels in preference to twin screws.

A screw, worked by a high-speed quadruple or multiple expansion engine is, undoubtedly, the best means of propulsion for a merchant steamer engaged in a deep sea trade, but for shallow water navigation a side wheeler is preferable, for as a propelling instrument the paddle wheel is not inferior to the screw, while its action is quicker in stopping and starting the hull, and side wheelers can back on a straight course which cannot be accomplished by a screw steamer. Moreover, a side wheeler does not sag at the stern when under way, and this is a very important feature in its favour. The screw is more liable to be disabled by picking up a submerged log, or by striking some such obstruction and breaking two or more blades. This is not an unusual occurrence.



THE AMERICAN LAKE PASSENGER STEAMER "NORTH WEST," BUILT BY THE GLOBE IRON WORKS, CLEVELAND, O. LENGTH, 388 FEET. BEAM, 44 FEET. TWIN-SCREW, QUADRUPLE EXPANSION ENGINES, 7000 H. P.

As regards the seaworthiness of side wheel steamers the immunity from dis-



THE STEAMER "NORTH LAND," A SISTER SHIP OF THE "NORTH WEST," IN THE WEST SUPERIOR DRY DOCK, DULUTH, MINN.

aster enjoyed by such lines as the Holyhead packets, the Isle-of-Man steamers and the Queensboro-Flushing boats should be sufficient to prove their staunchness for channel service, but a more signal proof of their safety may be cited.

The Cunard Royal Mail Steamship Company have, during the last fifteen or twenty years, lost several screw steamers, accompanied by loss of life and letters, but previous to that it was their proud boast that they had never lost a ship, a life or a letter for a period of forty years, and the remarkable fact, in connection with such marked success, is that during the whole of that time their best boats were side wheelers, viz., the *Persia* and the *Scotia*.

If reliance may be placed in an article which recently appeared in one of the technical journals, an interesting comparison may be drawn from a so-called race between a high-speed twin screw and a side wheel passenger steamer. It is stated that the latter covered a certain distance in forty-six minutes against forty-seven minutes occupied by the former, the ratio in knots per hour being as 19.67 : 19.27. For steamers so nearly alike as regards speed it may be fair to compare them by the above quoted formula, viz.:

$$\frac{\text{Dis.}^{2/3} \times \text{Speed}^3}{\text{I. H. P.}} = C,$$

the corresponding figures being:—

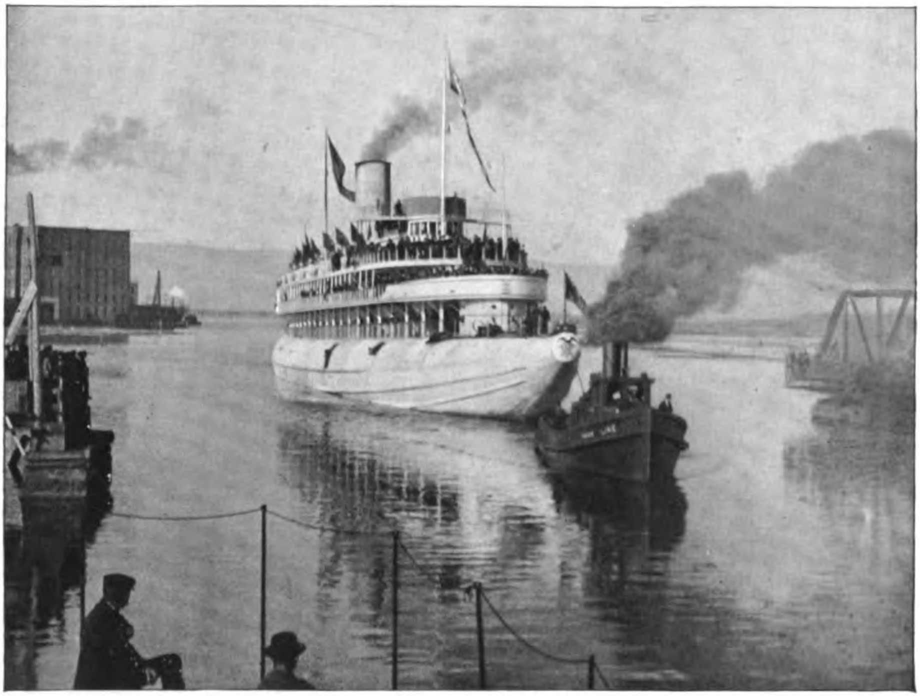
Side-wheeler.

$$\frac{4940^{2/3} \times 19.67^3}{8500} = 260.83$$

Twin Screw.

$$\frac{2270^{2/3} \times 19.27^3}{4347} = 285.74.$$

Judged by the above expression, the higher efficiency belongs to the twin screw. It is intimated, however, that the side wheeler was greatly retarded



THE PASSENGER WHALEBACK LAKE STEAMER "CHRISTOPHER COLUMBUS."

by a change of trim; be that as it may, such efficiency is remarkably high for a side wheeler as well as for a twin screw.

To attain an equal speed with twin screws, the horse-power would have to be increased as follows:—

$$\frac{2270 \times 7645}{285.74} = 4700.$$

That means 353 more horse-power or fully 8 per cent. This increase, if maintained, would probably involve some extra weight and augmented displacement and wetted surface, so that the same co-efficient could not then be used as a constant. From this it appears that as propelling instruments, side wheels are not inferior to twin screws.

As the steamer *North West* is the first high-speed twin screw passenger steamer that ever floated on the American inland seas, it may be permissible to make a brief comparison between that magnificent vessel and an ocean liner of about the same breadth, speed and horse-power, though some eighty-five feet longer. The *Arizona* has averaged fully 17 knots,—about 19.6 statute miles,—per hour, with 6300 indicated horse-power over an ocean voyage. This is high efficiency; she has a single screw. Many years ago Scott Russell said that two screws could not propel as economically as one, and I think he was right to that limited extent, though somewhat mistaken in his general views on the advantages of twin screw propulsion.

Not less than 7000 horse-power must occasionally be indicated by the engines of the *North West*, but the mean indicated horse-power over a voyage will probably not exceed 6000. As to her speed, she has steamed through Lake Huron, a distance of 228 miles, in nine and three-quarter hours. That equals an average speed of 19.58* miles an hour or about the same as the *Arizona*. Such a high speed has never before

* I am assured that the *North West* has gone much faster for several hours than as stated above, and the *North Land*, a sister ship, is faster.

been equalled on these lakes for so many hours. The wetted surface of the *Arizona* is 23,600 feet, and this, divided by $100 = 236$, and $\frac{6300}{236} = 26.7$, which is the horse-power required per 100 square feet of wetted skin.

The *North West* has a wetted surface of 16,680 feet, and this, divided by 100 and again by the I. H. P., gives 36. From this it would seem that the twin screw steamer requires much more horse-power than the single screw steamer; but it must be remembered that the absolute length of the latter is much greater than the former, the ratio of length to breadth is higher, her length of entrance is 26 per cent. greater, and angle, 3½ degrees finer. I have calculated the wetted surfaces by block models.

If the length of entrance of the *North West* were increased 31 per cent., which would make her total length on the water line 405½ feet, she would have the same angle of entrance as the *Arizona*, viz., 7°30′; then, with the dead wood cut away, and certain other modifications made, the horse-power per square foot of wetted surface could be reduced about 25 per cent. to attain the same speed, or a speed of nearly 18 knots per hour could be obtained by the present power, as the weight of machinery would then be largely reduced.

In other words, I may say that a single screw steamer, having an angle and length of entrance made, in effect, to correspond with the *Arizona* a speed of 18 knots, or nearly 20¾ miles, an hour could be obtained in deep water with 5949 horse-power.

Indicated Horse-Power per 100 Feet of Wetted Skin.

Steamers.					
Campania	54.7	at	22	knots	per hour.
Torpedo	60.9	"	22	"	"
Priscilla	34.7	"	19.67	"	"
City of Lowell	30.25	"	19.27	"	"
" " "	32.29	"	19.69	"	"
Arizona	26.7	"	17	"	"
W. D. Rees	7.	"	9	"	"

THE SALOON OF THE STEAMER "CHRISTOPHER COLUMBUS."

As a further comparison of the efficiency of single and twin screws, the foregoing table, showing the horse-power required per square foot of wetted skin, may prove interesting.

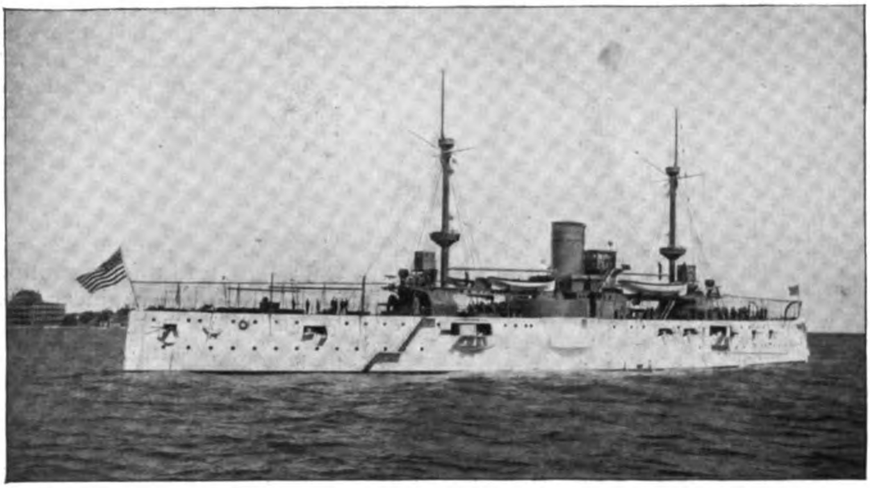
There are, no doubt, certain great advantages connected with the adoption of twin screws, but, in my opinion, these advantages may be too dearly bought. For merchant steamers the cost of production is greater, the cost of insurance increases in an equal ratio, a larger engine room staff is required, and extra cost of maintenance is involved. But of more importance than all is the extra weight of machinery required for a twin screw over a single screw of equal speed.

The owners and builders should be the best judges of the type of steamer most suitable for their trade. Increased length means increased risk when navigating shallow and tortuous rivers and harbours, and for such work twin screws are certainly more suitable than a single screw would be; but the general economic efficiency available by resorting to augmented length and single screw propulsion is manifest.

However naval architects and marine engineers may differ in their views with regard to form or motive power, one thing, I think, has been clearly demonstrated, viz., that the higher the speed, the greater the safety; and the more palatial and luxurious the apartments and furnishings, the more satisfactory will be the commercial results of operating lake, sound, or ocean steamships.

Current Topics.

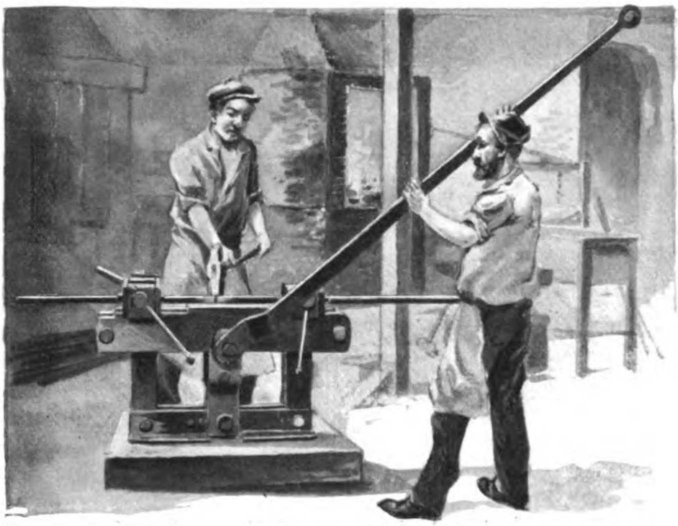
STORAGE batteries have pretty well demonstrated their value as electric central station auxiliaries and are now used in many cases with satisfying results, helping admirably to " take the peak off the load line,"—that bugbear of the station manager. There is another use, however, to which a storage battery plant may be put, and which will appeal perhaps most strongly to the electric street railroad man. This, as pointed out recently before the American Street Railway Association by Mr. Richard McCulloch, is to install the battery plant as a sub-station to maintain the voltage at the ends of long feeders, which are subject to fluctuating loads. In this case the batteries are charged from the distant power house and discharged into the trolley wire, and the feeders from the power house to the storage batteries are figured only for the average load instead of the maximum load, as would be necessary in case the line is fed directly from the power house. The economy in this installation depends very largely upon the difference in cost between the feeders in the two cases. Besides the question of economy, however, the sub-station will give the better service, as the voltage will not fall and rise with the fluctuations of the load.



THE UNITED STATES BATTLE SHIP "TEXAS." LENGTH, 290 FEET. BREADTH, 64 FEET, 7 INCHES. INDICATED H. P., 8600. SPEED, 17 KNOTS.

NAVAL engineers on both sides of the Atlantic, who have become more or less familiar with the remarkable behaviour and performances of the United States battle ship *Texas*, must have reached the conclusion before this that in her the American government possesses a freak ship of the first order. From the very beginning, even before any trial had been made at sea, she developed defects of design and construction too numerous to recount here; she passed through accidents of almost every variety, from the loss of an anchor to running aground on the New England coast, and as a final exploit she recently sank to the bottom at her anchorage in the New York Navy Yard. And with all this she has cost about as pretty a penny as any ship that the American government has ever floated. It is now, therefore, an interesting question in the United States, if not in England where she was originally designed, as to who should bear the burden of responsibility for her in her present shape. Her English designers may well lay it upon those who juggled with her from the commencement of the construction work, and the particular officer of the United States naval construction corps who had her in hand from the outset has a splendid opportunity to make explanations. At this date of writing these explanations seem to be in process of manufacture, and if they should ever be made public they ought to make reading of a most interesting and suggestive kind.

WHAT is known as the Debombourg forging machine, for which the Joseph C. Nicholson Tool Company, of Newcastle-on-Tyne, England, and New York, are the agents, has, of late, gained considerable prominence as a smithy's adjunct of a very convenient kind, enabling the welding together of either flat, square, angle or round iron and steel sections most expeditiously,—certainly in less time than is required with the ordinary method. The machine is a very simple piece of apparatus and the accompanying little sketch tells about all that seems to be



THE DEBOMBOURG WELDING MACHINE.

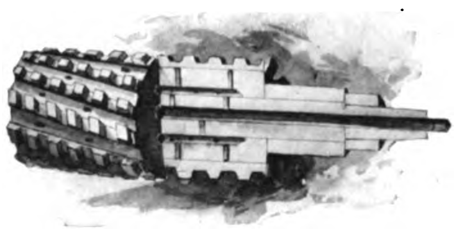
necessary in the way of description. There are a couple of vises, set to suit the sizes of the pieces to be jointed, care being taken to see that the ends come directly opposite each other when tried in the machine. No scarfing of the ends is needed. The pieces are brought to a welding heat, put into the machine as shown, and, being immediately gripped by the vises, are squeezed together by turning the lever. While the pressure is on, the outside of the weld should be closed by hammering, the bottom side being reached by lifting the lever, opening the vises and turning the bars. Should it be desired to forge a collar on the end of a bar, a square block, furnished with the machine, is fitted into one of the vises, and the end of the bar, being heated, is pressed against the block till the iron is swollen to a size large enough for the collar required. A collar in the middle of a bar is forged in the same way, except that the bar is gripped in both vises. There should be an anvil block on the machine at each side of the part of the bar which is heated. Different shapes may be pressed out on the machine by means of dies and moulds, and metal bars may be elongated whilst hot by forcing the vises apart instead of together. In fact, a variety of uses will readily suggest themselves for which the machine will prove of good service.

RECENTLY brief reference was made to the prostration of two engineer officers of the United States battle ship *Indiana* through overwork. One of these has been, since then, placed on the retired list of the navy, it is said. The other, a chief engineer, who, it is stated, was thirty-six hours on duty in the exhausting temperature of the engine room, is yet in hospital. Lately, it is reported, there were breakdowns in the cases of two engineer officers attached to the American fleet in Chinese waters. And, again, the now familiar story comes from the Mediterranean station that an engineer officer there has succumbed to the strain. One may well ask what overpowering motive lies beneath the opposition to an increased force of engineer officers which has wrought such havoc in the United States Navy. The answer to this question is bluntly given in the words of one of these gentlemen of the Line:—"In our engine rooms we want the class of men who run the engines of the great liners. * * * These men would be attached to the service by warrants. * * * We do not want college graduates, looking forward to commissions and advancement; we want practical engine drivers." In other words, let there be of the present engineer corps but a chief engineer and one or more assistants on the larger ships for supervisory duty, leaving the watch duty on those ships and the entire duty on the smaller ships to the proposed warrant engineer. It is decidedly questionable, however, whether it will be practicable to draw into the American naval service "the class of men who run the engines of the great liners." In fact, it is a good deal more than likely that these men would be the last to enter the naval service. Its whole system, as stated not long ago in the *North American Review*, by the president of the American Marine Engineers' Beneficial Association, "is distasteful to them, founded, as it is, on the tradition of the past, and exalting, as it does, one class of officers unduly, while it minimises the importance of the engineer. * * * Yet we hear continually that, in time of emergency, the engineers of the merchant marine will seek these difficult and dangerous positions which, in times of peace, have no attraction for them."

THE prostrations to which allusion has been made, the recent grounding of the *Texas*, and the later accident to that somewhat absurd fighting machine in the New York Navy Yard, should ring the knell of the obsolete organisation of the United States corps of naval engineers, with its scanty numbers, its responsibility without authority, and the many other onerous conditions under which it labours. Unless a change shall come, and soon, there will yet be some disastrous calamity on American war ships, which, in loss of life and property, will stir the nation. That the inevitable has been delayed thus far, is due only to the fact that engineer officers, with remarkable self-sacrifice, have fallen in their places in the fight to ward it off. There is, however, a limit to their physical endurance and the strain will yet conquer the strongest and bravest of them.

FROM France there comes a story which, if mayhap not true, has at least the germs of possibility in it, and has been served up as a warning to teamsters who drive high loads of machinery on roads where electric wires are strung. While a large boiler was being drawn through the streets of Calais by sixteen horses, so the tale goes, the upper portion of it came in contact with overhead electric wires, breaking them. Some of the wires caught on the boiler and the framework of the truck, and all the horses were knocked down and several of them were killed. The men engaged in transporting the boiler received violent shocks, from the effects of which some of them are said to have died. All this has a suspicious colouring, and yet it is suggestive of a possible danger which it would be well to bear in mind.

THE principal trouble in running milling machine cutters at high speeds and rapid feeds is, that no matter how much water or lubricant is allowed to flow over the outside of a cutter, the cutting edges will become heated. The heat gradually recedes into the body of the cutter and satisfactory cooling becomes difficult. To overcome this, the Newton Machine Tool Works, of Philadelphia, have devised an ingenious



A NEW FORM OF MILLING CUTTER.

arrangement in which the cutter arbour is made hollow, with several perforations, as shown in the annexed sketch. The cutter is made with a little bit deeper chamber and with numerous perforations and with small holes drilled between the teeth. The lubricant is pumped direct into the arbour from one end to the other, and is thus not only on the inside of the cutter, but passes also through the channels and tends to keep the whole body of the cutter cool. The sketch shows a broken-tooth cutter which allows very rapid cutting; but the same system could be used for plain spiral cutters, inserted tooth cutters or any other kind. In milling a block of hammered steel, 7 inches wide, taking off a 1-16-inch cut, the Newton Works have run a cutter, like that here shown, at a speed of 90 feet a minute, and have fed the work at the rate of 10 inches per minute. After allowing the cutter to run for a long time on this work, it was found to be perfectly cool. The same system has been used on cast iron. While the wear on the cutter is much more excessive than it would be if running it dry at a slow speed and slow feed, the amount of work produced by the cutter before becoming dull shows a great percentage of gain. Another point in the system is that the numerous holes drilled in a cutter allow for expansion and contraction in hardening it, so that the risk of cracking it is reduced to a minimum. Taken altogether the arrangement seems to be a very effective one.

THE Wilson-Squire Naval Engineering and Educational Bill, now before the United States Congress, should receive the support of every patriotic American citizen. For years the growing needs of the new American navy, in point ot larger engineering personnel, have been given due prominence in the annual reports of the engineer-in-chief of the service, and painful prominence besides, by the prostration from overwork of many able engineer officers, so that the government, and the people, too, should be pretty familiar by this time with the general fact that while the nation has war vessels equal to any afloat, it has also a lamentably short-handed staff of properly trained engineers to take care of them. The engineering features of every navy to-day are the predominating ones of the naval service. The modern war ship, from stem to stern, is a mass of machinery. It is propelled by machinery; it is controlled by machinery; it is defended and it attacks by machinery. The engineer's achievements and his promptness in action make it what it is. And yet, withal, his worth is but grudgingly allowed. Individually, every engineer in the American navy, and in the British navy as well, has a little more than a fair share of professional burdens. His corps has been kept down numerically to an unwise, an unreasonable, degree; his responsibilities have been multiplied year after year, and his work has been maliciously belittled and his rank assailed over and over again by addle-pated, though politically influential, gentlemen of what should be a loyal, co-operating branch of the naval service; so that why he should still remain faithfully in that service, were it not for patriotic spirit, has been the wonder of the engineer in civil life.

AN important measure of relief in the United States Navy would be afforded by a successful outcome of the Wilson-Squire bill, the prime purpose of which is to increase the number of engineer officers to the extent demanded by modern war ship requirements. One of its provisions, accordingly, is that graduates of technical schools, whose course of instruction in mechanical engineering is considered satisfactory by the head of the naval engineering service and the Secretary of the Navy, shall be eligible for appointment as engineer cadets, and the additional purpose would thus be served by the bill of opening a further career for such engineering school men whose influence in the navy; too, would react most beneficially on the service. The civil school graduates would necessarily carry into the service more of the civilian habit ot mind and manner of viewing things, and would, in the natural order of events, compel the members of the regular naval corps to compete, not among themselves exclusively, but with picked men representing the best training of the country at large. It is right in connection with this excellent feature, however, that the antagonism is aroused of the chronic opponent of naval engineering progress,—that species of Line officer whose conception of what is good for the service and his country does not extend beyond the small limits of a mental horizon circumscribed by unworthy selfish interest and traditions of a dead past. In an unreasoning way he tries to make believe that military discipline is not to be achieved "unless it begins at the beginning,"—in other words, that engineer officers, in order to be useful, should be educated as youths in the government schools and nowhere else. This is simply rubbish. From the beginning, surgeons and paymasters have been educated at civil schools; engineer officers in the United States Navy, too, have come from such schools to within thirty years; and marine officers to within a very few years. Further, in the Line of the navy there is now a considerable number of officers who entered it from civil life during the war between the North and South; and in the United States army there is a far larger proportion of officers who entered in the same way. Has discipline been "difficult of achievement" with this large official body?

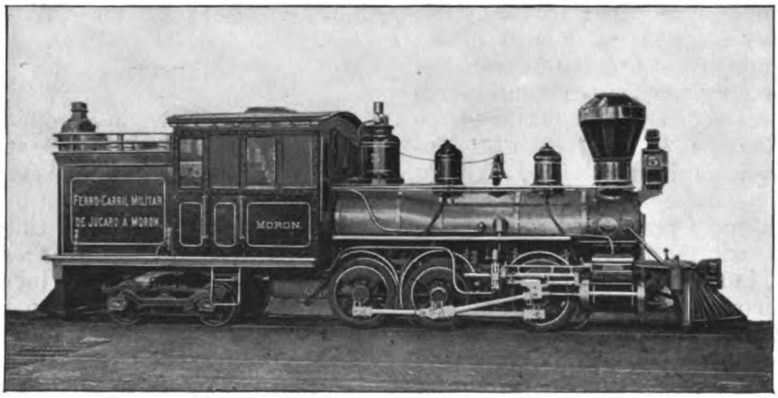
THE truth about the Line dread of the college feature of the Wilson bill is that if colleges would send their graduates into the Engineer Corps of the navy, they would see to it also that laws and regulations were so worded and carried out as to give their graduates full justice. As long as the officers of the Line have only the Engineer Corps to fight, they are numerically in the proportion of about four to one and may be able to successfully continue their policy of staff persecution; but facing the influence of large institutions of learning is a different matter, and would probably lead to results based upon honesty of purpose and integrity of methods. Neither of these, it must shamefully be acknowledged, have been conspicuous in the conduct of those gentlemen of the Line in the United States Navy who have lent themselves to work against just recognition of the proper status and importance of the naval engineer. It is time for the people themselves to take a hand in the matter; it is time, indeed, that the navy be regarded in its true light,—as a very elaborate and costly, though a very necessary, engineering establishment, in which engineering talent is the underlying, primary requisite for efficiency. Every possible honest effort should be exerted in the United States to make the Wilson bill a law.

ELECTRIC railways in Europe formed the subject of some interesting statistics recently embodied in a report sent to the United States government by Vice-Consul J. F. Monaghan, at Chemnitz, Germany. According to these the number of such railways was increased, during the year 1895, from 70 to 111, while the total length was raised from about 435 to 560 miles, the number of cars from 1236 to 1747, and the horse-power from a little over 18,000 to a little over 25,000. Of all the European countries Germany, according to Mr. Monaghan's figures, stood at the head with about 250 miles to her credit, and an equipment of 857 cars and 7194 horse-power. The other countries followed in the order given below:

	Miles.	Horse-Power.	Cars.
France	82	4,490	225
England	59	4,243	143
Austria-Hungary.	44	1,949	157
Switzerland	29	1,559	86
Italy	25	1,890	84
Spain	18	600	26
Belgium	16	1,120	48
Ireland	8	440	25
Russia	6½	540	32
Servia	6¼	200	11
Norway & Sweden.	5	225	15
Bosnia	4	75	6
Roumania	4	140	15
Holland	2	320	14
Portugal	2	110	3

With this showing it is suggestive to compare the position of the United States in which, according to the latest available figures, there were 12,133 miles of road with a total of 34,971 cars. It is not without reason evidently that the United States is known as the home of the electric railroad. Canada shows a total of 450 miles of road with 1150 cars, and thus stands next in rank to the United States.

ARMOURED locomotives and armoured railroad trains, for war service, have been in evidence, more or less, for twenty years, if not longer, and England, in one of her early Egyptian campaigns, found them effective equipments for offensive as well as defensive operations in the enemy's country. Since that time, such engines and trains have been under experiment and in actual service with various degrees of success, with every indication pointing to the probability of their becoming increasingly important factors in modern warfare. Sand bags, which were among the earliest armour used in this comparatively novel branch of military engineering, have been replaced by iron and steel, and the war locomotive of to-day is a decidedly more businesslike structure than its makeshift predecessor. It is well represented in its latest form by the locomotive *Moron*, which is one of two recently built for the Spanish military corps in Cuba by the Baldwin Locomotive Works, of Philadelphia. Both engines have cabs of heavy steel plate, capable of resisting rifle balls, and the windows and doors are fitted with steel shutters, having loop holes through which the guards can operate rifles or the machine gun which is to be mounted in the cab. The locomotives have a total weight of about 72,000 pounds each. The cylinders are 12x18 inches, and the driving wheels measure 38 inches in diameter.



AN ARMOURED LOCOMOTIVE FOR SPANISH SERVICE IN CUBA.

THE action, in a heavy seaway, of the United States coast line battle ships, has recently been such as to cause comment. It is reported that the *Oregon* of this type rolled very heavily during a gale which prevailed on her return from her official inspection trip to the southward on the California coast. It is said that her commanding officer remained all night on the bridge; that, later, she made port and anchored; and that there her rolling increased so, from the heavy ground swell, as to necessitare her weighing anchor at once and proceeding to the open sea. Again, there is the *Indiana*, of the same type, which in passing through the heavy gale of last October, on her passage from Hampton Roads to New York, gave her crew an experience which its members will not readily forget. As reported in the press, one of her officers said:—"Soon after we left Hampton Roads Monday, all four of the 8-inch turrets broke loose at once from their gearing. That was about two o'clock in the afternoon. We went to work with 5-inch hawsers to tie the guns up. We tied the two forward turrets together by binding the guns, each to the other, and fastening the hawsers to the bitts, and managed the after ones the same way. It was a very hard job. About two o'clock the next morning the forward ones snapped their hawsers and got loose again. The storm was then very severe and the ship was rolling at an angle of 36 degrees. The decks were flooded with water and this, with the pitching of the ship, made working on deck very dangerous. To make matters worse, the forward 13-inch gun turret got loose, and those enormous guns began thrashing about in full command of the deck. We fastened a 5-inch hawser on the 13-inch gun and it snapped like a cotton string. We finally caught the big guns with an 8-inch hawser and tied them securely to the superstructure. It was an awful job, though, and we were in danger of being washed overboard every minute."

It is not to be presumed that the United States government, in expending over three millions of dollars in constructing the *Indiana*, ever intended that, in a gale which other war vessels, even the *Texas*, weathered safely, she should present the absurd and perilous spectacle which has been described,—charging the waves of the wild Atlantic with her 8-inch turrets swinging, like massive pendulums, at every roll, and her enormous 13-inch guns "thrashing about" with the force of Titanic hammers. Furthermore, the regulations of the United States Navy, which its Line officers have formulated with such exactness of detail, solemnly declare that the commanding officer of a vessel of war shall not, save in routine matters, "delegate his power." Since there were then, in this instance, those enormous guns "in full command of the deck," superseding the commanding officer for the time, may it not be assumed that fault lies either with those guns, or with the ship herself; and that one of those courts of inquiry which have been so energetic recently in recommending scant mercy to the staff, would be most opportune?

It is not a light matter that, possibly through negligence, one of the most powerful vessels of the American fleet has been thus endangered, and it is proper to inquire whether the rolling of the ship was excessive for her type and the weather encountered, and, if so, what, in the form of the ship or the location of her weights, was its cause. It is worth finding out, too, whether the guns were so secured as to bring the least strain on the locking bolts of the turrets, and whether, when the locking devices showed signs of undue straining, prompt measures were taken for securing in other and additional ways, the turrets and guns. It is strange, indeed, that, in a matter apparently so important, no court of inquiry has been convened.

The battle ships referred to were built subsequently to those of the *Royal Sovereign* class of the British Navy. As to these, Sir William White has remarked:—"The reason which led to the decision not to fix bilge keels to the *Royal Sovereign* class during construction * * * may be briefly recapitulated. In ships of these large dimensions and great inertia, it was anticipated, on the basis of previous observation and experiment, that any practicable bilge keels which could be added would have a relatively small steadying effect. The presence of bilge keels, even of moderate depth, necessarily interfered with facilities for docking the ships in some of the docks which they would have to enter. Further, it was estimated, and experience has confirmed the estimate, that in their period of oscillation, the *Royal Sovereign* class would approximate to the *Inconstant*, *Hercules* and *Sultan*, which had a high reputation for steadiness at sea."

AFTERWARD, however, the *Repulse* of this class was fitted, as an experiment, with bilge keels. In commenting on the results of the first test, the authority above quoted, says:—"The first opportunity for comparative trial occurred in June, 1894, when the squadron was cruising off the west coast of Scotland. A long, low swell was encountered, with a length, said to vary from 300 to 400 feet (crest to crest) and a period estimated at ten to twelve seconds. * * * After making all allowances for possible exaggeration in the pendulum observations, the facts reported indicated conclusively the very great value of the bilge keels in the *Repulse* in reducing her arc of oscillation. This will appear from the following summary:—The *Resolution* (without bilge keels), by orders from the Admiralty, had been purposely kept in very nearly the same condition of stability as the *Repulse*. Comparing the returns from these two ships, it appears that the *Resolution* on one occasion reached a maximum inclination to the vertical of 23 degrees, whereas the *Repulse* never exceeded 11 degrees. The mean angles of oscillation were, of course, considerably below these maxima, probably about one-half. * * * In view of this experience, although the trial was limited and not representative of many conditions occurring at sea, it was decided to fit all the other ships of the class with bilge keels similar to those which had proved so effective in the *Repulse*."

IF the published plans of the *Indiana* and *Oregon* are correct, no bilge keels have been applied to these vessels. It is impossible to assume that the results of the experiments with ships of the *Royal Sovereign* class are unknown to the very able corps of constructors of the United States Navy. In view of these tests and of the late experience with the *Indiana* and the *Oregon*, the public is assuredly entitled to information from the Navy Department as to why the dangerous behaviour, as reported, of the *Indiana* especially, is not investigated; also, as to whether bilge keels would not improve the action, in a seaway, of this type; and, if so, as to why they are not fitted, that the recurrence may be prevented of the remarkable scenes which have been reported.

IT is interesting to note how differently different people regard the same thing. The good people of Geneva and of the Canton of Vaud, in Switzerland, are sadly afraid to drink the water of the Lake of Geneva, and well they may be, for the observer high up on the mountain side can readily see the discolouration which the sewage makes in the blue water, the line of demarcation extending far out into the lake. Meantime the city of Paris, anxious for a purer and larger water supply than can be obtained from the basin of the Seine, is casting longing eyes toward the Alpine lake 355 miles away, and planning a possible aqueduct to bring this pure (?) water to the metropolis. Surely the saying "a man is best appreciated where he is least known," might be extended to inanimate things.

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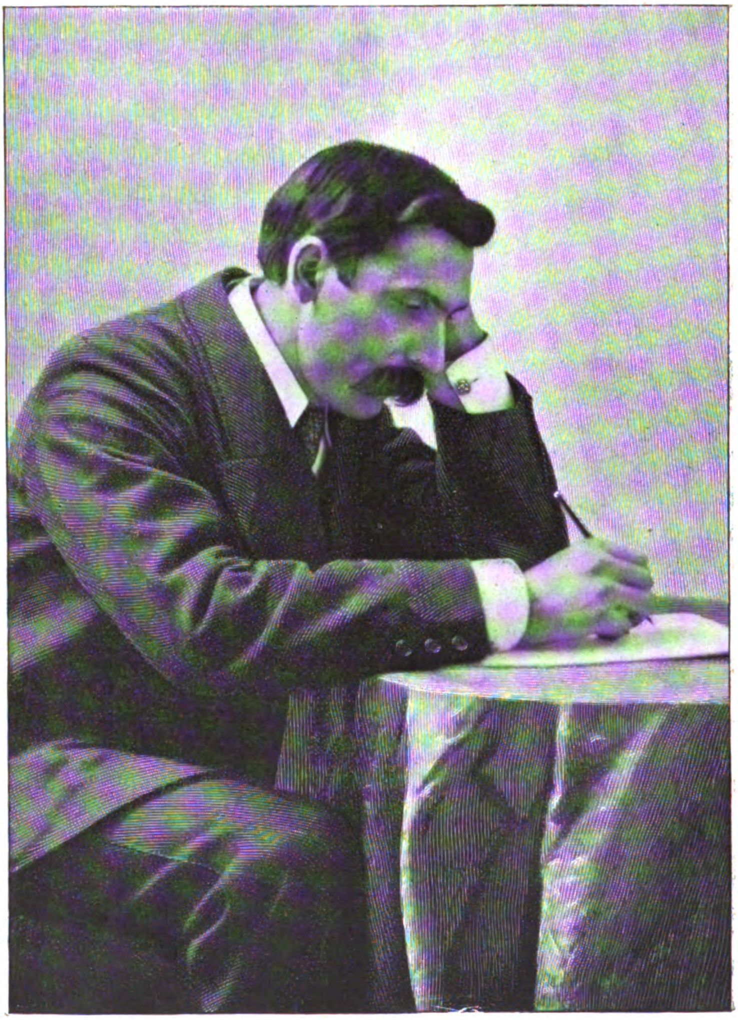

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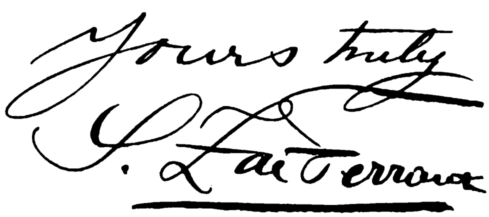

CASSIER'S MAGAZINE.

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THE WHITEHEAD AUTOMOBILE TORPEDO.

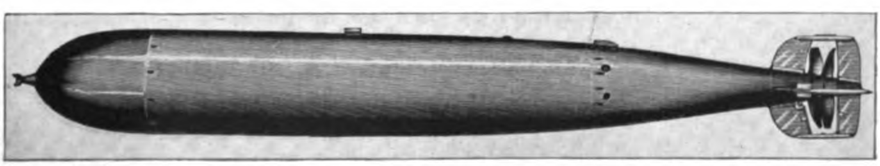
ITS CONSTRUCTION AND OPERATION.

By R. B. Moyer.

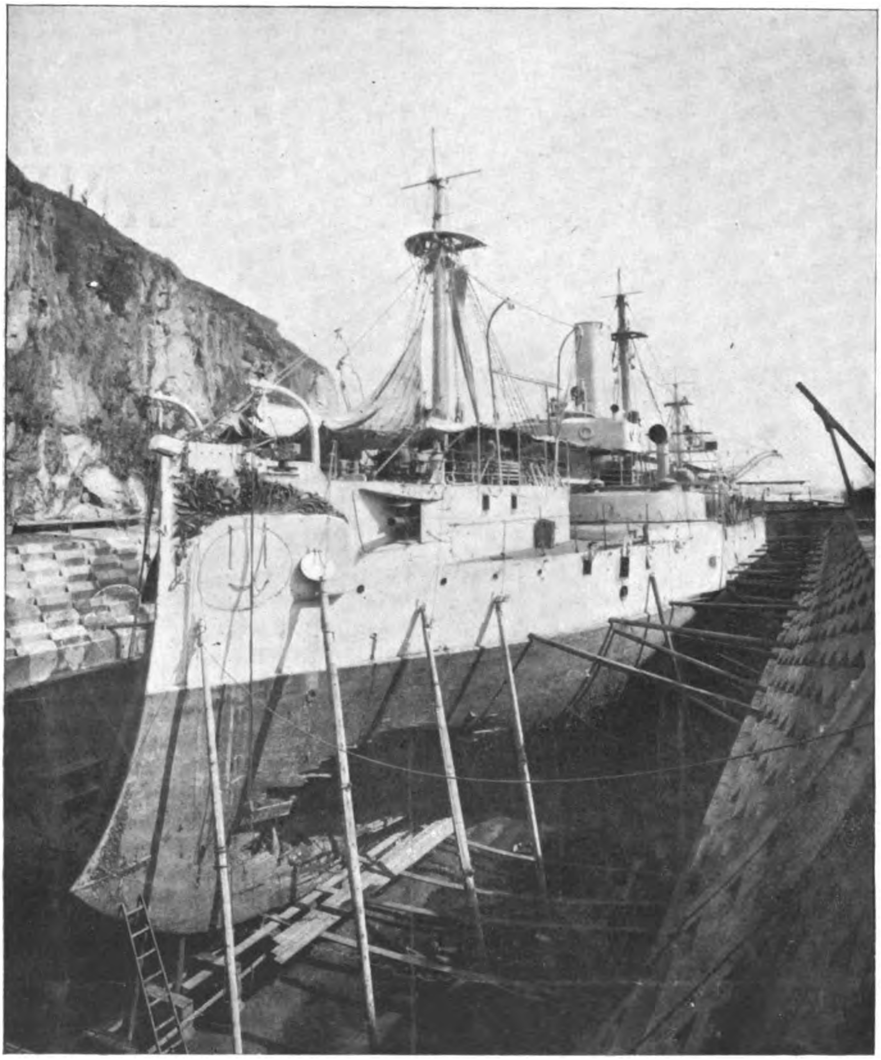
THE automobile torpedo easily takes rank as the most terrible of all the weapons of modern warfare. Machine guns, dynamite bombs and other latter-day inventions for the wholesale destruction of human life have to yield the palm to an engine which, fired from the swift and stealthy torpedo boat, glides beneath the surface of the water, seemingly with intelligence of a human order, and deals general destruction to what it encounters in its way.

As a triumph of inventive genius, too, the automobile torpedo ranks as one of the most marvellous achievements of modern mechanical skill. Great were the problems to be solved and the obstacles to be overcome to construct a torpedo that would dive from the deck of a ship, find and keep its own proper level, and run with speed and accuracy upon its target. In comparison with torpedoes of the "controllable" type, which are connected by means of wires with an operating station and are electrically controlled from there, the automobile torpedo has a much wider range and greater possibilities. The former type can be used only for harbour and coast defense, and even in such service it is not regarded by naval experts as of dependable value. The latter is used both for coast defense and in active sea service.

Torpedo boats are designed solely for bringing the automobiles within range of an enemy's ships. In addition to those carried by these dreaded sea marauders, nearly all modern war vessels are furnished with the necessary guns, mounts and appliances for dis-



A WHITEHEAD TORPEDO.



THE BRAZILIAN BATTLESHIP "AQUIDABAN" IN THE DRY DOCK, SHOWING THE RESULTS OF A TORPEDO EXPLOSION.

charging them and carry a certain number as a part of their regular equipment.

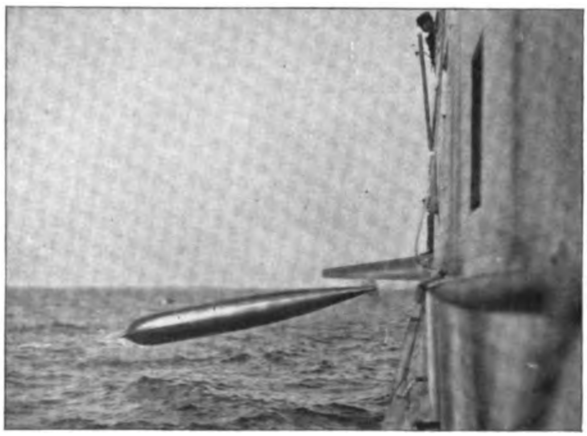
Whitehead, the inventor of the torpedo that bears his name, was an Englishman, but received no encouragement at home until, by the aid of the Austrian Government, he had established a factory at Fiume, in Hungary, and fully demonstrated the possibilities of his invention. All the European powers are now supplied with Whiteheads, England herself having in commission and in reserve a total of more than 3000. Excepting Germany, which country makes its own torpedoes, following with very slight modifications the Whitehead model, Europe's supply has come from the Fiume factory. England has recently established at Woolwich factories of her own, and will endeavour to supply her navy's requirements in the future. Until a few years ago the United States possessed none of these grim destroyers, but they are now being made for the American Government by the E. W. Bliss Company, of Brooklyn, N. Y. The chief engineer of that establishment, in company with Lieutenant Thomas C. McLean, of the United States Navy, journeyed to Fiume to study the plant there and receive instructions in the secret processes and points of special intricacy in manufacture of the torpedoes.

The body of the Whitehead torpedo is divided into five separate compartments. The forward compartment, or head, contains the explosive charge, and is made of sheet metal about one-sixteenth of an inch thick. Protruding from the nose of the torpedo is a firing pin, which, upon striking any obstacle, is driven back upon the percussion cap of a cartridge set in the nose. By means of this cartridge a small quantity of dry gun-cotton is set off, which communicates to a heavy charge of damp gun-cotton the proper vibration to excite it into action and liberate its powerful gases. This process is so rapid as to be practically instantaneous in its effect. As a precaution against accident in handling and launching the loaded torpedo, the firing pin is held out of contact with the primer by means of a travelling nut. A small propeller revolves this nut as the torpedo passes through the water, bringing the pin into the proper position for firing at a distance of fifty or sixty yards from the starting point.

Next to the head is a reservoir about five feet* long, which is three-eighths of an inch thick and is forged without seam or weld from steel of very great tensile strength. In this reservoir compressed air, which constitutes the motive power of the torpedo, is stored at a pressure of 1350 pounds to the square inch. The after end of the compartment is closed by a head, screwed in, and the joint is soldered. Each reservoir is hydraulically tested up to 2025 pounds per square inch, before it enters into the construction of a torpedo.

Abaft the reservoir are, first, a buoyancy chamber, fourteen inches long, fitted at its after end with a water tight bulkhead; next, the engine compartment, eight inches in length, and communicating freely, through openings in the shell, with the water outside; last, a second buoyancy chamber, separated from the engine compartment by a water tight bulkhead.

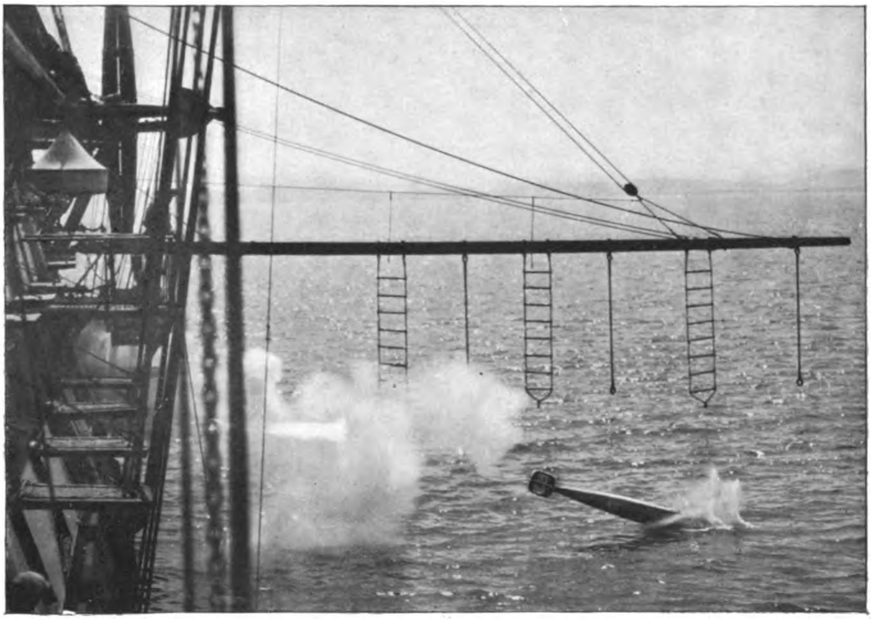
The first buoyancy chamber contains the diving gear which regulates the depth at which the torpedo shall travel. Through it, also, passes the air pipe which conducts the compressed air from the reservoir to the engine. The admission of water to the engine compartment tends to prevent the freezing which otherwise would result from the rapid expansion of the air, and serves a useful purpose in connection with the diving gear; it also avoids the difficulty of making water tight joints at the openings. Tubes for the propeller shaft and steering rod pass through the last chamber to the tail.



GOING.

The two propeller wheels are set between the two blades of the tail. They are arranged to revolve in opposite directions, one being directly connected

* These dimensions refer to the smaller size of Whitehead torpedo.

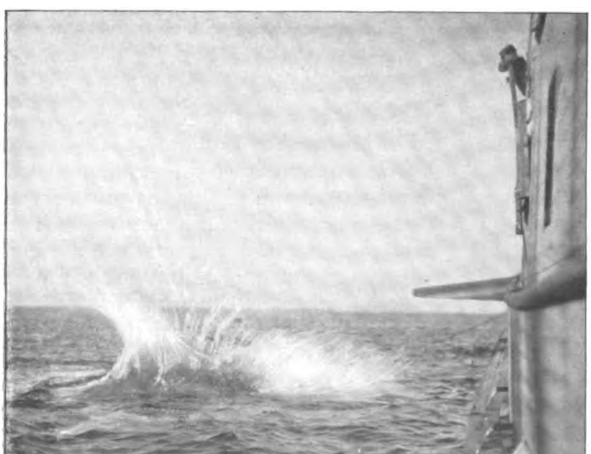


FROM A COPYRIGHTED PHOTOGRAPH BY G. WEST & SON, SOUTHSEA

THE FINAL PLUNGE.

with the propeller shaft and the other joined to a sleeve concentric with the shaft and geared by four mitre wheels, located in the forward part of the tail, in such a manner as to give it reverse motion. This right and left hand arrangement of the propellers balances the moment which would rotate the torpedo on its axis if but a single propeller were used.

The propellers are driven by an engine consisting of three single-acting cylinders, grouped equidistantly around the crank shaft. They are cast in one piece with the crank case, valve chests and air passages. The connecting rods are jointed directly into the pistons and all work upon one crank pin. The valves are of the piston type, and a single cam on the crank shaft serves to operate them. The exhaust air passes into the crank case, whence it escapes at the rear of the torpedo through a passage drilled the entire length of the propeller shaft. A reducing valve is provided, by means of which the pressure upon the engine can be regulated. The starting lever is connected with the reducing valve in such a



GONE

manner that it serves also as a throttle valve.

A "distance gear" closes the valve when the engine has made a prescribed number of revolutions, thus determining how far the torpedo shall run. A latch, placed in the launching tube, throws open the starting lever as the torpedo leaves the tube. As the lever opens it operates a "retarding gear," which prevents the engine from racing while passing through the air.

The torpedo is steered horizontally by two small rudders, which can be adjusted to perfect alignment by experiment.

The most complicated part of the machinery is the gear for steering it to a set depth and keeping it at that depth. It is difficult to explain clearly this mechanism without the aid of drawings. But it has been very concisely and perspicuously described by Mr. F. M. Leavitt, chief engineer of the E. W. Bliss Company, in a paper published some years ago in the *Stevens Indicator*. Nothing else can serve the present purpose so well as to quote from this paper as follows:—

"It should first be stated that the torpedo, when fully charged, has a slight surplus of buoyancy, and is kept below the surface entirely by the action of a horizontal rudder, so that, when its headway is checked at the end of the run by the stoppage of the engine, it floats on the surface. This is, of course, necessary for its recovery in practising.

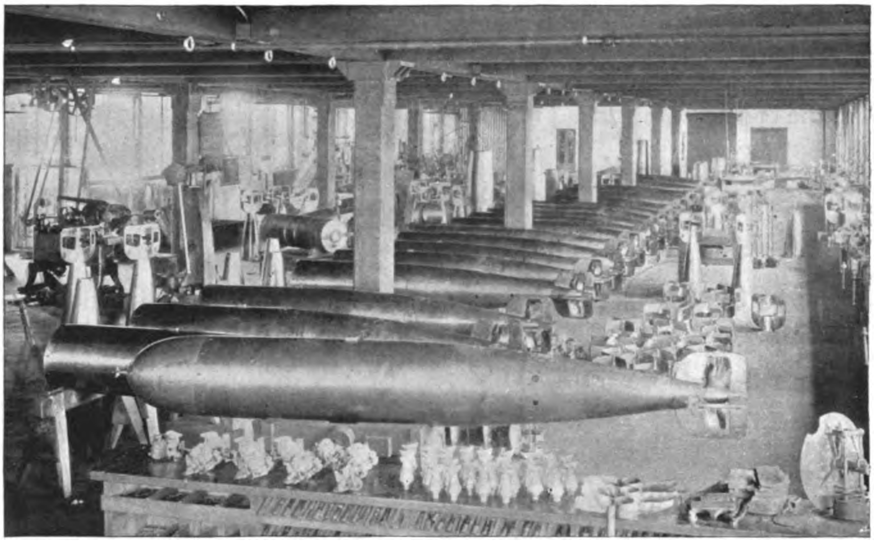
"The rudder is controlled by a small steering engine, operated by compressed air, which is situated in the engine compartment. The valve of the steering engine is connected with a heavy pendulum, located in the diving compartment, and so arranged that when the pendulum hangs vertically and the axis of the torpedo is horizontal, the rudder is held in a horizontal plane. When the position of the axis of the torpedo is changed 3 degrees, with the nose downward, the pendulum moves forward, and with it the valve of the steering engine; the rudder is thereby thrown up, tending to steer the torpedo back to the horizontal plane. The opposite action takes place when the nose is thrown upward. Thus, the action of the pendulum alone would keep the torpedo travelling in a horizontal plane, without regard to the depth of that plane below the surface.

"In the bulkhead dividing the engine compartment from the diving compartment, is placed a movable diaphragm, which, being presented to the free water in the former compartment, receives a pressure therefrom due to the head of water above the torpedo. This pressure is counterbalanced by a spring within the diving compartment, which may be adjusted to balance any desired hydrostatic pressure upon the diaphragm, and which determines the 'set depth.'

EXPLOSION OF A TORPEDO CONTAINING 67 POUNDS OF GUN-COTTON.

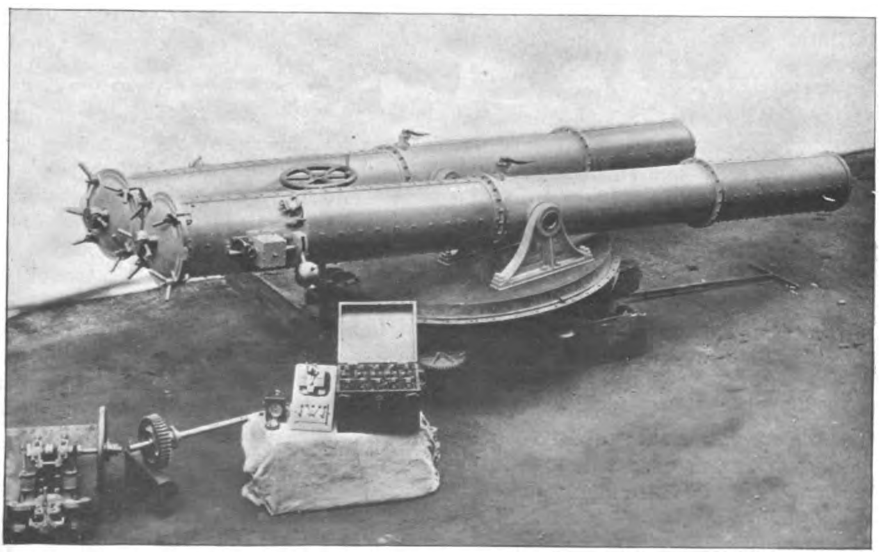
"The movement of the diaphragm is so adjusted to the tension of the spring that the diaphragm remains hard up against one limit of its travel until the torpedo has descended to within six inches of the set depth, and moves to the other limit when six inches below that depth is passed. The valve of the steering engine, instead of being connected directly with the pendulum, is linked to one end of a lever, the centre of which is linked to the pendulum, and the other end, which may be considered as the fulcrum, is linked to the diaphragm.

"When the diaphragm is at its cen-

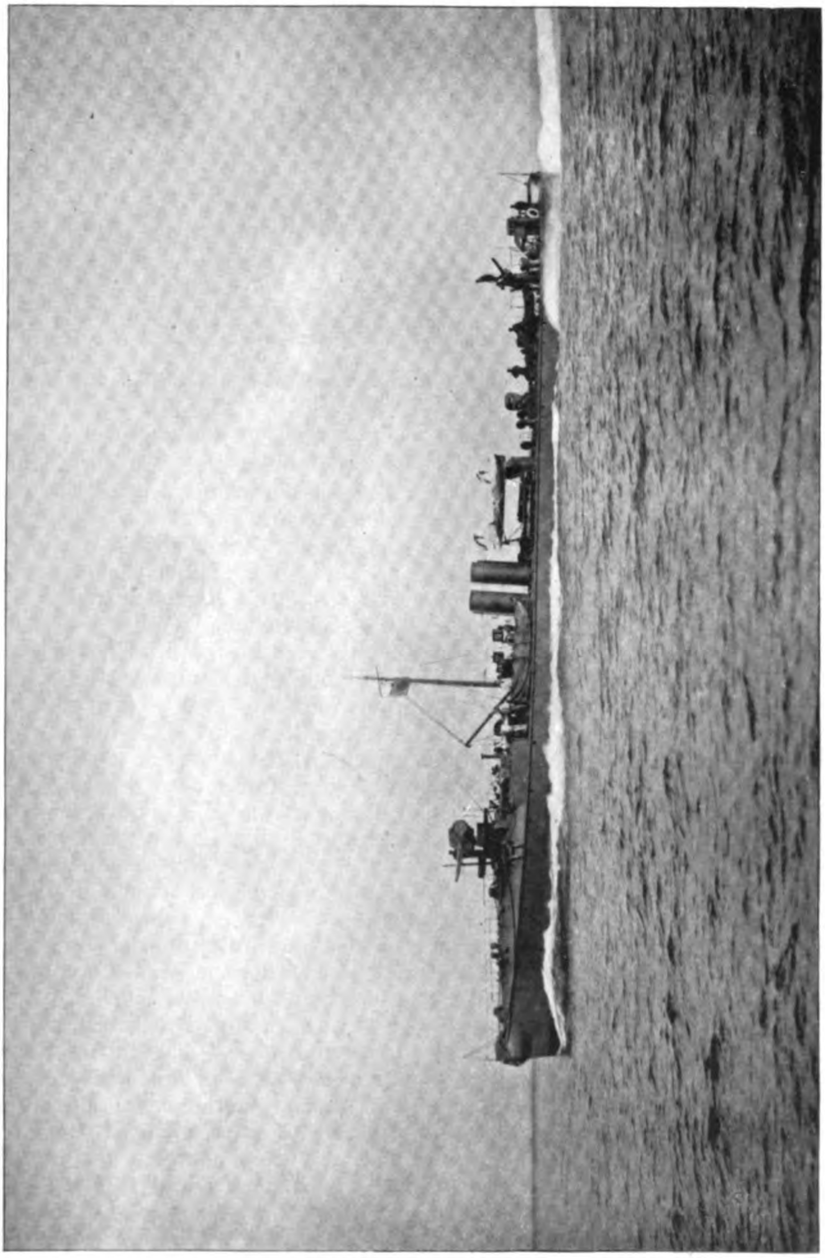


THE TORPEDO ASSEMBLING SHOP AT THE WORKS OF THE E. W. BLISS CO., BROOKLYN, N. Y.

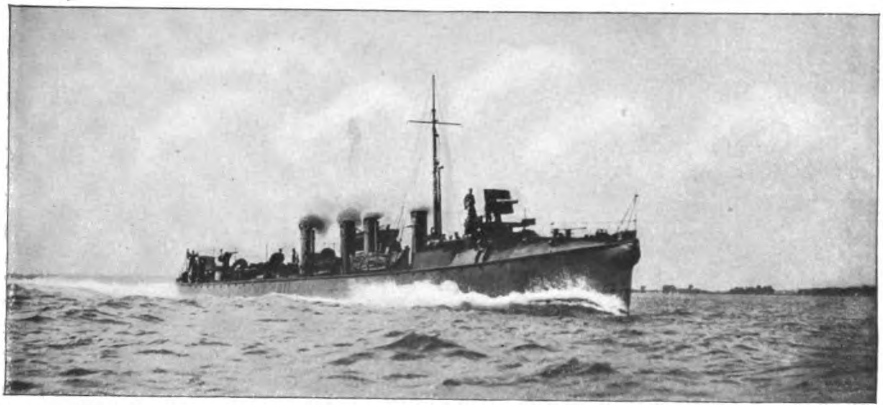
tral position—that is, when the torpedo is at its set depth—the action of the pendulum is as described above; and, as explained, it keeps the torpedo in a horizontal plane. If, however, the torpedo is above the set depth, the diaphragm has moved the fulcrum of the lever to such a position that, instead of the pendulum holding the rudder amidships when the torpedo is in a horizontal plane, it holds the rudder down until the torpedo is inclined downward at an angle of 3 degrees, at which point the rudder is brought to mid-position; while, if the torpedo were to be inclined at a greater angle, it would throw the rudder up and bring her back to 3 degrees. If, on the other hand, the tor-



A SET OF TORPEDO TUBES.



THE BRITISH TORPEDO BOAT DESTROYER "HAVOCK," BUILT BY MESSRS. YARROW & CO., LONDON. LENGTH, 180 FEET. BEAM, 18 FT. 6 IN. SPEED, WITH A LOAD OF 35 TONS, 27 KNOTS.



THE TORPEDO BOAT DESTROYER "SOKOL," BUILT FOR THE RUSSIAN GOVERNMENT BY MESSRS. YARROW & CO., LONDON. SPEED, 30 KNOTS.

pedo be below the set depth, the diaphragm, moving to the opposite end of its stroke, causes the rudder to assume the amidship position when the torpedo is inclined 3 degrees upward.

"It will thus be seen that the torpedo is steered in a straight course downward at 3 degrees with the horizon when above the set depth, parallel with the horizon when at the set depth, and upward 3 degrees when below the set depth. Therefore, when launched from above water, at whatever angle she happens to enter the water, she will at once be steered to 3 degrees downward until the set depth is reached, at which point her course will change to horizontal.

"In the above explanation it has been assumed that the pendulum will at all times hang in a vertical position. This, however, is not the case, and it is therefore necessary to provide additional mechanism.

"The velocity acquired by discharge from the launching tube is much less than that attained subsequently. Therefore, during the period of acceleration, which takes place through about fifty or sixty yards, the pendulum, instead of hanging vertically, lags behind, and the downward angle at which the torpedo travels is increased beyond the 3 degrees by just the angle that the pendulum hangs back from the vertical. The result is that when the torpedo nears its set depth it does not come to a horizontal course, but runs considerably below it, until acceleration ceases; then it comes to a horizontal course, and then upward to set depth.

"This initial 'dive' has a tendency to deflect it in its horizontal direction, especially in shallow water, where it may even strike bottom and be thrown entirely out of its course. To overcome this a locking gear is provided, which securely holds the valve of the steering engine at the centre of its stroke, and, therefore, the rudder amidships, without regard to the pendulum and diaphragm. It is automatically released when the engine has made a prescribed number of revolutions. This gear may also be adjusted so as to change the locked position of the rudder a trifle up or down, as experience may prove to give the best results."

Up to last autumn the United States Government had but 150 of these destroyers—all of the smaller size. After the passage of the naval appropriation bill last summer, an order was placed with the Bliss company for 100 of the larger size, to cost $313,000, and fifty of the smaller size, to cost $121,000. The small Whitehead is 11 feet 8 inches in length, about 17.7 inches in diameter, and carries a charge of 120 pounds of gun-cotton. The larger size is 16 feet 4 inches long, somewhat larger in diameter, and carries 220 pounds of gun-cotton. Separate orders are placed with the Bliss company for the mounts, launching tubes, air compressors, and other apparatus necessary for firing. The torpedoes are tested by the company—without the explosive charge, of course—from its own boat, at Sag Harbor, L. I., under the supervision of a naval officer. They are rigidly inspected at all stages of construction by a government officer stationed at the company's works, and in the final experimental test must meet a high standard of requirements.

As built by the Bliss company, either size of torpedo is capable of maintaining throughout an 800-yard run a speed of from twenty-seven to twenty-eight knots. The United States Government requirement is that at a range of 800 yards the torpedo shall not vary more than fifteen inches perpendicularly nor more than twenty-four yards horizontally from the centre of the target.

It was a Whitehead torpedo that sank the *Blanco Encalada* in the harbour of Valparaiso during the Chilian war a few years ago, and it was the same weapon that sent the man-of-war *Aquidaban* to the bottom off the coast of Brazil during the Brazilian rebellion. The latter vessel was sunk by the Brazilian torpedo boat *Gustavo Sampio.* Two Whiteheads were successively launched at a distance of about seventy-five metres, both missing their mark. The third torpedo, launched at a range of about fifty metres, struck the battleship about ten feet below her water line and twenty-five feet abaft her stem. No attempt was made by the *Gustavo Sampio* to direct her torpedoes accurately. They were fired with no one on deck, strings being fastened to the triggers and carried below decks, as the machine guns of the *Aquidaban* were at work upon the torpedo boat.

STEAMBOATS ON WESTERN AMERICAN RIVERS.

By William H. Bryan.

FORTY years ago the city of St. Louis was the centre of what was perhaps the most extensive river traffic that has ever existed in America. In addition to numerous regular packet lines, large numbers of independent steamers operated regularly from St. Louis to the headwaters of the Mississippi, Missouri, Yellowstone, Osage, Illinois, Ohio, Tennessee, Arkansas, Ouachita, and Red rivers. With the development and extension of the railway systems this traffic has suffered a natural decrease.

The first steam boat operated on Western waters is said to have been the *New Orleans*, which was built at Pittsburg in 1811. Not over seven or eight boats were built for this trade previous to 1816, but after that date they were constructed in great numbers, and there are authentic records of sixty having been built and put into service previous to 1820. The dimensions of the *New Orleans* were:—Length, 116 feet; beam, 20 feet; single-cylinder engine 34 inches in diameter. She was of about 400 tons burden, cost about $38,000 (£7600), and sank near Baton Rouge in July, 1814.

The first steamer to reach St. Louis was the *Zebulon M. Pike* in August, 1817. She was driven by a low-pressure engine with a walking beam. She had but one smoke stack and no wheel houses. The first boat to navigate the Missouri river was the *Independence*, which ascended that stream 200 miles in June, 1819.

The Western river steamer is *sui generis;* there is nothing exactly like it anywhere else. The construction of these vessels seems to violate every known law of mechanical engineering and marine architecture. They are a law unto themselves. Their hulls are rude and uncouth in appearance, and apparently unwieldy. The machinery seems to be of an antiquated type. The advanced ideas of compound and condensing engines are rarely used. The entire structure appears to be of the most flimsy character, lacking all the elements of stability and durability. It is not surprising, therefore, that the design should have been severely criticised by engineers of known standing and experience in other and parallel fields of work.

Figs. 2 and 3 are views of the Anchor line passenger steamer *City of Hickman*, now running regularly between St. Louis and New Orleans. Fig. 4 is an interior view of cabin of a typical steamer, the *City of St. Louis*, of the same line. Figs. 1 and 2 are fairly representative of the characteristic side wheel passenger steamer so common on Western American rivers a few years ago, and which, to a considerable extent, is still in service.

Fig. 5 is not, as might be thought, at first glance, a view of one of Robert Fulton's early steamers, but represents the ferryboat *Napoleon Milikil*, now plying between St. Louis and East St. Louis, as she appeared after the memorable and destructive cyclone of May 27,

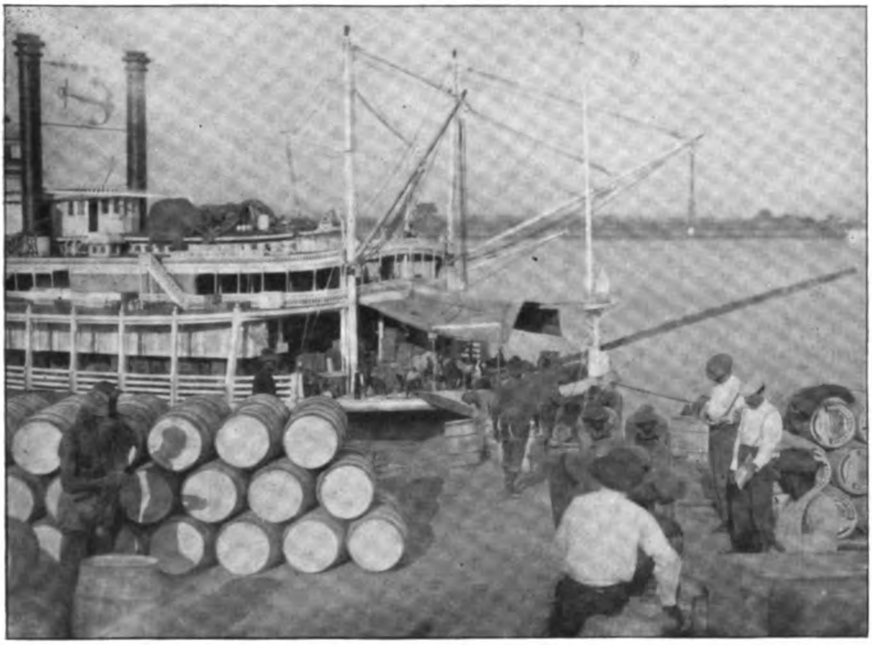


FIG. I. JUST LANDED.

1896. Fig. 6 represents a similar steamer undamaged.

Fig. 7 represents one of the St. Louis and Mississippi Valley Transportation Company's boats, engaged in freight traffic between St. Louis and New Orleans, with barges in tow. These boats are loaded exclusively with their own machinery, and are very powerful, as is necessary in handling large tows of heavy barges.

Practically all the steamers on Western rivers are of characteristic type. Their hulls are always of considerable "beam," and of shallow depth, it being necessary that their draught be a minimum. The engines are of the long-stroke, single-cylinder type, designed to work with high pressures and late cut-offs, thus developing maximum power with minimum weight. The boilers are designed with the same object in

FIG. 2. A MISSISSIPPI RIVER PASSENGER STEAMER.

view, with the additional necessity of using the muddy water direct from the river. Many of the large passenger steamers have independent side wheels. The stern wheel steamer, with the engines coupled at right angles to opposite ends of the water wheel shaft is, however, coming into more general favour, on account of less weight, and needing the services of only one crew of engineers.

While the Western river steamer may be improved in some minor points, it is, in general design and construction, admirably fitted for the peculiar work that it has to do. Considered from a strictly engineering standpoint, it is a creditable structure. Furthermore, it is a striking example of the survival of the fittest.

But there are also many iron hull steamers on the rivers of the West, and there are some short-stroke, high-speed engines driving propellers. These, however, are usually confined to local work in the deep harbours of large cities. In many sections stern-wheel boats have become more numerous than side-wheelers. The machinery, while preserving the original characteristics, has undergone many improvements in detail.

In comparing the advances which have been made in the ocean and American lake marine with those on the Western rivers, the latter have generally been made to appear in an unfavorable light. The fact, however, has been overlooked in most cases that the conditions of service are radically different, and these differences necessitate, in fact compel, corresponding differences in the character of the steamers. The boilers and engines of the magnificent ocean liners would be as much out of place, and would fare as disastrously, on the Western river steamboat, as would the machinery of the latter if transferred to ocean service. Machinery essentially similar to that employed on the American lakes has been tried many times on Western rivers. Large sums of money have been spent on experiments, and the result has always been failure. Even the vertical engine has been abandoned. Barring unimportant details, the machinery of the Western river steamer is pre-eminently "the right thing in the right place."

The peculiar conditions of service

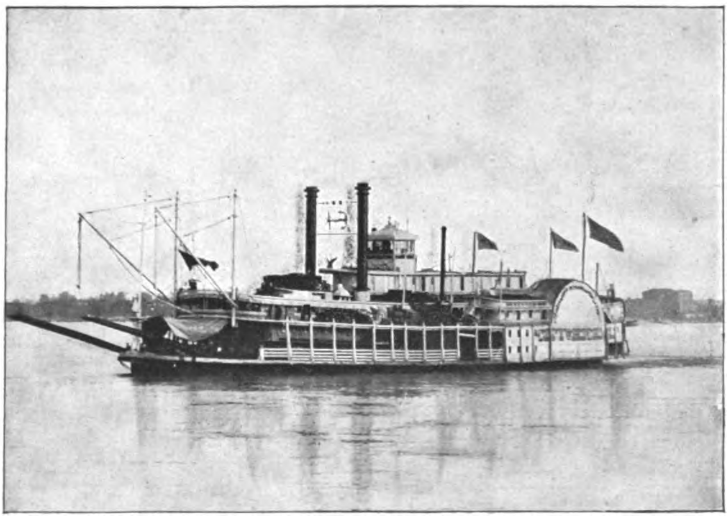


FIG. 3. SOUTHWARD BOUND.

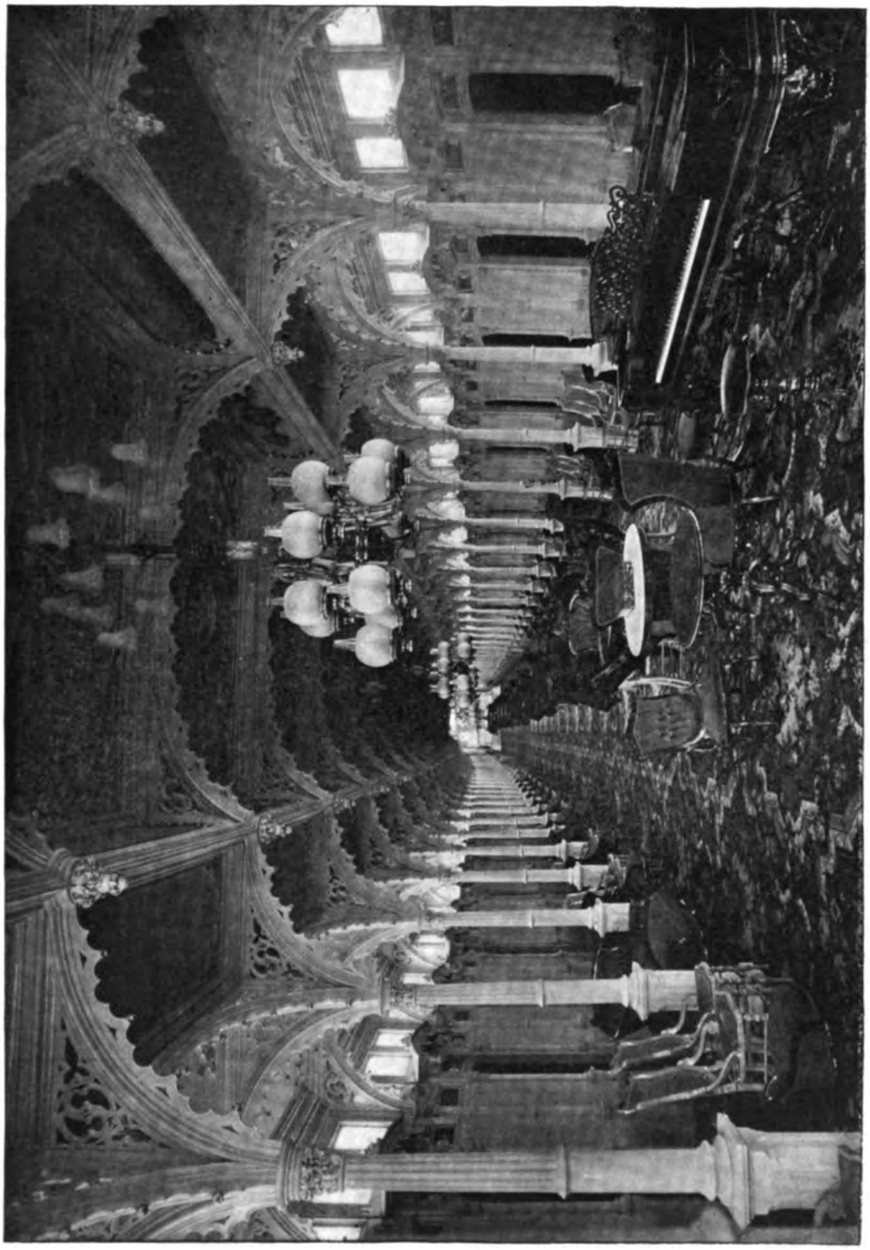


FIG. 4. THE MAIN SALOON OF A MISSISSIPPI RIVER STEAMER.

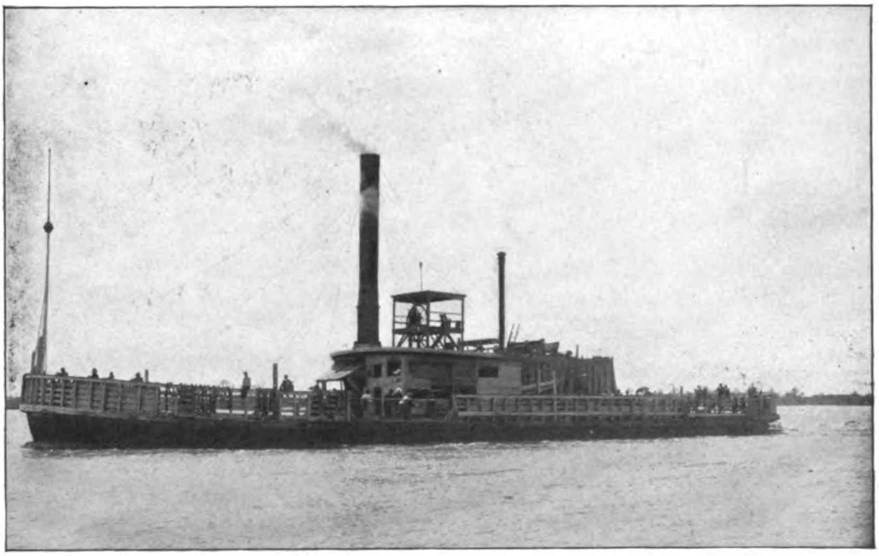


FIG. 5. THE FERRY BOAT "NAPOLEON MILIKIL" AFTER A CYCLONE.

which render necessary the characteristic types of machinery may be stated as follows:—

First. — The necessity for light draught.— For many months of the year, particularly in the upper rivers, the depth of the channel is so slight that every superfluous pound of weight must be done away with, in order that the boats may be as light in draught as possible. This compels the use of machinery which can be worked to the utmost per pound of weight. From this results the necessity of high pressures, single cylinders, and few complications.

Second.—Bad feed water. — The steamers, as a rule, must use water for their boilers directly from the river, which water, particularly in the Mississippi and Missouri rivers, carries large amounts, not only of mineral matter in solution, but of finely divided particles of silt in mechanical suspension, the latter sometimes running as high as one-half of 1 per cent. by weight. As neither sedimentation, filtration, nor surface condensers are practicable, the boilers must be so constructed as to give satisfactory service with this water fed directly to them. The battery of small boilers usually found is, therefore, abundantly justified by the three conditions,— getting the maximum work out of a given weight, carrying high pressures, and using bad feed water. The latter consideration also causes silt to be carried over to the engine valves, resulting in rapid wear, and necessitating a type of valve which will keep approximately tight, and which is capable of being easily ground tight when worn.

Third.—Absolute reliability required.—The river channels are often narrow and crooked, and steamers must find their way on the darkest nights among shoals and snags, and around short bends. The engines must always be under the quick and positive control of the attendant, whether to change speed, stop, or reverse. Any derangement or failure at such a time would be disastrous. It has been found that all improvements in machinery necessarily increase the complication of parts, thereby lessening the reliability, and increasing the likelihood of accident.

Fourth.—The necessity, common to all water-craft, of having the machinery occupy as little space as possible, in order that the remaining room may be devoted to the carrying of profitable cargoes, is nowhere more strongly emphasised than in the case of the Western river steamer.

Fifth.—Low fuel cost.—Improvements in modern machinery are almost wholly in the direction of reducing fuel expenditures. After all, this is a relatively unimportant item, as it usually forms but a small percentage of the total expense of operating the steamer. Fuel can generally be purchased at short intervals along the river, in abundant quantity, of excellent quality, and at low prices. The steamer need only carry enough fuel to reach the next point of supply.

Sixth.—The question of first cost has, when added to the above points, helped to prevent the adoption of higher priced machinery. The average life of a steamer is short, the rates of insurance are high, and the period of employment during the season is limited, all of which make it imperative that the investment be a minimum.

Seventh.—It is not uncommon for such boats to run aground, and it is still more common for the cargo on board to be badly distributed. Either of these conditions will cause an immediate distortion of the entire steamer, and the machinery is thrown out of line. The peculiar type of engines employed stands this severe service without injury or derangement.

Eighth.—The accepted type of machinery is so simple and reliable that it can be handled satisfactorily by a small number of men, and these need not necessarily be highly skilled, nor of long experience. This is of some importance in view of the fact that the months of idleness render it difficult to retain the best men, and that it is always necessary to keep the salary account down. Experiment has demonstrated that the saving in fuel due to improved machinery does not, as a rule, compensate for the drawbacks accompanying its use, such as increased weight, space occupied, greater first cost, and less reliability.

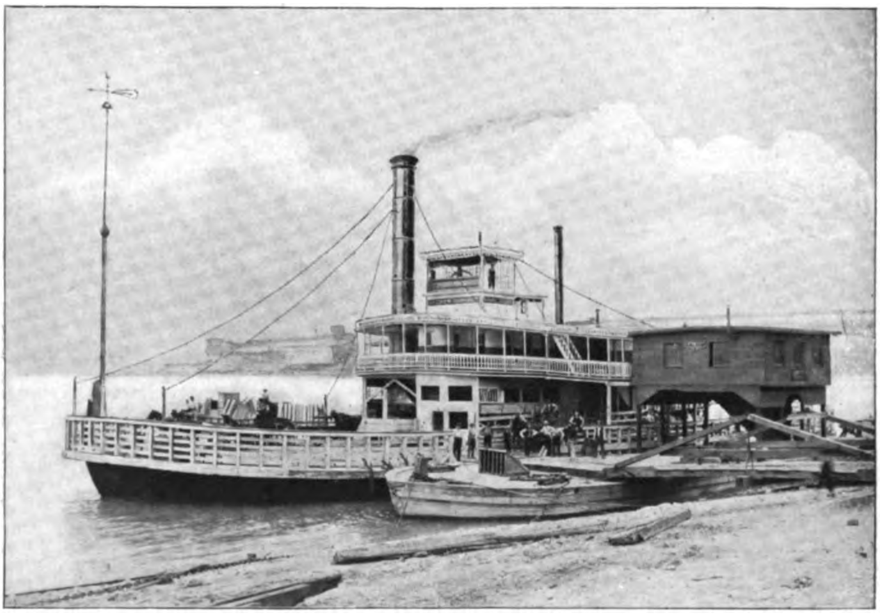


FIG. 6. A TYPICAL MISSISSIPPI FERRY STEAMER.

Iron or steel hulls are already becoming common on Western rivers, and would be used almost universally if the expense were not so great. A few years ago the cost was about double that of

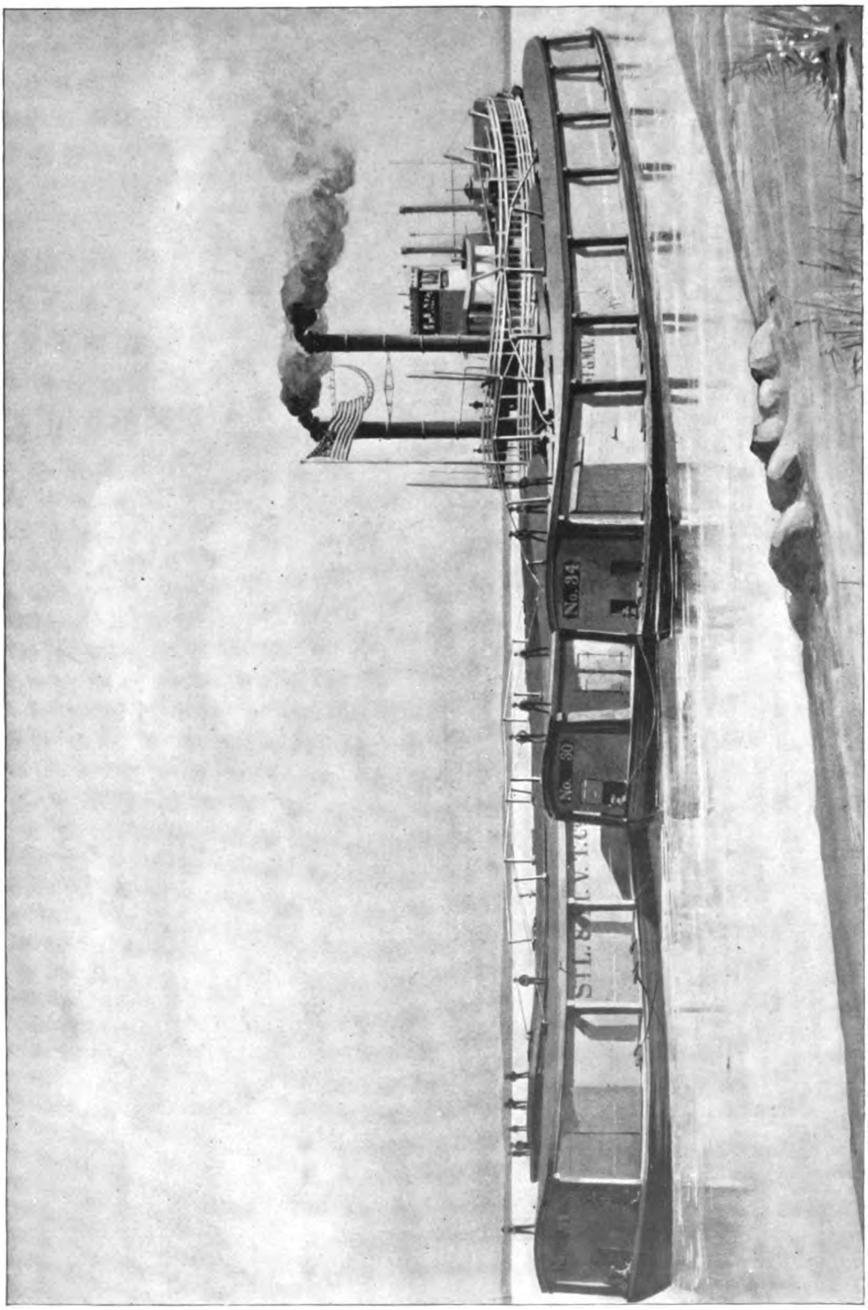


FIG. 7. A TOW OF GRAIN BARGES ON THE MISSISSIPPI RIVER.

wooden hulls, but at the present low price of iron the outiay would probably be but little, if any, greater, if the hulls were built in yards equipped with special tools. Iron hulls, undoubtedly, add to a steamer's life, and reduce its draught.

Long-stroke engines, and side or stern wheels, are necessary, as previously stated, on account of the shallowness of the channel. Two forms of adjustable cut-offs have been introduced on the standard poppet-valve engine in recent years, with considerable success. Instead of the usual fixed cut-off of one-half, five-eighths, or three-fourths, it is adjustable at any point throughout the length of stroke. It is an excellent feature to be able to vary the point of cut-off at will, but an early cut-off is not always desirable. It necessitates larger cylinders, greater weight, space, and first cost, to do the same work. Furthermore, the usual fly-wheel,—which is essential if the full benefit of early cut-off is to be realised,—cannot be employed on account of weight. This is to some extent remedied on the stern-wheel steamers by coupling the two engines at right angles. Probably some substitute for the fly-wheel, such, for instance, as the Worthington high-duty attachment for pumping engines, could be advantageously employed on side or even stern-wheel steamers, in connection with the adjustable cut-off.

The decline of Western river transportation in the United States is not, as has been claimed, due to lack of improvement in the steamers. Neither would the introduction of lake and ocean machinery rehabilitate river traffic. The reduction in business is due to other, easily discernible causes, and the remedy must be found in other directions.

The most important cause is, of course, the widespread construction of railways. These frequently parallel the river routes,—in some cases on both banks. They operate throughout the entire year, and make better time than steamboats, although they do not, as a rule, attempt to compete in rates, as water transportation offers the cheapest method of moving goods.

Additional causes are the length of the low-water season when traffic cannot be conducted at a profit, if at all; the snaggy condition of the channel, particularly at low stages of the river, and the cost of insurance, often procurable only at excessive rates, and sometimes not at all. The larger cities are further apart in the West, and the country is less thickly settled. This reduces the amount of freight traffic, and almost wholly precludes passenger business.

Some other conditions, too, have helped to reduce river traffic, among them being the fact that the upper rivers are usually closed by ice for several months in the year, and by low water for several months more, so that in some districts boats cannot be operated much over half the time. The extremely dangerous condition of the river in low water, in addition to the ordinary fire risks, has retarded investments in river steamers.

When compound engines have been used on the rivers the engineers soon learned the trick of "bleeding" a little live steam directly into the low-pressure cylinders, using as much steam in this way as the boilers could make. This practice became almost universal, as the loss in fuel was more than made up by the increased speed, and the shortening of time between terminals, which, on long trips, resulted in a considerable reduction of general expenses.

Even were the condensing engines defensible from other points of view, the adding of, say, twelve pounds to a mean effective pressure of 125 would usually be a gain so small as not to warrant the expense and complications necessary. Where there is a deep-water channel for the greater part of the year, compound engines with surface condensers, furnishing distilled water for boiler use, and thereby permitting improved types of boilers, might be entirely proper. Where the fuel is expensive the saving on long runs might warrant the increased weight, space occupied, and first cost.

ANCIENT POMPEIIAN BOILERS.

By W. T. Bonner.

A partial reprint of a paper recently read before the American Society of Mechanical Engineers.

IN preparing a recent paper on "Water Tube Boilers," read by the writer at a meeting of the General Mining Association of Quebec, several newspaper accounts were noted descriptive of some very interesting relics discovered among the ancient ruins of Pompeii. As two or three of these relics showed unmistakable evidence of having been utilised as boilers in some form or other, my curiosity prompted me to extend my investigations further, with the result that I am able to present to this society what may be considered abundant proof that the water tube principle, the crowning feature of the most successful boilers of to-day, was fully understood and appreciated by the Greeks and Romans two thousand years ago.

In the centre of the first hall in the National Museum at Naples, containing the bronze relics of Pompeii, are preserved two apparatuses for heating water, and numbered in the museum inventory 73,018 and 78,673.

A description of the above apparatus, together with photographs and drawings fully illustrating their detail construction, has been furnished me by M. Francisco Milone, a Neapolitan engineer of considerable reputation, at the request of the directors of the National Museum, to whom my communication to the Minister of Public Instruction was referred. Reprints of these drawings and photographs are presented herewith, and from them it will be seen that there is a remarkably close analogy between the ancient Pompeiian boilers and the water-leg boilers, water grates, and water tube boilers of to-day. Indeed, the principle may be said to be identically the same in both, for little change would be required to construct from the drawing shown in Fig. 2 a very efficient boiler for high-pressure work. Inasmuch as the ancients had little or no use for steam under pressure, and as their boilers were principally used for heating water, it was sufficient that the boiler shells and covers offered only a slight resistance, requiring merely a heavy, well-fitted cover, which was sufficient to prevent the escape of the steam.

The first apparatus (No. 73,018), illustrated by the photograph (Fig. 1), and the drawings showing vertical and horizontal sections (Figs. 2 and 3), consists of a cylindrical receptacle, *A*, which measures thirty centimetres in internal diameter and forty-two centimetres in height. The thickness of the walls is a little more than a millimetre, and as one does not see any joints in the sides of the cylinder, it may be supposed that it was cast, as were generally all of the Pompeiian vases, and then worked or turned all round to even the thickness. The top of this receptacle was closed by a beautifully engraved or chased lid, *B*, which was removable, but neatly fitted over a bronze reinforcing ring, *C*.

At the bottom of the external cylinder it is joined to an internal cylinder of smaller diameter, which rises to a certain height, and terminates in a spherical cap. The diameter of this internal shell

FIG. 1. AN ANCIENT POMPEIIAN BOILER.

is twenty-five centimetres, and the height thirty centimetres. The annular space, or jacket, between the cylinders constitutes the water capacity of the boilers, while the interior of the inner cylinder constitutes the furnace chamber, the grate for which forms a very interesting feature of the construction.

A careful examination of the particular boiler illustrated herewith shows that the annular water space does not preserve the same thickness all around, especially the oven, due more to having been damaged than to imperfect construction. Neither is the furnace chamber exactly central to the boiler. It is clear, however, that all of the surface of the inner chamber constitutes the heating surface in this Pompeiian apparatus, the same as in our water-jacket boilers of the present day. The grate bars (see Figs. 2 and 3), seven in number, were made from sheet bronze, rolled, and soldered or brazed. These tubes open at both ends into the bottom of the water jacket, thus forming water tubes, or grates, upon which rested the fuel, and through which traversed the water as it circulated in the boiler.

To quote from the description furnished me by Mr. Milone:—" By this arrangement of the grates not only was the heating surface greatly increased, but the heating was rendered more efficient, thus showing that the ancients fully understood the principle of distributing across the furnace a certain number of tubes, in order to increase the heating surface, and to aid the evaporation by means of a more active circulation of

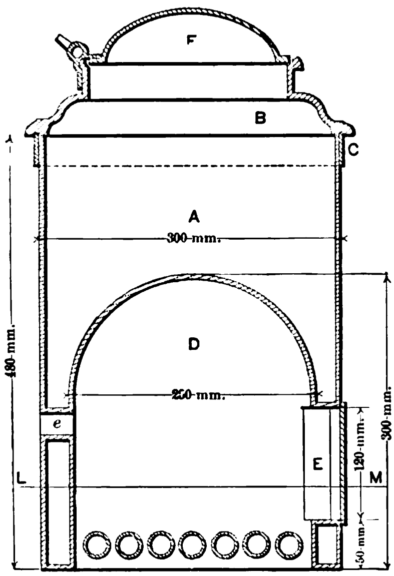


FIG. 2. A VERTICAL SECTION OF FIG. 1.

the water." The rectangular opening through which the fuel was fed, was placed five centimetres above the bottom of the boiler, and is one hundred and twenty millimetres in height and one hundred millimetres in width. This opening was provided with a small door, made of bronze, hung on two vertical hinges, the door being operated by a bronze knob or handle, representing a ram's head.

There is no evidence that these Pompeiian boilers were connected to a stack or chimney; but little annoyance was caused by the escape of gas or smoke, as the Pompeiians used charcoal as a fuel, the real "carbo" of the Latins. In order to permit the escape of the gases, at the height of one hundred and forty millimetres from the bottom of the boiler, there were provided three openings from the combustion chamber to the outside. These were formed by tubes which crossed the annular zone, or water jacket, and terminated at the outer end in a masked face, as may be seen on the left side of the photograph.

It is interesting to note here the artistic turn of mind of the ancients, for no matter how simple or how ordinary might be the article under construction, it seemed to be second nature to them to ornament every detail. The cover, *B*, referred to above, is made of cast bronze, decorated in a very artistic manner, and can be removed and put in place by means of two small handles, each one gracefully representing two athletes wrestling, as is shown by Fig. 1. The cover of the boiler is made in two parts, the larger of which was probably removed only in case of making internal repairs, or for the purpose of cleaning the boiler. There is a supplementary lid, *F*, much smaller, that opened on hinges, shown in Fig. 2, and it was through this opening that the water was poured into the boiler. The hot water was extracted by means of a big ladle with a long handle, or a pan or vessel. This second lid, or cover, had in the centre a knob that represented an "Eros" or Cupid, entwined with a dolphin, having in his left hand a lyre and in the other the "plettro," or bow.

Finally, the boiler is raised thirty centimetres, on an artistic tripod rep-

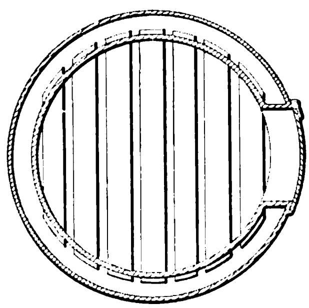


FIG. 3. SECTION THROUGH L M.

resenting lion's claws, thus allowing the entrance, below the grates, of the air necessary for the proper combustion of the fuel. Two handles that are attached to the outer shell of the boiler take the form of a man's hands, and serve to lift

FIG. 4. ANOTHER FORM OF ANCIENT POMPEIIAN BOILER.

the entire boiler with the tripod. As near as can be ascertained, the above boiler was found in Pompeii proper, but my informant is not able to indicate the exact spot. It probably belongs to the old collection of Pompeii.

The second Pompeiian boiler (No. 78,673), illustrated by Fig. 4, and shown in vertical and horizontal sections by Figs. 5 and 6, is much more simple than the boiler above described, not only in the internal construction, but also in the decoration

This boiler has the form of an urn or an ancient vase, and is constructed of bronze, cast in one piece. On the outside it measures nearly thirty centimetres in diameter in the widest part and forty-four centimetres in height. Inside is the oven or furnace, *B*, consisting of a cylindrical shell attached to the outer shell at the mouth, *C*, from whence it turns inward and downward, widening in the meantime until it reaches the grate, just below which it flanges outward, and is attached to the outer shell.

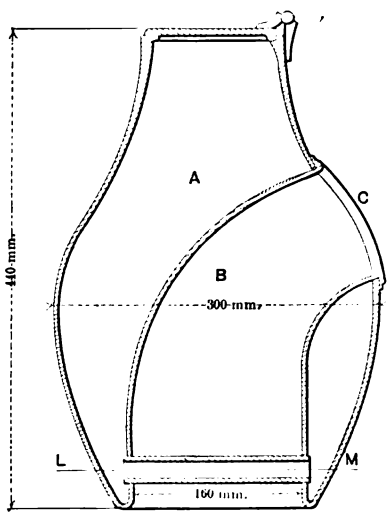


FIG. 5. A VERTICAL SECTION OF FIG. 4.

Thus we have an inner and outer cylinder, the annular space between forming a water jacket, in which was contained the liquid to be heated. The surface of the inner cylinder constituted the heating surface of the boiler. The boiler is also provided with water grates, consisting of tubes made from sheet bronze, and opening at both ends into the annular water space, or jacket. Here, then, is another ancient example of the water tube principle, this apparatus being constructed with a view to attaining greater efficiency by the more extensive heating surface and more active circulation.

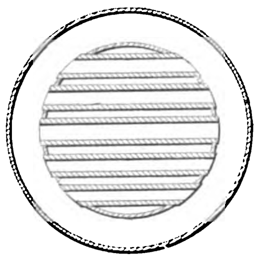


FIG. 6. SECTION THROUGH L M.

To the sides of this urn-shaped boiler are attached two very simple handles, and the whole is supported by an elegant tripod of a little more than ten centimetres in height.

It has been suggested that this apparatus may have served at some time to heat wine as well as water, which suggestion appears reasonable, as many competent authorities agree that the Pompeiians made great use of hot drinks. Probably this urn, or boiler, was found in one of the "termpodi," or, in modern language, cafés, in Pompeii or some other city of the Campagne. At Pompeii were to be found several of these merchants or dispensers of hot drinks, but my informant states that he has not ascertained to what other city of the Campagne it may have appertained; that is to say, he is not positive that this apparatus was really found in Pompeii, though he is fully satisfied as to the origin of the first apparatus described above.

It should be noted also that the opening through which the fuel entered was judiciously placed on the same side as the hinge for turning the lid, thus enabling the attendant to incline the urn

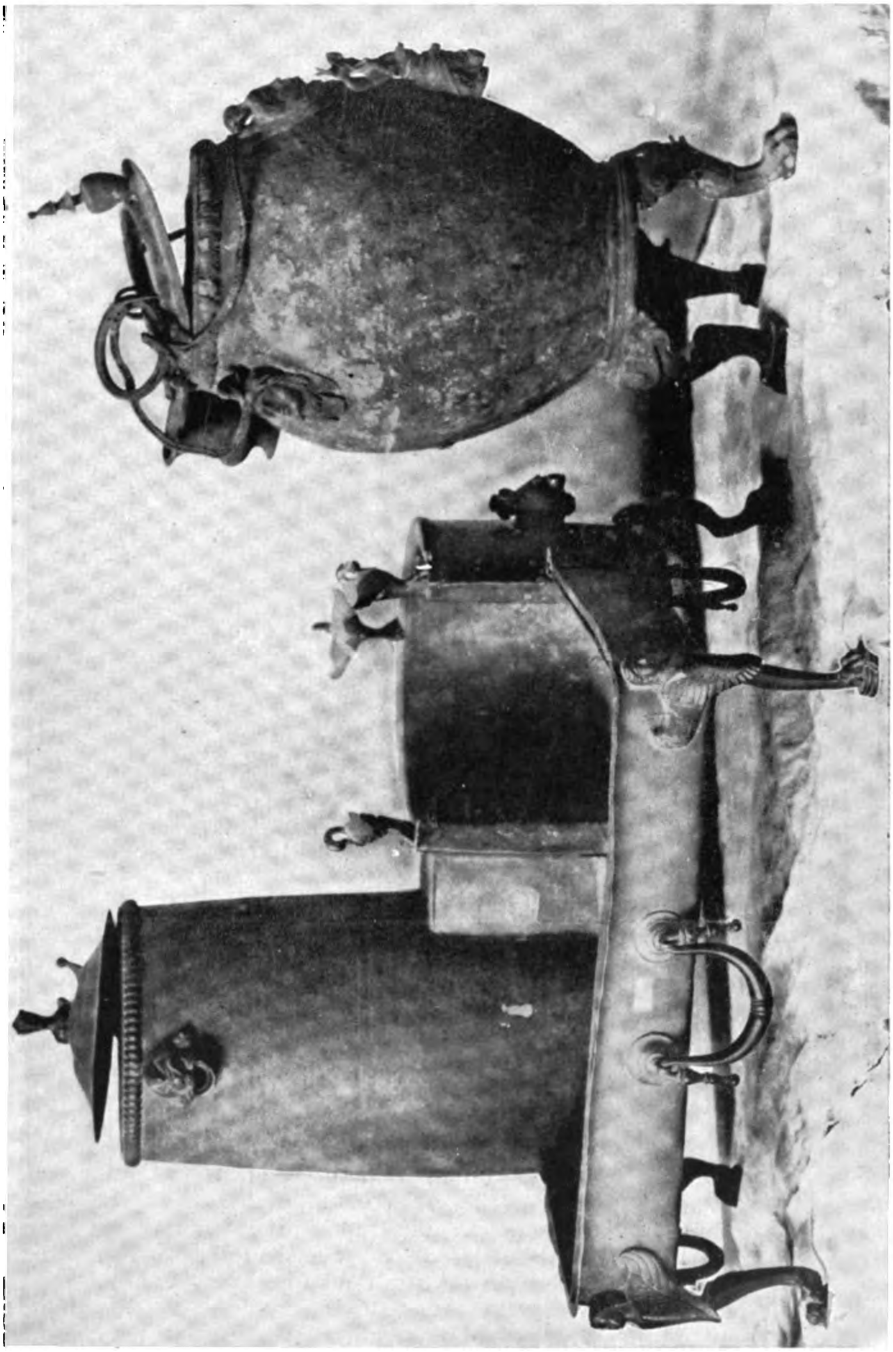


FIG. 7. ANCIENT POMPEIIAN BOILERS. FIG. 8.

for the purpose of pouring out part of the liquid contents without spilling the fuel.

I have also received from the Dutch Consul at Genoa photographs of a group of ancient Pompeiian relics obtained through a friend of his in Naples. The photographs reproduced here are Figs. 7, 8 and 9. Evidently the subject offered this layman little in the way of either romance or sentiment; consequently our record is deficient in that it lacks any accurate description of the articles illustrated in the photographs. The apparatus shown in Fig. 9 is said to be constructed similar to Fig. 8, but whether it consists of an annular waterspace connected by horizontal water tubes, or simply an outer vessel containing an inner smaller vessel whose flanged rim rests on the upper edge of the outer vessel, after the manner of the ordinary double boiler so common in the modern household, our informant does not state.

The group, Fig. 7, is said to represent merely ordinary kitchen furniture, used no doubt in the culinary department of some large household. Certain features ot this group, brought out by the photograph, might indicate that this apparatus was utilised for more important work, and it is unfortunate that we cannot have some further information as to its internal construction.

The description of the two boilers is somewhat meagre and unreliable, but sufficient is given to establish the fact that the large boiler (Fig. 8), at least, is provided with a water jacket, with some form of grating for supporting the fire underneath. A cock at one side, which appears to be very artistically decorated, served to draw off the heated liquid.

The latter photographs, reproduced herewith, were obtained from the gallery opposite the National Museum at Naples. Apparently little effort has been made by the authorities at the museum to trace the origin and history of the different relics I have described above, my informant stating that no one had interested himself in the matter, although some of the articles were discovered as many as forty years ago.

This delinquency seems all the more apparent from the fact that in order to give a proper reply to my inquiry, it

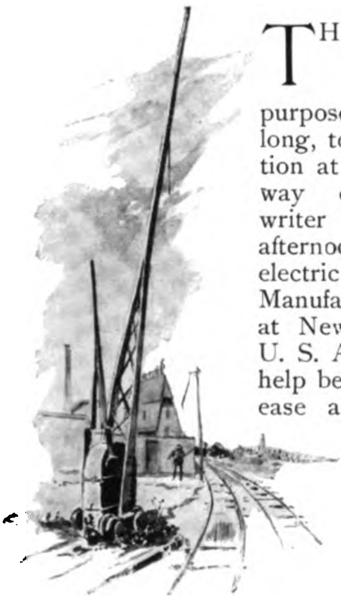
FIG. 9.

became necessary to call in the services of a photographer and an engineer to illustrate and describe these precious relics of ancient days. I only regret that the same effort was not made to give us fuller information regarding the apparatus illustrated in Figs. 7, 8 and 9.

For much of the data contained in this paper I am under obligations to M. Francisco Milone, a very able engineer of Naples, and to the Dutch Consul at Genoa, N. I. Tiedman. I have also to acknowledge the courteous and valuable assistance rendered by the Hon. Com. G. Solimbergo, Consul-General d'Italie, for Canada, and the Hon. K. Boissevain, Consul-General for the Netherlands, at Montreal.

ELECTRIC SWITCHING LOCOMOTIVES.

By E. H. Mullin.

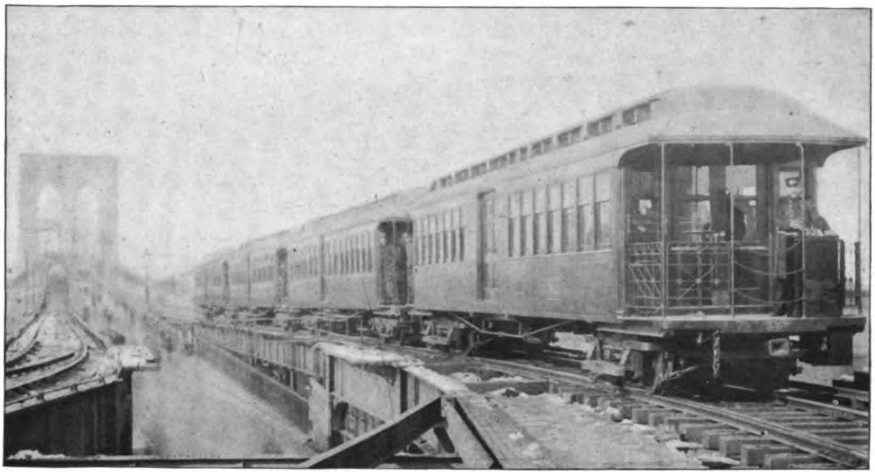


THE utility of electric locomotives for switchyard purposes is likely, before long, to receive recognition at the hands of railway companies. The writer recently spent an afternoon on the 30-ton electric locomotive of the Manufacturers' Railway, at New Haven, Conn., U. S. A., and could not help being struck at the ease and celerity with which the massing and separating of freight cars was done, as contrasted with similar work performed by a steam locomotive. The Manufacturers' Railway is a short line, only a mile and a half in length, which connects the sidings of several large factories with the main line of the New York, New Haven and Hartford Railway. During its course, it has an up and down grade of 2½ per cent., and it also has many sharp curves, some of them with as short a radius as fifty feet. The road is owned by the manufacturers jointly, and has hitherto been worked by horses. This mode of traction proving expensive and troublesome, the establishments concerned made a contract with the General Electric Company, of New York, to equip it with the overhead trolley, and to provide one of its thirty ton electric locomotives to replace the horses. Although the new system of traction had been in working order only a few days when the writer first saw it, the manufacturing owners seemed delighted with the change.

The power house, from which the necessary current is obtained, is very conveniently situated at about the middle of the line. The nominal pressure is 550 volts, and the actual working pressure about 500 volts. The locomotive is designed for a maximum speed of ten miles an hour, and will give a speed of seven miles an hour under full load up a 2½ per cent. grade, while exerting a draw bar pull of 7000 pounds. Reckoned in horse-power, the effective energy of the locomotive is about 230.

There are two pairs of wheels, each wheel being 44 inches in diameter. Sleeved on each axle is a motor, the prolongation of the armature fitting into a clutch which, in turn, braces itself against two lugs projecting from the axle. The motors are hung by springs from the frame, so as to relieve them from the wear and tear incidental to inequalities in the rails. At the same time it should be said that the roadbed has good, hard ballast, and the rails are heavy and well spiked to the ties, making altogether a permanent way superior to that usually seen in private sidings and their approaches.

The most striking thing about the behaviour of this electric locomotive is the certainty with which it may be moved over short distances, varying from a few inches to a few feet. The obedience of the motors to the controller is practically instantaneous, thus doing

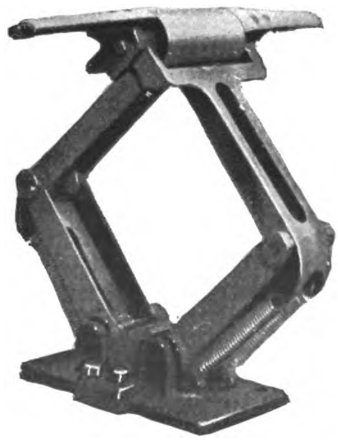


AN ELECTRIC MOTOR CAR ON THE NEW YORK AND BROOKLYN BRIDGE.

away at one stroke with one of the chief drawbacks to steam switching engines with which there is a noticeable delay between the time when the throttle valve is opened and the pistons begin to move, in this way often causing the engineer, no matter how careful he may be, to overshoot his mark.

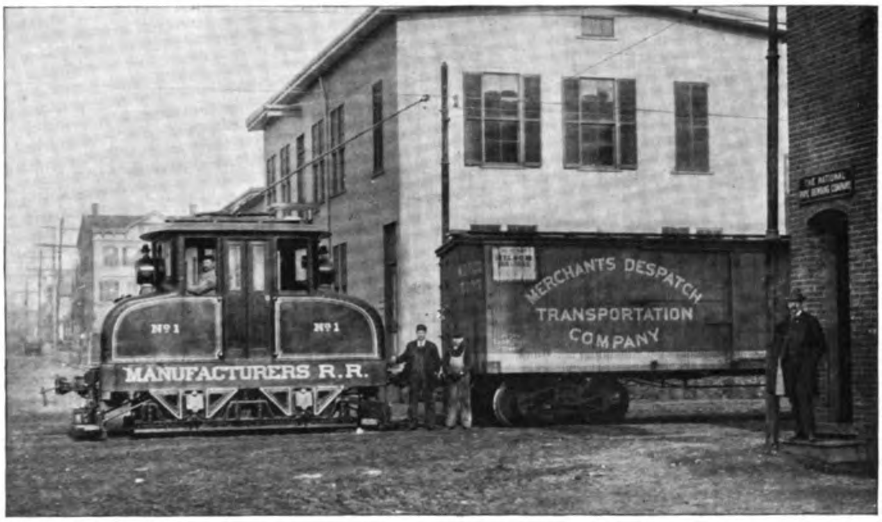
This delay in action, while generally only a few seconds in each case, mounts up seriously in the course of a whole day's work, and is the chief cause of the proverbial lateness of freight trains which have much switching to do at intermediate stations. From the fact that the movement of the electric locomotive can be graduated so nicely, a full third of the time usually occupied by steam locomotives can be saved, particularly as single empty cars unprovided with automatic couplings need never be bunted off by too rapid an approach of the engine, as frequently happens under switching conditions as they now are.

Again, the acceleration of the electric locomotive is so even that the freight cars of a comparatively long train are started, one after another, without jerking and without apparent strain. A weak draw bar is thus protected against sudden fracture, and no "easing off," with consequent reduction in speed and delay in getting under way, is necessary as in the case of the steam locomotive. The electric locomotive, further, is fitted with a quick-acting air brake, the pressure for which is kept at its maximum by an automatic electric air pump, instead of the comparatively slow-acting steam brake which is usually attached to steam switching engines. The highest rate of speed permissible in such cases may, therefore, be indulged in with the certainty of a quick stop, should occasion require it.



THE CURRENT COLLECTOR ON THE BROOKLYN BRIDGE MOTOR CARS.

The handiness with which an electric locomotive may be operated is another point in its favour. There is neither the internal pressure of the steam against the throttle valve, nor the stiffness and weight of the link reversing gear to overcome. A dainty controller handle, which could be moved by a child, and a reversing handle almost equally light and movable, open and arrange the paths for the current. It is the literal truth that an engineer could work the controller, the reversing lever and air brake valve on the electric locomotive at New Haven for an hour with his finger and thumb without unduly tiring himself. So handy, compact and complete is the electric switching locomotive that a second man in the cab is as unnecessary as an assistant motorman on a trolley car would be.



THE 30-TON ELECTRIC LOCOMOTIVE ON THE MANUFACTURERS' RAILROAD AT NEW HAVEN, CONN.

When the current for operating an electric switching locomotive is derived from a trolley power station, as is the case at New Haven, there are obvious economies in using an engine of this kind instead of a steam locomotive. No time is required to get up steam, and there is no waste steam when the engine is housed for the night. At the lowest calculation, a locomotive, standing idle, but under steam, will have a coal consumption equal to that entailed by a constant speed of six miles an hour; while in doing a very moderate amount of switching, with waits between, its consumption will not be less than the equivalent of twelve miles an hour. The electric locomotive, on the other hand, wastes no power, except when actually doing work.

There is a great future before electric switching engines if the designers of them will rouse themselves from their lethargy and strive to adapt them more perfectly for such work. To do this, it will first be necessary to consider the form and equipment of an ideal cab for such engines, without reference to present steam or electric models.

Let us consider what the engineer who had spent his life in a switch yard would demand if he had an Aladdin's lamp whose powers were confined to effecting this object. He would want his cab made like a circular conning tower, so that, seated in the centre of it, he could see out in all directions by merely turning his head. He would also, upon discovering that he had neither boiler nor coal tank to impede his vision, demand that he should be able to see both his coupling bars from his perch in the cab, and in this way be able to watch the approach of his engine to the car to which it was to be attached, be able to see an automatic coupling snap fast, or the trainman drop the pin in and stand clear in case the coupling was not automatic. Then he would want the handles of his controller, reversing lever and air brake valve so placed that he could reach them all from his seat or from any part of the cab. All these improvements are practicable in the electric locomotive, which has all its moving parts below the foot plate, and which has room for other apparatus there if necessary.

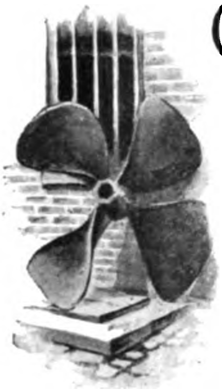
The next point to which designers of electric switch engines should direct their attention is the form which the contact parts between the moving engine and the fixed conductor should take. If the under-running trolley is retained it should be constructed so as to run equally well in either direction without its having to be pulled around by hand to a direction opposite that in which the engine is running. This might be accomplished by a modification of the lazy tongs now in use in the engines which run through the tunnel at Baltimore.

The elevated third rail, while highly successful in the switching terminals of the Brooklyn Bridge, would present almost insuperable difficulties against its adoption in a complicated switch yard where much of the work would have to be done after dark, and where switchmen would always run the deadly chance of tripping up at the wrong moment. The depressed rail in the centre of the track is open to grave difficulties of insulation in switch yards. In the light of present knowledge, and considering the matter simply from the switch yard point of view, the overhead trolley, in some form, seems to have the advantage over other methods, especially if the wheel or shoe could be made to follow the locomotive automatically.

There is one more advantage in using electric locomotives in switch yards which may be pointed out here in view of the coming displacement of steam by electric traction, than which nothing is more certain, in the writer's opinion, to come to pass in a few years. When present railway companies change their form of traction, they will need, above all things, the services of their locomotive engineers, the only available persons who are skilled in signals, the location of stations, rates of speed, keeping time and handling trains. These men cannot be suddenly turned loose with a piece of machinery to the proper use of which they are wholly unaccustomed. The switch yards have always hitherto been the birthplace of steam locomotive engineers. Would it not pay the large railway companies which contemplate the use of electricity for traction purposes to fit up at least one of their moderate sized switch yards with electric locomotives so that their engineers might be gradually broken in to use the new form of power with intelligence and confidence?

THE BAZIN ROLLER BOAT.

By Johannes H. Cuntz.



ON August 19, last year, at St. Denis on the Seine, in France, there was launched a novel craft, which, if it realise the expectations of its inventor, will have greater speed in proportion to its driving power than any other vessel now afloat.

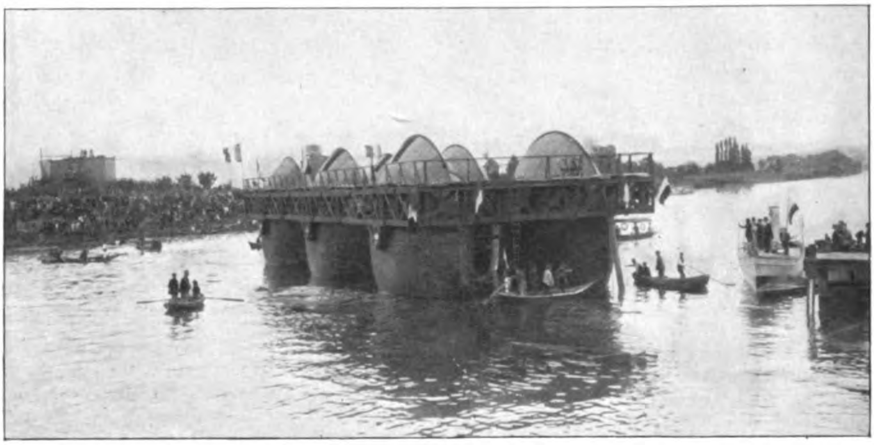
This boat, which bears the name of its designer, M. Ernest Bazin, a French marine engineer, consists essentially, as outlined in an earlier number of this magazine, of a platform above the surface of the water, supported on six upright lenticular wheels, which are immersed to about one-third of their diameter and which revolve as they move over and through the water. The propelling power is communicated to a three-bladed screw at the end of a long shaft by an engine on the platform. There are special engines for turning the wheels, one for each pair, for in order to secure the greatest efficiency, these rollers must revolve at a speed proportional to that with which the boat advances. By this contrivance, rolling friction takes the place of the usual sliding friction between the water and the outer skin of a vessel, and it is expected that the resistance to the forward movement of the boat will thus be reduced to a minimum.

M. Bazin, it appears, has not arrived at his conclusions hastily, for he has been working at the idea of a roller boat for twelve years or more, and the craft which has recently been launched embodies the results of many trials and experiments. Some of these experiments were repeated by him not long ago, in the presence of a large company, in a tank constructed for the purpose at his Levallois Works, and were recently described as follows in *The Engineer*, of London:—

" First, a hollow wheel was placed in the tank, and it floated vertically with about a third of its bulk immersed. Spun round without any forward movement, the wheel continued to revolve for some time without moving from its place, and this proved to M. Bazin that he could not rely upon the revolution of the wheel alone for the propulsion of the vessel. He then pushed the wheel forward without revolving it, and the effect was exactly the same as with an ordinary keel, that is to say, it threw up a good deal of water in front and left a trail behind. Moreover, it only advanced four or five feet, and did not show the slightest tendency to revolve.

A FRONT VIEW.

" This convinced M. Bazin that he would have to give to the wheel both a revolving and a forward motion. Thereupon, spinning the wheel and pushing



AFTER THE LAUNCH.

it forward, the hollow disc travelled the whole length of the tank with scarcely any agitation to the water whatever. Still pursuing the experiments, the inventor gave a more convincing illustration of the absence of any resistance and friction with the revolving disc. Two sticks were placed in the water, and a disc was propelled horizontally. On meeting the sticks the wheel pushed them forward a few inches and then stopped. Repeating this experiment with a revolving disc, the wheel passed over the sticks, which sank under the wheel and rose at the identical place, while the disc continued its course to the end of the tank.

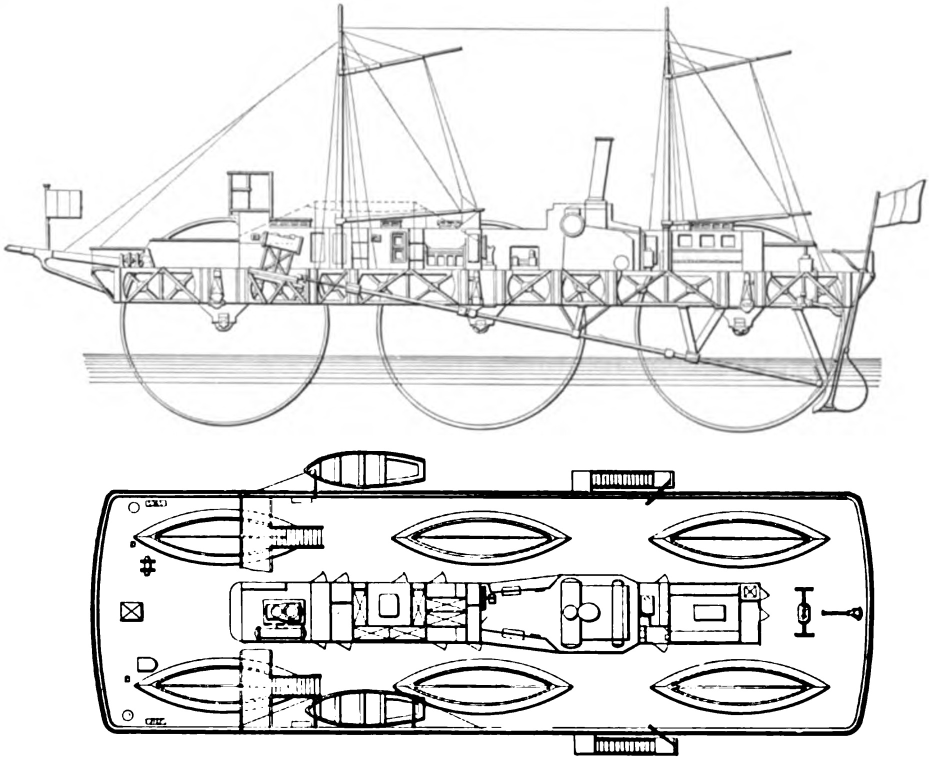
"After thus proving that the wheel must have both a revolving and a forward movement, M. Bazin soon found that nothing was to be gained by revolving the disc too quickly, and that it was merely necessary to do this in proportion to the propelling force of the screw. If anything, too much power upon the wheels would be likely to cause a certain amount of friction. Under these circumstances, the relative power upon the propeller and the wheels would have to be calculated with a certain nicety, as the discs would have to turn in exact proportion to the distance covered by the boat.

"This fact having been settled, M. Bazin proceeded to demonstrate the stability and speed of the wheels. A framework carrying six disc wheels, three on each side, was placed in the tank. A cord was attached to it and drawn up over a pulley and carried a weight of 200 grammes, which represented a certain propulsive force. The frame was pulled back to one end of the tank and allowed to go forward by the action of the weight at the end of the cord. According to the watch, the time occupied in travelling the whole length of the tank was twenty-three seconds.

"The same experiment was then repeated with the wheels revolving by clockwork, and though losing two or three seconds at the start before getting up full speed, the apparatus went from one end of the tank to the other in eleven seconds. By comparing these results, M. Bazin estimates that the speed of a disc wheel steamboat would be thirty-one or thirty-two knots, while the smaller power required results, according to his estimate, in an economy of about 66 per cent. of coal.

"One of the advantages claimed for the system is the practical impossibilty of sinking. Supposing that one or two, or even more, of the wheels were perforated in collision, the vessel would not do more than sink a few feet, a fact which was exemplified by the inventor removing the plugs from two of the wheels, and allowing the water to enter. As soon as the water had entered to a certain height in the wheel, it turned up with the orifice at the top, thus permitting of the damage being repaired with the greatest ease. Meanwhile, it would be possible for the vessel to proceed at reduced speed.

"Having thus, as he considers, demonstrated the speed, economy, stability and safety of the Bazin wheels, the inventor showed a working model in a large basin constructed for that purpose. As the model is on a scale of one-twenty-fifth of a transatlantic boat, which it is proposed to build with a length of 130 metres, the deck or platform represents a height of six or seven metres above the sea, while the upper deck is about thirteen metres above the water level. The deck itself is built up with girders, and being hollow, it has an enormous carrying capacity, either for merchandise or coal. There are six discs or floats, three on each side, and owing to their convex form they offer little resistance to the wind, while the head wind has a clear passage underneath the deck. In appearance the model is very elegant, and certainly destroys any prejudice that might be entertained against the form of the vessel.



ELEVATION AND PLAN.

"The motive power was supplied by dynamos, one working the propeller and four others turning the floats. Upon the connection being made, the propeller revolved with great rapidity, and the wheels turned slowly, and after a few seconds lost in getting under weigh, the model sailed the whole length of the basin at great speed. To show the conduct of the vessel in rough weather, the water was agitated to represent waves, on the same scale as the model, of five to seven metres in height, and though rolling slightly at her moorings the model behaved splendidly when in motion. The miniature waves rose nearly to the level of the deck, but the model rode as steadily as in the previous experiments. It is claimed that in the roughest weather the passengers would feel very little movement of the vessel

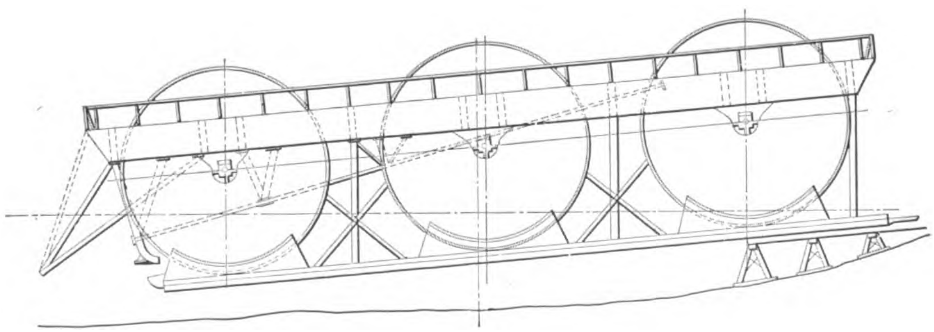
"In the experimental boat constructed, the steering is done with an ordinary rudder, but it is proposed to steer the transatlantic vessels by means of a column of water forced out of the stern by a pump, so that instead of the progress of the vessel being impeded by the resistance of a rudder, it will be assisted by the water thus expelled at the stern. On the boat taking up its berth it may be driven by the steering gear alone, and this acts, it is alleged, so efficaciously that the vessel can be turned round its own length."

These experiments will be repeated on a much larger scale when the *Ernest Bazin* is made ready for its trial trip, and many of the French naval experts and marine engineers expect that they will be equally successful. The present boat is intended only for service in the English channel and other coast waters, but in the event of its success, it may be the forerunner of a fleet of transatlantic liners, constructed on the same principles, with such modifications as experience may suggest.

The *Bazin* has six rollers, each shaped like a double convex lens, 3.6 metres (11.8 feet) thick at the centre and ten metres (32.8 feet) in diameter. These wheels are arranged in pairs, each pair being connected by a steel shaft or axle. There are four journals on each shaft, making twelve supports in all for the superstructure, which contains the machinery and the accommodations for crew and passengers. This superstructure consists of four parallel girders, each 1.7 metre (5.6 feet) deep, strongly braced and tied together. A deck forms the top of this platform, which is 38.5 metres (126.3 feet) long and 12.18 metres (40 feet) wide, over all, and overhangs the rollers.

On the platform are deck houses containing the boiler and engine rooms, saloon, staterooms and other apartments, with the bridge well forward. The boiler is of the multitubular type, with small water tubes, and has a heating surface of 183.6 square metres (1970.4 square feet). The grate surface is 4.84 square metres (52.1 square feet). The weight of the boiler, with accessories, is 10,100 kilogrammes (22,267 pounds), and the volume of water which it contains amounts to 2.2 cubic metres (77.7 cubic feet).

One engine, of about 500 horse-power, works a three-bladed bronze propeller, while each pair of rollers is driven by a separate engine of about fifty horse-power by means of gearing with a ratio of 1 to 3. The propelling engine is of the compound vertical type, with Stephenson link motion, and has a surface condenser. Its principal dimensions are:—

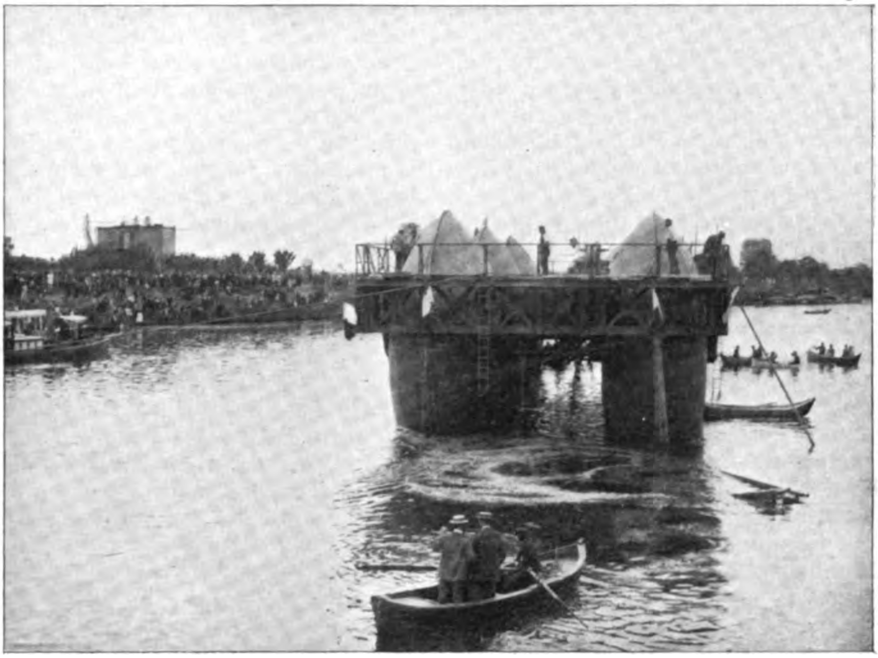


LAUNCHING THE BAZIN BOAT.

Diameter of high pressure cylinder $14\frac{9}{16}$ inches (0.37 m.).

Diameter of low pressure cylinder, $25\frac{6}{16}$ inches (0.64 m.).

Stroke of piston, $14\frac{3}{16}$ (0.36 m.).



A STERN VIEW AFTER THE LAUNCH.

The engines for turning the rollers are vertical, have two equal cylinders without reversing gear, and exhaust into the condenser of the large engine.

Owing to the distance of the platform above the water several difficulties have arisen, due to this method of construction. One of these, the problem of obtaining a supply of sea water for the engines and other purposes, has been ingeniously solved by the constructor, M. Paul Dubar. He makes use of the stern post, which is necessarily in the water, and which is a cast steel tube, solidly braced to the superstructure, with its lower end open and pointing forward. The water rises part way up this tube owing to the speed of the boat, and is raised the rest of the way by a suction pump on deck.

As the engine is at such an elevation the propeller shaft is necessarily inclined. This disadvantage is minimised by placing the engine forward and as low as possible, so that the angle which the shaft makes with the horizontal has been reduced to 11 degrees. The length of the shaft is 28 metres (91.8 feet); its outer diameter is 0.16 metres (6¼ inches) and its inner diameter 0.1 metres (4 inches). M. Bazin believes that with large vessels of this type paddle wheels should be used instead of screw propellers, but as the present boat is only an experimental one, the small reduction in speed, due to the inclination of the propeller shaft, will not interfere with the test of the correctness of the inventor's principle.

The lattice girders which form the framework of the superstructure are calculated to resist the maximum stresses which occur under the most unfavourable conditions:—(1) When the boat is supported on the middle pair of rollers, while the bow and stern rollers are out of water; and (2) when the boat rests on the end rollers while the middle pair is suspended in air. The boat is not long enough for either of these conditions to arise often, but such a case may occur in a very rough sea. The roller shafts, bearings and other parts are considered to be amply proportioned to resist the stresses to which they are liable. The displacement of the *Bazin* is about 242 tons. The inventor expects that a normal speed of eighteen knots and an extreme speed of from twenty-two to twenty-five knots will be attained with a total horse-power of about 650. Now the horse-power necessary to drive a vessel of the ordinary type is proportional to the cube of the speed, and so for the fast steamships of the present day, every small increment in the speed makes necessary such a great increase in driving power that the economical limit on the prevailing system has been almost reached. The French periodical *Le Yacht* says that the combined immersed midship section of the six wheels of the *Bazin* is 419.8 square feet. To drive this same section at twenty-five knots in a vessel of the ordinary form would require at least 9,370 horse-power.

This method of comparison may seem exaggerated for the reason that the real cross section of the roller boat is that of only one pair of wheels,—that is, 139.9 square feet. But even with this reduced figure, the corresponding horse-power for an ordinary type of vessel would be 3,126, or about five times that of the *Bazin.*

Admiral Coulombeaud, one of the foremost naval authorities in France, who is showing a keen interest in the Bazin boat, has come to the conclusion that it requires only about one-twenty-seventh of the power necessary to drive an ordinary boat of the same size at a given speed. Taking the transatlantic liner *Touraine* as an example, he further states that if this vessel travelled at twenty knots, the roller boat, with the same power, would attain a speed of forty-seven knots; but as it is not proposed as yet to construct a vessel to run at more than thirty knots, such a boat would require only a fourth of the power employed in the *Touraine.* The rollers of these ocean steamers would be about seventy-two feet in diameter, while their draught would be twenty-four feet, or about the same as that of the present Atlantic liners.

The *Ernest Bazin* was built and launched at the yard of Messrs. Cail & Co. at St. Denis, under the supervision of M. Paul Dubar, the director of the works. The superstructure was put together on an immense staging, which brought the platform up to its proper height. The rollers were erected on independent stagings, and when finished were placed in position and connected with the superstructure.

The launching was a rather delicate operation, the chief obstacles being the short length of the launching timbers, the shallowness of the Seine and the difficulty of distributing the load equally over the six rollers, which, taken separately, were comparatively fragile. But these and all other difficulties were overcome, and the launch was a brilliant success, reflecting great credit on the builders and the director of their works.

The *Bazin* has since been towed to Rouen, where its engines will be put in and where it will be otherwise fully equipped.

ELECTRICITY IN AGRICULTURE.

By John McGhie.

THE employment of artificial incentives to the growth of plants is almost as old as the discovery of the resuscitation of the planted seed, and dates back to the very beginning of agriculture—the primal pursuit of man. The aboriginal farmer, like every member of his race that has followed, became early dissatisfied with the slow process of nature under the changing seasons.

The chemical action of the rains upon the earth, the disintegrating influences of the cold and the vivifying effects of the sun's rays were not speedy enough in results, and the primitive mind cast about to discover a means of accelerating the growth of, and increasing the return from, his crops. The curse of Adam lay upon the soil, and to Cain himself, under the biblical ban, may belong the honour of first employing the artificial incentive in his farming work, to overcome the terrible interdict,—"When thou tillest the ground, it shall not yield to thee her strength."

No tiller of the soil, since that early curse was pronounced, but has sought to coax the earth to yield still a little more, and to this persistence of effort and the constant exercise of ingenuity and experiment, is due the marvellous diversity of domestic plant life.

Of the artificial influences which have been brought to bear upon vegetation since history began, the most recent is electricity. The discovery of the operation of the wonderful new force, and the early explanation of its phenomena gave rise to sanguine predictions of a faerique nature, in their conception and expression not less ingenious and fantastic in the last century than those which pass current in the present.

Inventive talent, working under disadvantages, almost inconceivable in these days, was excited and its attention turned upon the newly discovered force. The stories of its marvellous effects upon the human body and its ills, gained ready credence in a century prone to take *omne ignotum pro magnifico*, and to the contemporary inventive mind, if electricity could work so beneficently upon the human body, it might be employed with equal benefit upon plant life, did not appear mistaken logic.

Could scientific history have been written then with that scrupulous regard for truth which prevails to-day, the account of the numerous experiments undoubtedly carried on, would prove interesting reading. No records exist, however, to show what the student of those early days attempted in this direction. Until the invention of the dynamo, the electric light and the motor, experiments with electricity upon plant life were necessarily confined to the determination of the results of the direct application of the battery current, or of static electricity, upon the ungerminated seed and the growing plant, and peculiar were the methods employed.

In 1783, the Abbé Bertholon published an elaborate treatise "Concerning Electricity on Plants," and after recounting the results of his experiments, demonstrating the favourable effects of electricity on the development of vegetation, he described a primitive method of applying the current to the growing plant

BERTHOLON'S ELECTROVEGETOMETER.

through what he termed an " electro-vegetometer."

This consisted of a cart, with an insulated bottom, on which stood a man with a watering can. The cart was drawn over the field by a horse, and one end of a flexible conductor, wound around a bobbin in the cart, was attached to the man and the other to the poles of an electrical machine. The good abbé's theory was that the current would pass from the machine, through the man and the water to the plants and thus exert on them a beneficial influence. We are not told whether the results obtained came up to his expectations.

The savants of the time discussed the subject as thoroughly as their light allowed, and during the early part of this century many experiments were carried on. These early investigations, however, resulted contradictorily. Indeed, in the then embryonic condition of technical electricity nothing less could have been expected. Certain experimenters, —Jolabert, Nollet, Mainbray, Achard, Pardini-Van Marum and others,—affirmed that the development of the seed was favoured and the growth of the plant accelerated by electricity, while Imgenhouse, Van Trootswyck, Sylvester, Senebier and others rejected the theory utterly.

Further experiment under better conditions, determined the beneficial influence of the current on plant life, and the work of Sir Humphrey Davy, Bischoff, Humboldt, Wollaston and Becquerel, largely contributed to the establishment of this fact. Their labours were, however, confined principally to the theoretical side of the question, and it is from 1845 only that genuinely practical experiment in electro-culture may be said to date.

About this time we hear of experiments with copper and zinc plates connected by wires, the plates being buried and the seed sown between them. This was the application of battery current. Other experiments were carried on with electricity from large static machines.

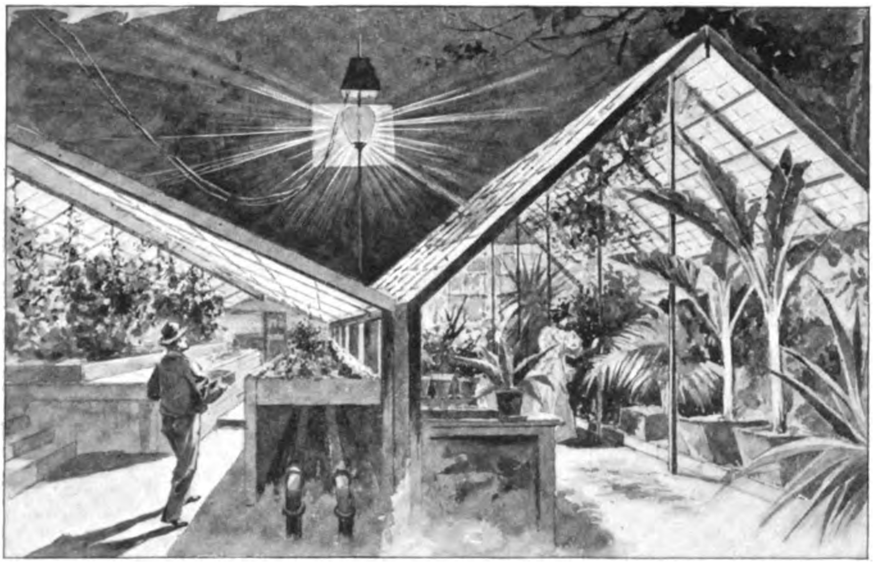
The first method was employed in England in 1846 by Sheppard; then in Scotland, by Forster, and in 1847, Hubeck, in Germany, surrounded a field with a network of wires. Sheppard's observations led him to believe that the electricity only increased the return from root plants, while grass in the vicinity of the electrodes perished.

Hubeck declared that under the same influence seeds developed more rapidly and that buckwheat gave a heavier return, but that in other cases results were unsatisfactory. Fife in England and Otto Von Ende in Germany also carried on a number of experiments, but as the results which they obtained were unsatisfactory, they advised the complete abandonment of further attempt to apply electricity directly to agriculture.

After some years, investigation was renewed by Fichtner, who used a current from a battery, the two wires from which were buried parallel to each other in the soil. Between these wires were planted peas, grass and barley. The result was most encouraging. The crop showed an increase of from 13 to 27 per cent. when compared with similar crops obtained by the ordinary methods of cultivation.

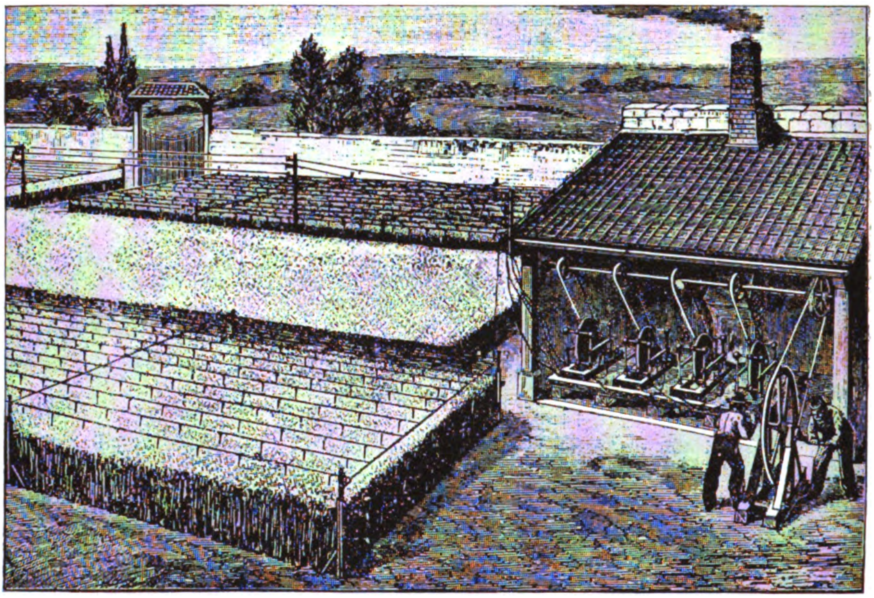
In 1878 Grandean, Leclerc and Celi took up the question. The first showed that plant life is benefited by atmospheric electricity, and that, if deprived of it, plants will produce from 50 to 70 per cent. less of vegetable matter and fruits than under ordinary conditions. The same facts were also determined independently by M. Leclerc.

M. Celi's experiment consisted in planting three seeds of Indian corn in each of two flower pots, each pot filled with earth of a similar nature and each pot covered with a bell jar. One bell glass only was electrified. On July 30, 1878, the seeds were planted, and on August 1 they began to germinate. Three days afterwards the plants under the electrified glass showed that they were growing faster than those under the unelectrified glass. On August 10, those under the influence of electricity had attained a height of seventeen centimetres, while those growing under natural conditions were only eight centimetres high.



ELECTRIC LIGHT GREENHOUSES.

At Brodtorp, in Finland, Selim Lemstrom stretched a system of insulated wires, provided with points, over a wheat field. Four electric static machines, driven by two men, were employed to furnish the electricity. The result was a large crop, exceeding by nearly one-half that from portions of the same field not submitted to the electric influence. In 1886 the wheat crop on the experimental field was phenomenal, and could not, it was thought, be exceeded; yet, in 1887, the crop exceeded that of the 'preceding year



STIMULATING PLANT GROWTH BY SURROUNDING FIELDS WITH ELECTRIC WIRES.

by 28 per cent. per square metre. From the results Lemstrom concluded that plants could be divided into two groups,—one comprising wheat, rye, oats, barley, beets, parsnips, potatoes, celery, beans, raspberries, strawberries and leeks, which were favoured by electricity; the other, the development of which is interfered with by the current, comprised peas, carrots, turnips, cabbages, tobacco, etc.

In 1890 Mr. N. Specnew gave the results of his investigations. He used the seeds of peas, beans, sunflowers and barley, — twelve groups, each of 120 seeds. These were soaked in water until they swelled; then they were introduced into long glass tubes, open at both ends. A copper disc was then introduced at each end, and these were pushed in until they compressed the seeds. Rods, attached to the discs, were connected to the poles of an induction coil, and the current was passed through the seeds for about two minutes. The seeds were then sown. The result of this experiment is shown in the following table:—

	Peas.	Beans.	Barley.	Sunflower.
Electrified seeds developed in days	2.5	3	2	8.5
Non-electrified seeds developed in days	4	6	5	15

At the Botanical Gardens at Kiew, in Russia, a second series of experiments was undertaken by Mr. Specnew. These were a repetition of those originally made with the large plates of copper and zinc, connected by wire, the whole buried in the soil. Pot herbs and flowering plants were sown between the plates, with the result that the influence of the current was shown in a larger crop, and in the enormous growth attained by the vegetables.

The third series of experiments carried on by Mr. Specnew, involved the use of static electricity. On a selected number of plots were planted poles with crown shaped collectors, all connected by wire. The plants, therefore, matured in the midst of a highly electrified atmosphere. These experiments were carried on for five years. The result showed a considerable increase in the yield both of straw and seed, proving that a slow discharge of static electricity assisted the plants in assimilating nitrogen. The ripening was more rapid, barley coming to maturity about twelve days earlier under electro-culture. It was also shown that potatoes, grown under the influence of electricity, became impervious to infectious disease and instead of from 10 to 40 per cent., the percentage of rottenness ranged between 0 and 5. The results tabulated below show the increased yield per cent. :—

Plant.	Increase Per Cent. Grain. In Size.	In Weight.	Straw in Weight.
Rye	29	28	60
Wheats	56	56	1
Oats	57	62	58
Barley	48	55	18
Peas	22	25	23
Clover	32	31	18
Potatoes	11	11	34
Flax	42	44	16

Since 1890 a series of interesting experiments have been carried on at Cornell University, at Ithaca, N. Y., and the results of the six years' work have been incorporated in an interesting report, recently published by Professor L. H. Bailey. The earlier experiments were all made with an arc lamp which hung inside the house, and it was found that better results were obtained when the arc was screened by an opal globe, or even by a window glass.

The question arose—if this screen could not be afforded with equal advantage by the glass roof itself if the light were hung above it; and if this were true, how far the beneficial effects of the light would extend, or, in other words, how much glass one light could cover. Two parallel houses were built, each divided in the middle into two compartments. These houses are 60x20 feet.

In the valley between these houses, six feet above the nearest glass, the lamp was hung, in front of a large, blackened sheet iron screen, which completely excluded the light from the compartment behind the lamp. By moving the screen to the other side of the lamp, and rearranging certain curtains, it was possible to throw all the light into the other compartment. This change was made during the experiment. The lamp was of the ten ampère, forty-five-

AN ELECTRIC AGRICULTURAL POWER PLANT AT JAISPITZ, MORAVIA, INSTALLED BY MESSRS. GANZ & CO., BUDA-PESTH.

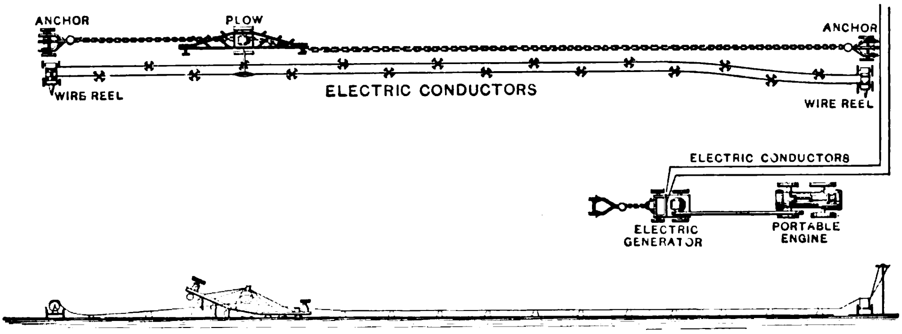
volt, 2000 nominal candle power, run from an ordinary street lighting system, and it seldom burned after 11 o'clock, while it often ran but an hour or two, and on moonlight nights not at all.

The lighted house was exposed to sunlight during the day, and in addition received this small and varying amount of electric light. The other, or so-called dark house, was lighted by sun during the day and received no light at night. The lamp carried a clear glass globe, so that the light passed through two glasses,—the globe and the roof,—before reaching the plants. The experiments are thus summarised:—

"The influence of the electric arc light upon greenhouse plants is greatly modified by the use of a clear glass globe or the interposition of a glass roof. Plants which are much injured by a naked light, may be benefited by a protected light. As a rule, plants are earlier under the electric light than when grown under ordinary conditions. Lettuce is greatly benefited by the electric light. An average of five hours of light per night hastened maturity from a week to ten days, at a distance from ten to twelve feet. Even at forty feet, in only diffused light, the effect was marked. The light appeared to injure young, newly transplanted plants. Radishes were also benefited by the light, but not to a great extent.

When the light was hung in the house, however, whether naked or protected by a globe, radishes were injured. Beets and spinach appeared to be slightly benefited by the light. Cauliflowers, under the light, tended to grow taller than in ordinary conditions, and to make fewer and smaller heads. This corroborates results obtained with other flowers in the earlier experiments. The electric light does not appear to determine or modify the hours of growth of lettuce and some other plants which have been studied in this particular. Plants which are benefited, simply grow more rapidly during the customary periods."

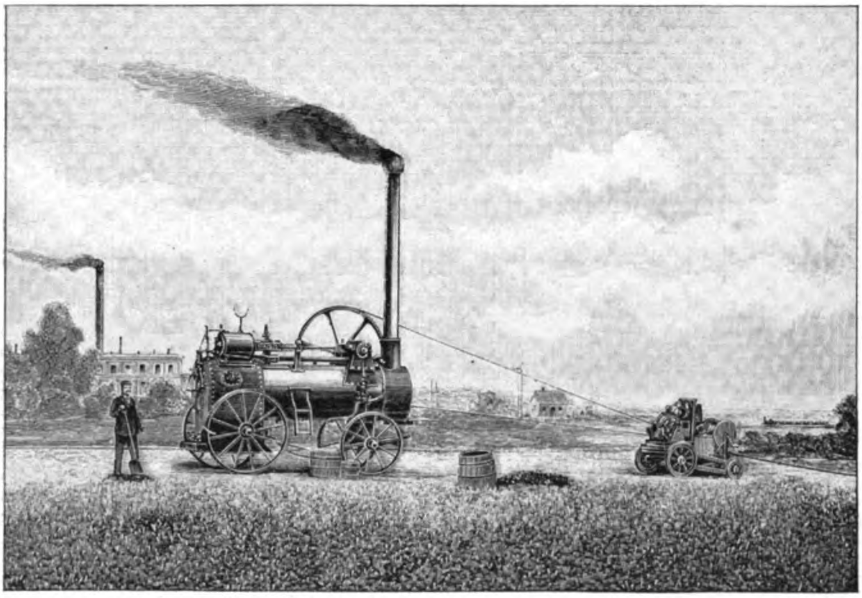
Professor Bailey mentions the fact that W. W. Rawson, at Arlington, near Boston, now uses the electric light in the commercial forcing of lettuce. The house is 33x370 feet, covering nearly one-third of an acre. Along the north side of this house are three 2000 candle power lamps which are run all night.



PLAN AND ELEVATION OF AN ELECTRIC PLOW LAY-OUT.

Mr. Rawson calculates that he receives a gain of five days on a crop of lettuce by the use of these lamps, and as he grows three crops during the winter, the total gain is over two weeks of time. The gain from one crop is estimated to pay the cost of running the lights all winter. The effect of the light is said to be marked at the distance of 100 feet. Professor Bailey concludes,—"I am convinced that the electric light can be used to advantage in the forcing of some plants."

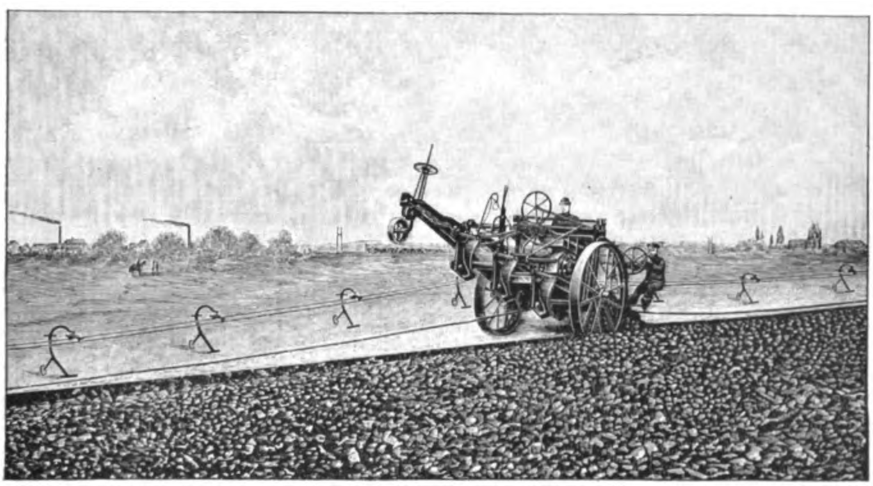
The direct influence of electricity upon plant life, it is thus seen, has so far never been made the subject of any very extensive operations; and we are as far away to-day, as at any time during the past ten years, from seeing the



AN ENGINE AND ELECTRIC GENERATOR OUTFIT FOR FARM WORK, INSTALLED BY MESSRS. F. ZIMMERMANN & CO., LTD., HALLE (SAALE), GERMANY.

electric current systematically applied directly in the culture of our fields. The reason is not far to seek. Magnifying the experiments enumerated, to cover a large number of acres, would entail an expenditure so out of proportion, as to render any attempt at electro-culture on a grand scale prohibitive. Electro-culture, therefore, if carried on at all, will, doubtless, be confined to gardens and hothouses, or will be practiced on the fields of only the most opulent.

But if we are not destined to see the universal application of electricity directly to the cultivation of plants, we find that indirectly, electricity has as-



AN ELECTRIC PLOW, BUILT BY MESSRS. ZIMMERMANN & CO., LTD.

ONE OF THE ANCHORS FOR THE PLOW HAULING CHAIN.

sumed an important role in farm work, and instead of aiding the plants in their germination and growth, has been helping the farmer in the tilling of his land, the harvesting of his crops, and the preparation of his farm products for the market. Farm life, at its best, has little of the poetic in it. Its drudgery is of the most arduous nature and anything to bring relief to the farmer would be welcome.

The ingenuity of the electrician has come to the rescue and has given to the farmer electrically driven apparatus which he can use with benefit and profit on his roads and fields, and in his barns, stables, sheds and dairies, in fact, in almost every branch of his work. The connection between electricity and agriculture has become intimate.

The requirements of farm work naturally divide the electrically driven apparatus into two classes,—those driven by stationary motors, and those moving machines to which motors can be directly connected. In the first category we place the threshing machines, hay and feed cutters, and beet slicers, corn shellers, grinders, cider presses, hay presses, pumps, elevators, churns, etc.; in the second, plows, harrows, seeders, and other field machinery, portable pumps and vehicles in use around the farm buildings and on the country roads.

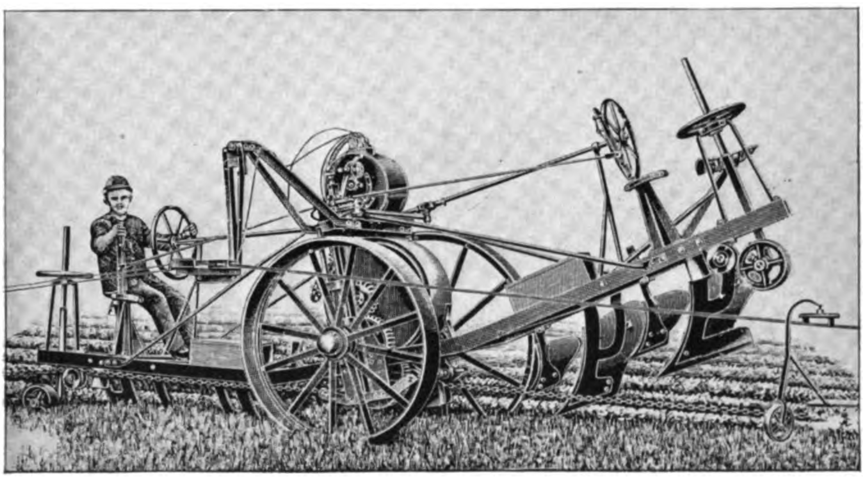
The application of the electric motor to the operation of farm machinery involves no great difficulty now that the motor has reached its present high pitch of mechanical and electrical perfection. Manufacturers of electrical apparatus are able to fall back upon years of experience in electrically driving machinery, and can readily cope with any demands in this direction likely to be made upon them.

Given the machinery, the power to drive it can be taken either from a small isolated steam plant, a waterfall on or near the farm itself, the nearest electrical railway line, or the distant power transmission plant. Instances exist of the use of these four sources. Since the development of the multi-phase system of alternating current operation, the transmission of power no longer appears to the farmer an unsurmountable difficulty.

Among the early experiments in the operation of agricultural machinery by electricity are those made in 1879, by Chretien and Felix at Sermaize in France. They devised a plow which was drawn across a field by wire ropes, wound on two electric capstans, and also used an electrical device for loading and unloading boats at Sermaize. In 1891 Camille Gonzy, at Mallas, in the Western Pyrenees, built a small water-driven electrical station and operated his farm by electricity. He supplied current to 180 sixteen candle power lamps, and applied motors to threshing machines, pumps, wine presses, and other appliances.

At Noisiel, Seine et Marne, France, where M. Menier has a large estate, on which are several farms, villages, a private railroad and the celebrated chocolate factory, all the farm machinery is operated by electricity. The current is supplied by a Brown two-phase 150-volt alternator, of seventy-five horse-power capacity, driven from turbines operated by a fall in the Marne river, by the side of which the factory is built. The current, raised to 2700 volts, is transmitted to the farm about one and one-quarter miles away. There the voltage is reduced, and the current is transmitted to the motors, of which there are two, of the two-phase type, fifteen and twenty horse-power and one single-phase motor of one and one-half horse-power.

One of the larger motors drives a large threshing machine; the other is belted to a counter shaft and operates a beet root washer, a root slicer and a hay cutter, while the smaller motor runs an elevator, used to hoist bales of hay to the loft. The threshing machine is set on rails extending from end to end of the barn floor, upon one side of which the sheaves of wheat are thrown. The machine is then started from one end and advances until the wheat is threshed. In addition to the motors, the installation comprises several dozen incandescent lamps and a few arc lamps, scattered throughout the barns, stables and sheds.



ANOTHER VIEW OF A ZIMMERMANN ELECTRIC PLOW.

In the summer of 1894 Messrs. Ganz & Co., of Buda-Pesth, installed a power plant for agricultural purposes on an estate at Jaispitz, in Moravia. The power is supplied from a large steam saw mill at one end of the estate, a continuous current generator of thirty horse-power being erected in the mill.

The current is taken along two circuits, each about three miles long, in directions almost at right angles, one running to a flour mill and dairy, with a branch to a neighbouring farm, while the other circuit runs to another large farm. At the dairy a ten horse-power motor drives two centrifugal separators, a pump and other apparatus, and helps out an adjacent flour mill which, owing to the limited supply of water, could previously be run only for a short time during the year.

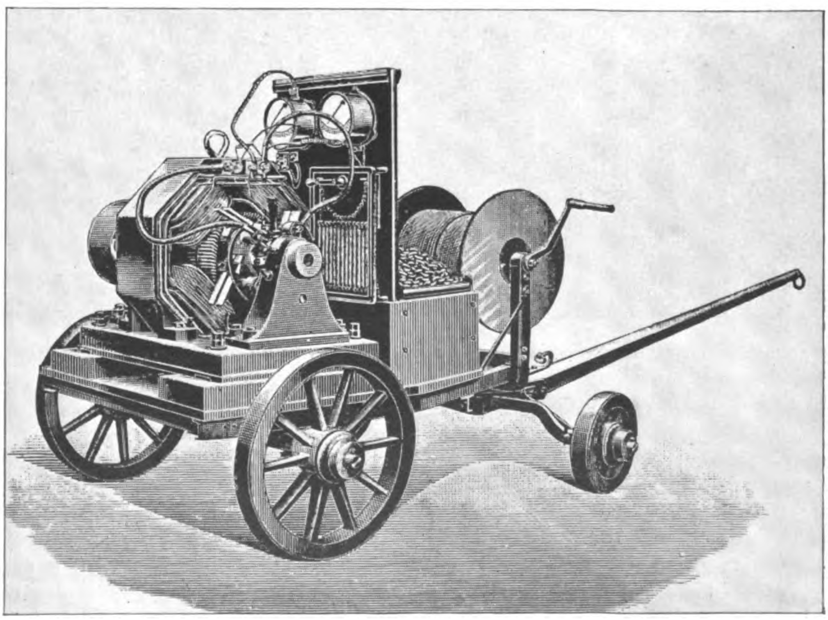
Each farm has a twelve horse-power motor, mounted on a covered wagon for transportation to different parts of the farm, there to operate threshing machines. Bare copper overhead wires, with sliding flexible contact, are used for the field circuits, and the motor wagons can thus travel from point to point on the field where the wheat is stacked, ready for threshing. After the harvest is in, these portable wagon motors are used for pumping purposes, and one of them finds useful occupation in a distillery on the estate.

The current used at the dairy under full load is about eight ampères, the flour mill requiring as much more. The threshing machines take ten ampères when handling peas, beans and other leguminous products, and from fourteen to sixteen for corn.

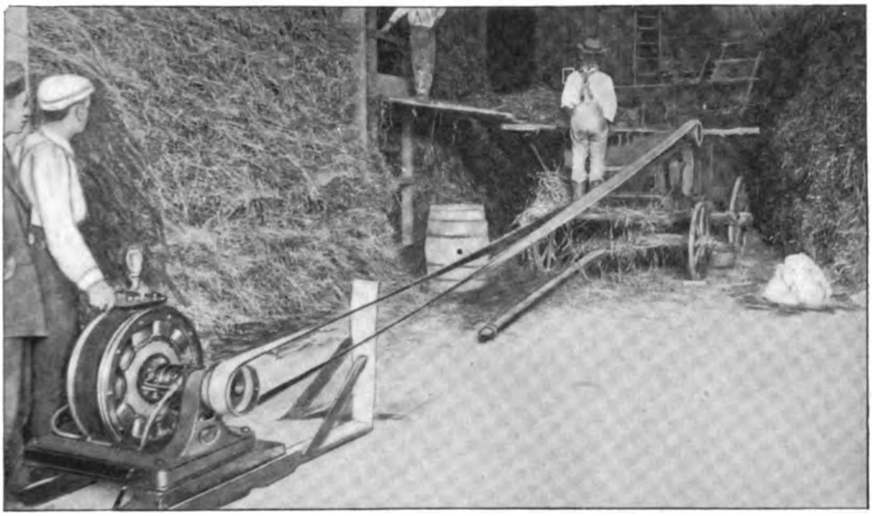
The conductors are of one-quarter-inch bare copper, carried on insulators set on wooden poles, and the same poles carry a telephone system. As the fuel for the steam plant is sawdust and waste wood, the cost of the current is little or nothing and the electric power service entails an extremely small outlay when compared with that necessary for a steam-driven threshing machine, or a fixed steam plant in the dairy and mill.

On the Allentown, Pa., stock farm of J. Roth, is a fifteen horse-power direct current motor, taking current from the trolley line of the Allentown and Lehigh Valley Traction Company by a specially constructed single wire line, 3300 feet in length. The current is sold by meter, at 8 cents (4d.) per kilowatt-hour. The motor is placed in a building back of the barn, and is belted to a main shaft supplied with pulleys for operating various kinds of farm machinery.

Threshing, cutting feed, grinding



A PORTABLE ELECTRIC GENERATOR FOR FARM WORK, BUILT BY MESSRS. ZIMMERMANN & CO., LTD.



A THRESHING MACHINE DRIVEN BY AN ALTERNATING CURRENT MOTOR, NEAR KENNETT SQUARE, PA.

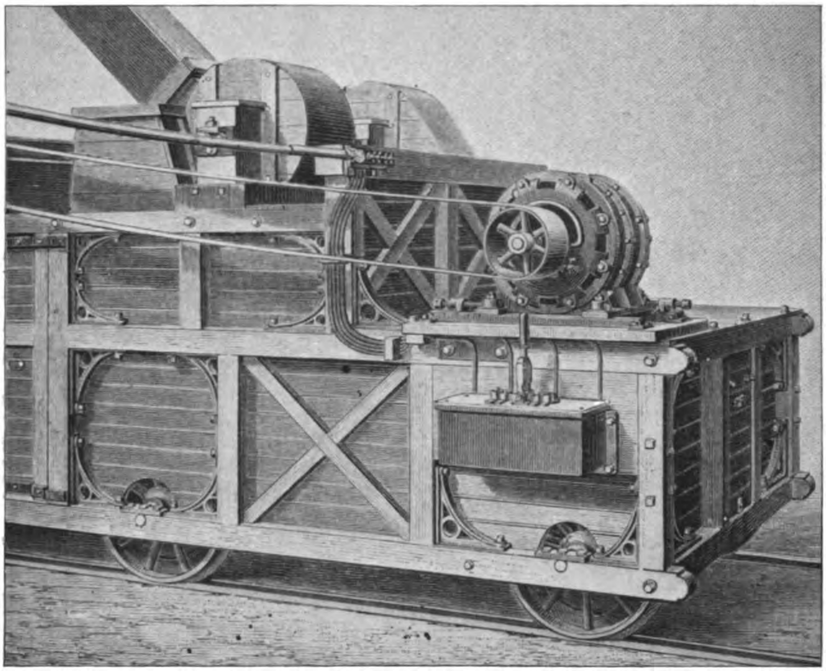
grain, shelling corn, pumping water, sawing wood, etc., are done in this way. A barn, 50x208 feet, is also supplied with electric lights. According to a statement from Mr. Roth, electricity for this work is not only much cheaper than steam or horse-power, but is far more convenient and safer. This plant is doing excellent missionary work among farmers in its vicinity.

The Crystal Hill farm and dairy, near Catasauqua, Pa., handles a large amount of corn fodder and ensilage, and is provided with silos having an average capacity of 1000 tons. The expense of preparing the ensilage by horse-power was found to be very great and this led to the substitution of steam power; but as this necessitated an engineer and the haulage of coal a long distance by teams, the expense was still considerable.

In the fall of 1892 a 220-volt circuit, two and one-half miles in length, was, therefore, extended from the terminus of the lines of the local lighting plant, and a five horse-power direct-current motor was installed at the farm. This was used to operate the churns, cream separator, bottle washer and ventilating fans during hot weather, while the same circuit furnished abundant electric light to all the farm buildings. This experiment proved so successful that a twenty-five horse-power steam engine was soon afterwards replaced by a ten horse-power motor of the same type as the first. The motor soon demonstrated its superiority. Seventy head of milch cows are fed on ensilage during the year, and the adoption of the electric motor has reduced the cost of preparing this from $1.50 (6sh.) to 80 cents (3sh. 2½d.) per ton. Threshing, wood sawing, etc., are performed by the same power.

At Kennett Square, Pa., an alternating current motor of seven and one-half horse-power, is working on a farm six miles from the lighting station. Last summer it threshed a crop of 450 bushels of wheat, and placed ten acres of corn in the farmer's silo. The threshing of the wheat, which occupied fifteen hours, would have given full occupation to an ordinary traction engine for three days. The same time would have been taken by the same engine to fill the silo which was effected by the motor in ten hours. The motor in actual work, with load on, requires 5500 watts.

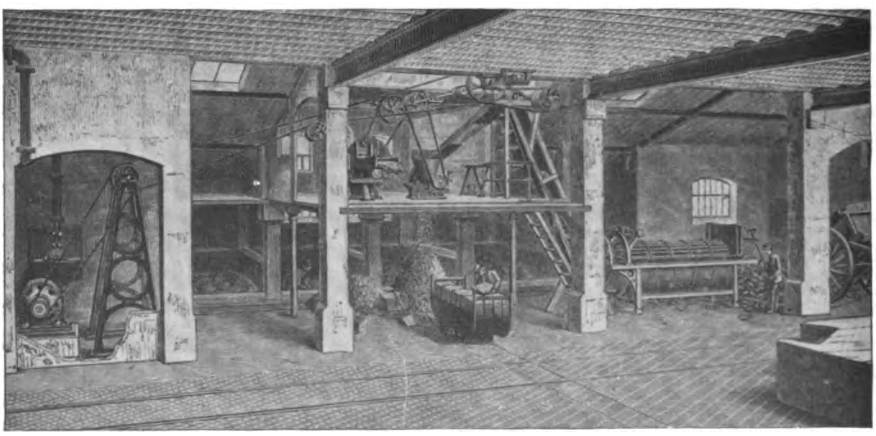
The foregoing are some of the recorded instances of the use of electricity in general farm work. The specific question of plowing has formed the subject of special study and experiment. Plowing by electricity presents peculiar



A THRESHING MACHINE DRIVEN BY AN ALTERNATING CURRENT MOTOR ON THE FARM OF M. MENIER, AT NOISIEL, FRANCE.

difficulties which have taxed the inventive energy of the engineer. To plow one acre seven to eight inches deep means the turning of about 1000 tons of earth. The difficulty met with in the electric plow is not in its movement over the field, but in the method of bringing the current to the motor with the plow travelling over the field.

Interesting experiments have been carried on by F. Zimmermann & Co., Ltd., of Halle, (Saale), Germany, with



AN ALTERNATING CURRENT MOTOR DRIVING A HAY CUTTER, BEET WASHER, ROOT SLICER, CORN SHELLER AND OTHER MACHINERY ON THE FARM OF M. MENIER.

two and four-share tipping plows carrying electric motors. The motor armature drives a shaft over which passes a chain stretched along the length of the field and securely anchored at each end. The plow, when in operation, is thus wound over the field on the stationary chain, and, by reversal of the motor, is wound back again, laying the chain sidewise for the next furrow. The manner of bringing the current to the plow is interesting. The cable connecting the generator to the plow is mounted on a series of small trucks which keep it out of contact with the ground and allow it to follow freely the movements of the plow.

The results of the operation of these plows was most encouraging both from the standpoint of equality of work and economy of power. The two share plow was driven by current from a dynamo belted to a ten horse-power portable engine. The plowing was done in a heavy, binding, clayey soil. The engine delivered about twelve horse-power. The two furrows had a combined width of twenty-three and one-half inches and a depth of nine and one-half inches. The plow was driven at a rate of about three feet a second. Eight horse-power was consumed, showing a loss of four horse-power between the engine and the plow, a small loss compared with that incurred with a steam plow. For the large plow a sixteen horse-power portable engine was used, and the shares made furrows of equal depth. It was estimated that from five to ten acres of land could be plowed in ten hours.

Inventive ingenuity is still at work on apparatus for agricultural purposes. The latest addition to electric plowing systems has been made by Edward M. Bentley, of New York, who erects along the two opposite sides of a field a number of poles on which wires are strung. Between these, stretching directly across the field, is a third wire which serves as a trolley wire to carry electricity to the plow motor. This does away with the flexible cable and greatly simplifies plowing operations.

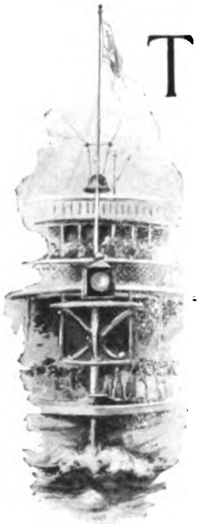
An electric spader has been invented by E. R. Whitney, of St. Johnsburg, Vt. In this device the spades are on a wheel, like the flanges of a paddle wheel, and these spade up the earth most effectually as the machine traverses the field.

Enough has been said to show the feasibility of, and economy in, the electrical operation of farm machinery. Most of the problems have been solved so far as the motor driven apparatus is concerned, but the crux was the economical transmission of power to the farm. Four years ago this presented considerable difficulty on account of the limitation in the economical transmission of the direct current, and the non-existence of the alternating current motor. To-day the transmission of power problem is solved, and electricity can be economically transmitted a distance of forty miles, while the alternating current motor is an accomplished fact. This enables the large farmer, with reasonable investment, to have his own central station, and to transmit power to any point of his farm, while for the cultivation of small farms a number of farmers could co-operate, and, taking current from the nearest station, arrange to use the electric apparatus in rotation.

With the farm work effected by the silent force, economically and efficiently, and the light electric railway introduced as a feeder from the farm to the steam road, farming would, perhaps, again assume that Arcadian attractiveness which painters have depicted and poets sung.

ELECTRIC SHIP LIGHTING.

By E. G. Bernard.



THE conditions governing the efficient installation aboard ship of an electric light generating plant and its circuits, are usually much more severe than met with on shore. The space allotted for the machinery is often circumscribed and frequently badly situated, the division and the control of circuits are more complicated, and the insulation requirements are particularly exacting.

When electrical plants were first installed aboard ship, lead encased cables, run in ordinary moulding, were used almost entirely, and in case of iron ships the hull was frequently employed for the return circuit. The latter method soon passed out of use, for it not only increased the fire hazard, but was inefficient mechanically and also liable to give rise to disturbing influences on the ship's compasses.

Lead-encased conductors in ordinary moulding were used on the first two United States men-of-war having electric lighting plants,—the *Trenton* and *Omaha*,—but with unsatisfactory results in each case. In the latter ship, the electrical plant of which was installed by the writer in 1884, the lead-encased port and starboard mains passed through holes bored in live oak knees (one hole to about each six feet of run), and the writer has a vivid recollection of the difficulties encountered in boring several hundred three-quarter and half-inch

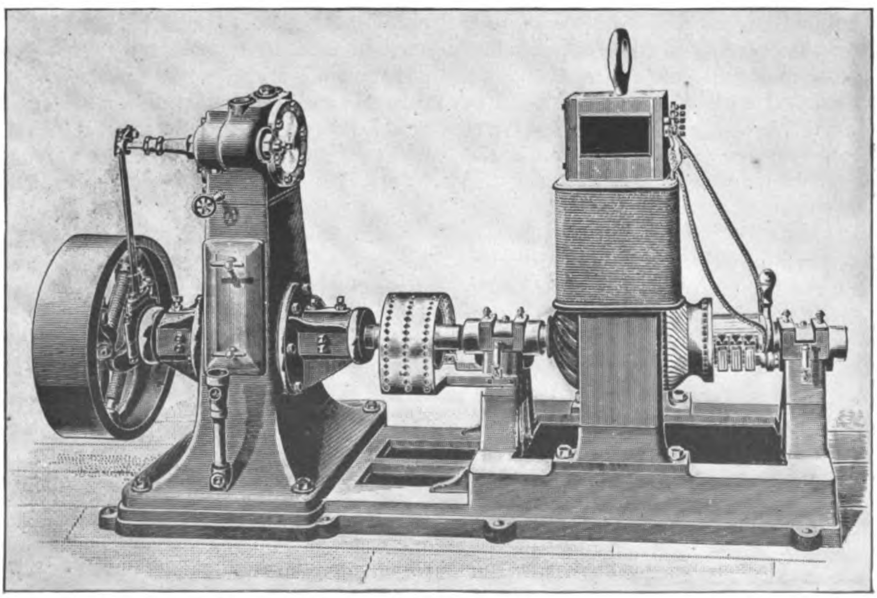


FIG. I. A DIRECT-CONNECTED ENGINE AND DYNAMO FOR SHIP SERVICE.

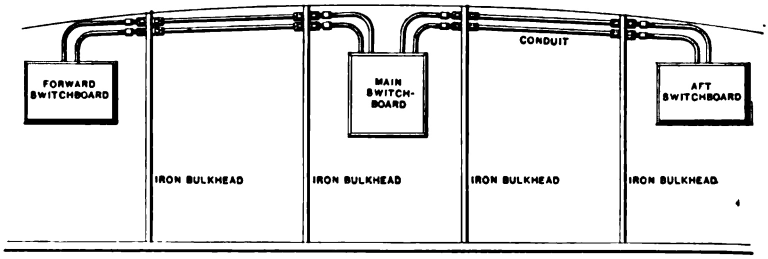


FIG. 2. IRON CONDUIT CIRCUITS.

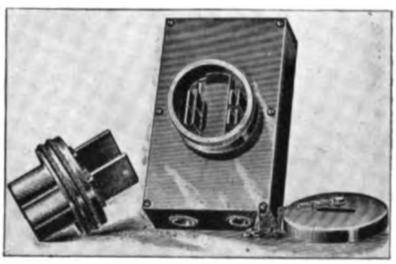
holes through about eight inches of gnarled oak very nearly as hard to pierce as some of the tougher metals. It is perhaps needless to say that the cost of labour and tools was no small item in the cost of installation.

Lead-encased conductors were finally discarded, except in some special work, as the protection from injury to the insulation and from moisture, which the lead sheath was supposed to give, was found to be illusory. Dents caused short circuiting on the sheath of the conductors, while punctures, permitting the entrance of moisture, led to bad grounds, as well as short circuits.

At the present day what may be called a composite system for the installation of the distributing conductors, is employed. Equal security in all parts of the installation is the object kept in view, and to obtain this, several systems are blended together as one. While moulding and flexible conduits are used in the saloons and cabins, the conductors in the machinery spaces and holds are run in iron conduits, which are thoroughly insulated on the inside, and special fittings are employed in passing through the decks and bulkheads. Special water-tight switches, cut-outs and fixtures (Fig. 3) are also used wherever there is exposure to the weather.

To illustrate in a specific manner the general details of a modern ship lighting plant, a short detailed description will be given of installations recently placed by the writer in a sea-going yacht and on board a ferry boat.

The former,—the *Josephine*,—has a bipolar, slow-speed Bernard dynamo, direct connected to a Case engine, which is run condensing. A special flexible coupling is used, which insulates the armature from the engine, and also admits of either shaft being considerably out of line without interfering with the running. The objection might be raised that such a coupling increases the length of the bed-plate about one foot. The points in its favour, however, arise from the fact that the dynamo and engine bearings do not wear alike, and that where a rigid shaft coupling is used, the armature is, as a rule, almost over one of the engine bearings, and therefore likely to receive more oil from the engine than is good for it.



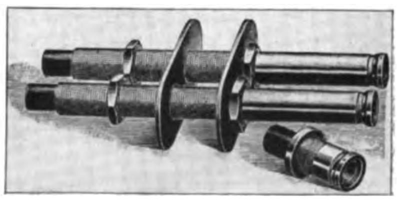


FIG. 3. WATER-TIGHT ELECTRIC FIXTURES.

The dynamo has a capacity for 200 sixteen candle-power, 110-volt lamps.

There are about 175 lights distributed throughout the cabins and holds, and besides deck and running lights, there are a 12-inch search light which has a range of about 2000 feet, and 130 red, white and blue lamps outlining an arch 500 feet long, extending from the bow to the stern over the foremast and mainmast, and used in dressing ship. Each cabin is furnished with an electric fan motor for ventilation, and electric motors are also used for flushing the closets. The fixtures are of several designs (Fig. 4), and finished in either dark steel or silver plate.

The plant is run, as a rule, until midnight, when it is shut down, the current thereafter being supplied from a storage battery of fifty-eight cells. The battery is so arranged that it can be charged either separately, or during the regular running of the plant; in both cases it is di-

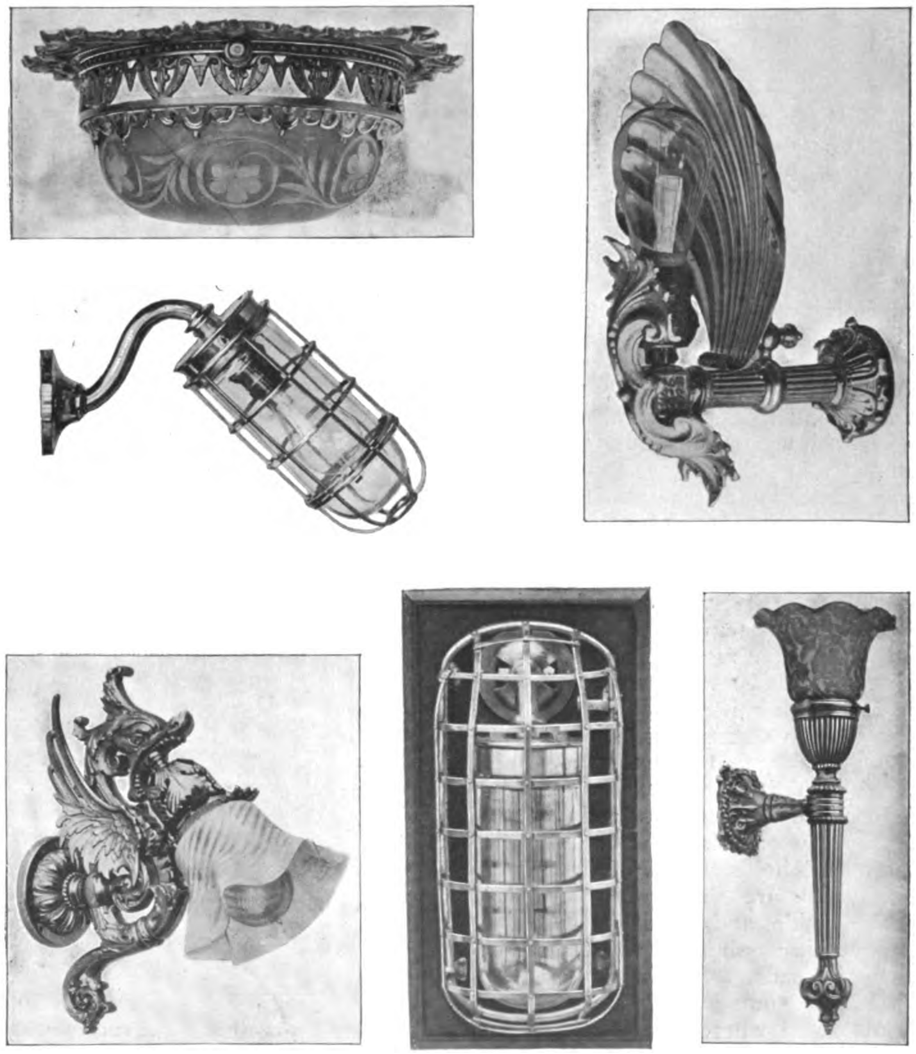


FIG. 4. ELECTRIC MARINE LIGHT FIXTURES.

vided for charging into two sets of twenty-nine cells each.

The main switchboard is close to the dynamo. This has voltmeters, ammeters, ground detector, overload switch, underload switch, reserve cell switch, special-throw switch for throwing the batteries in multiple or series, rheostats, necessary circuit switches, etc. There are also two auxiliary switchboards (Fig. 6) or cut-out centres—one forward, which controls all forward lights, and one aft, which controls all after lights.

The wiring is all of the best quality of rubber-covered wire, and so run in conduit tubing that any section may be withdrawn and replaced should it prove defective. The switches and cut-outs, where exposed, are of the special marine type used in the United States Navy,

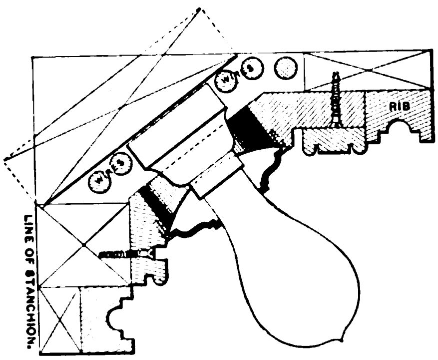


FIG. 5. CEILING CORNICE LIGHT.

and designed to withstand the corrosive action of salt water (Fig. 3). Each circuit of about ten lights is run separately and connected to a double-pole plug cut-out and a knife switch, which are mounted on a slate switchboard.

On the ferry boat, a somewhat complicated system of two-wire circuits is used, due to there being two distributing systems and two complete lighting plants. The arrangement is such that the main plant, which has a capacity of 150 lights, runs during the night, while the auxiliary plant, with a capacity of thirty-five lights, runs only in the day time. The wiring is so arranged that in case the main plant should break down, the auxiliary plant can be immediately put in circuit by merely throwing two switches. The connections are such, however, that it is impossible for both dynamos to be on the

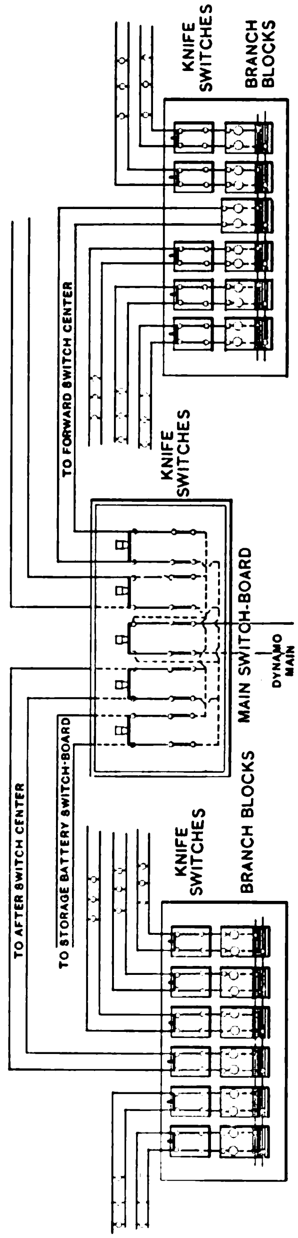


FIG. 6. SWITCH-BOARDS AND CIRCUITS ON THE YACHT "JOSEPHINE."

same circuit simultaneously. (See Fig. 8.)

All the circuits are composed of three wires, one common negative being used, with one positive wire from the day plant and one positive wire from the night plant. By throwing one switch, all lights in the cabin and the running lights are cut in. By throwing another switch, only about every sixth light and the running lights are put in circuit. This system is an exceedingly simple one for connecting any main plant with an auxiliary plant. The general wiring plan is shown in Fig. 7.

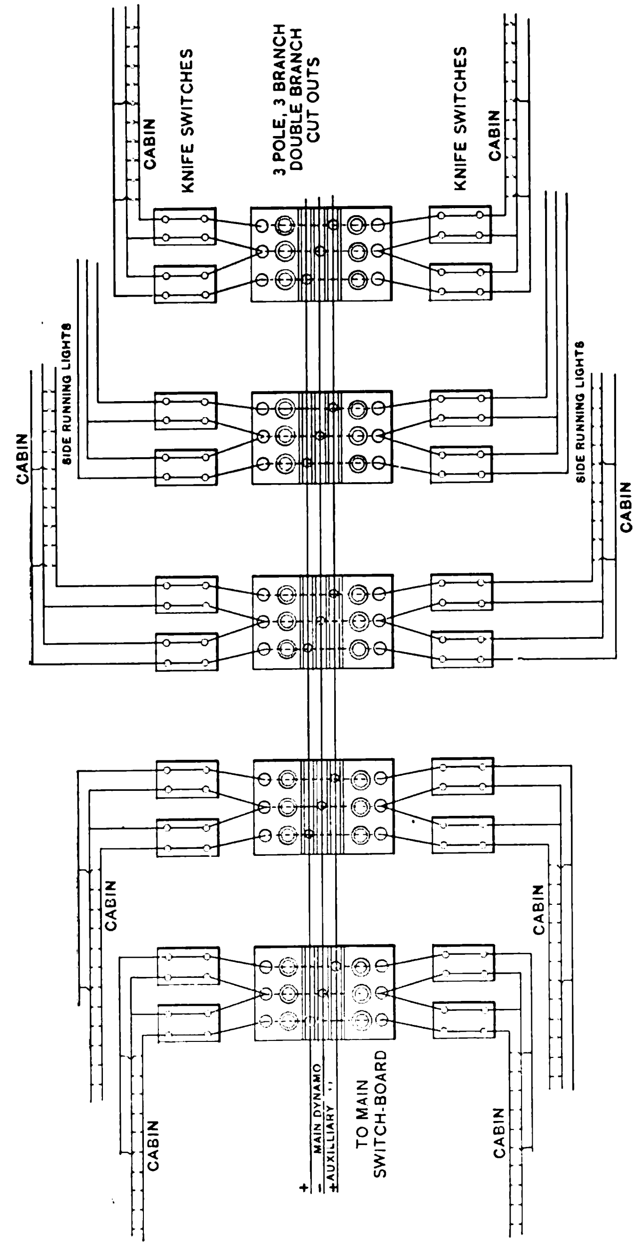


FIG. 7. FERRY BOAT CIRCUITS AND DISTRIBUTING BOARD.

The side running lights are here con-

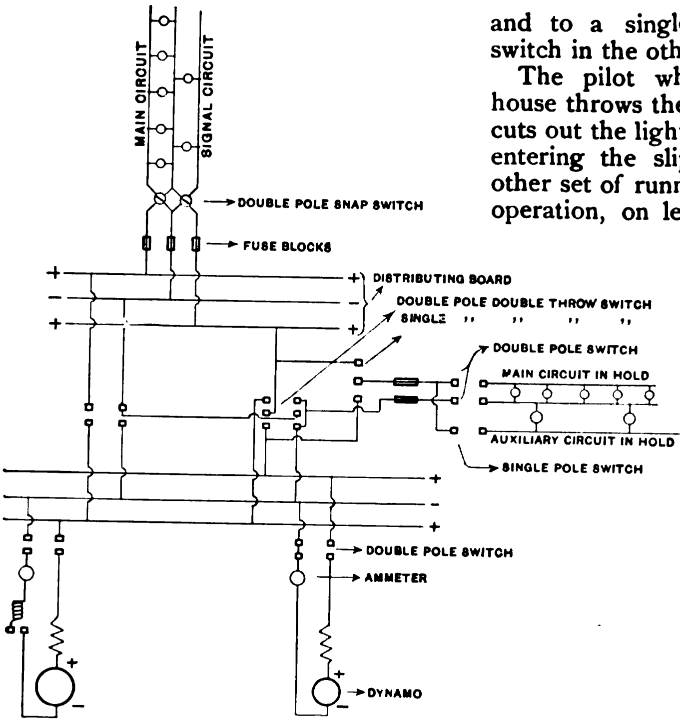


FIG. 8. FERRYBOAT SWITCH-BOARD CONNECTIONS.

nected differently than on any other boat of which the writer has knowledge. Their connection makes it practically impossible for any error to occur on the part of the pilot with respect to his running lights, which is of extreme importance aboard ship. Most ferry boats having double-end side lights, use two lights which burn continuously, and when the boat is reversed it is necessary to move a metal shutter so that a green light shows in place of a red light, or vice versa. This is done, as a rule, by means of a long rope and several pulleys, which system involves constant annoyance and trouble.

The double-end side lights in the case under consideration are separated by a partition, a pair of lamps being placed on each side of this. These are connected to a double-pole double-throw switch in one pilot house, and to a single-pole double-throw switch in the other.

The pilot when leaving the pilot house throws the switch, which at once cuts out the lights that were running on entering the slip, and throws in the other set of running lights. The same operation, on leaving the slip, again throws the lights from the other end.

The fixtures used in the cabins of the ferry boat are silver plated rosettes which fit the cornice and conceal the receptacle, the lamp screwing in at an angle of 45 degrees (Fig. 9).

The day plant is run by an automatic engine of five horse-power, and the night plant by one of fifteen horse-power, each belted direct to a Bernard medium-speed bipolar dynamo, the owners of the particular boat in question preferring belted to direct-connected apparatus.

The wire used runs throughout in conduits where concealed, and in moulding in open places. All cut-outs used are of the plug type, and the switches are of the knife pattern. The circuits are arranged so that none has more than ten lights, and are grouped at an auxiliary switchboard.

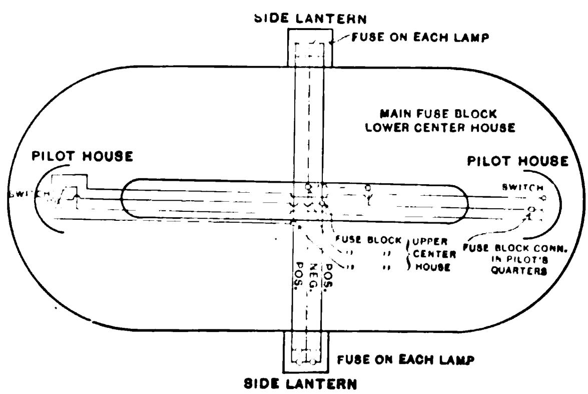


FIG. 9. DECK PLAN OF FERRYBOAT, SHOWING SIDE LIGHT WIRING.

WATER PURIFICATION AND FILTRATION IN THE UNITED STATES.

By Dr. Albert R. Leeds.

THE maximum amount of putrescent impurities of animal origin which is present in the waters of a grossly polluted stream is equivalent to 0.35 parts of albuminoid ammonia in one million parts of water. In addition thereto the organic matter of every description, which is capable of oxidation, including in this total not only the above putrefiable animal matter, but the vegetable substances derived from cultivated lands, forests, swamps, etc., requires five parts of oxygen to effect its oxidation. If we multiply this latter figure three times and then multiply again by eight, we shall have a total of 120 parts per million of organic matter of every kind, as representing the worst polluted and the most deeply stained and coloured waters that are anywhere made use of in the United States for city water supply.

These figures will be recognised as marking the extreme limits of organic contamination, the total impurities in the great majority of the city waters in the United States, reckoned in the same manner, being less than one-fifth of 120 parts in a million.

In other words, we may say of the worst supplies, that they consist of about 999,900 parts of pure water and 100 parts of impurities. It is the prerogative and duty of the chemist to decide whether or no chemical science has yet attained to such a stage of development that, on account of these 100 parts of impurities, there is any necessity or propriety of throwing away the 999,900 parts of pure water.

To illustrate these points, let us take an actual example and let us select, from among the many problems pressing for solution at the present time, that of the future water supply of the city of Philadelphia.

Fifteen years ago the councils of that city made an appropriation to have all the country located along the valleys of the Delaware, the Schuylkill, Neshamony, Tohickon, Prekiomen and Lehigh rivers,—an area of more than 100,000 square miles,—surveyed with the object of determining at what point, or points, in this great area the supply could be obtained which should be good enough and ample enough for the growing wants of an enormous population to come.

With this general object was coupled the economical question of deciding whether the present supply, taken from the Schuylkill and the Delaware, which is entirely adequate in quantity, was so polluted or so incapable of purification, that it should be abandoned in favour of the costly expedient of going to more distant sources. The survey required three years for its accomplishment and the results will be found in the annual reports for 1881, 1882, 1883 and 1884 of Colonel William Ludlow, then the chief engineer of the Philadelphia water department.

At the conclusion of the work, Mr. Rudolph Hering, the engineer in charge of the topographic and hydraulic part of the survey, made a number of recom-

A GRAVITY FILTER PLANT AT NIAGARA FALLS, N. Y. ERECTED BY THE MORISON-JEWELL FILTRATION CO., NEW YORK.

mendations, all looking towards the construction of great conduits from distant sources. The plan favoured as the best eventual solution, was recourse to the Delaware river above the point where it breaks through the Blue mountains at the Water Gap, a distance of ninety miles from the city. As an aqueduct, sufficient for present needs only, would cost ten millions of dollars, this source for a number of years to come was to be held in reserve, and the Delaware at a nearer point, at Point Pleasant above Trenton, a distance of thirty miles, was to be first resorted to.

The writer, who was the chemist to the survey, favoured the retention of the present intakes and the installation of purifying plants. The chief engineer disagreed with this conclusion, for the reason, as stated in his report for 1884, that in view of the then recent discoveries in relation to bacteria, and of their extreme minuteness, thousands of these bacteria might march abreast through the pores of the best sand filter, as at that time constructed.

In the light of generally received knowledge, his opposition is not to be wondered at, because while the interval, as measured in years, between the present time and 1884 is short, the distance travelled in all that relates to exact knowledge concerning the nature and mode of action of bacteria, both as polluting and purifying agents, is very long.

At that time there was a general horror of all bacteria; only a few specialists had occupied themselves in their investigation; no determinations had been made of the numbers and kinds present in various water supplies, and but little had been done in determining the nature and amount of their functions in affecting the purification of water as it passed through a filter bed.

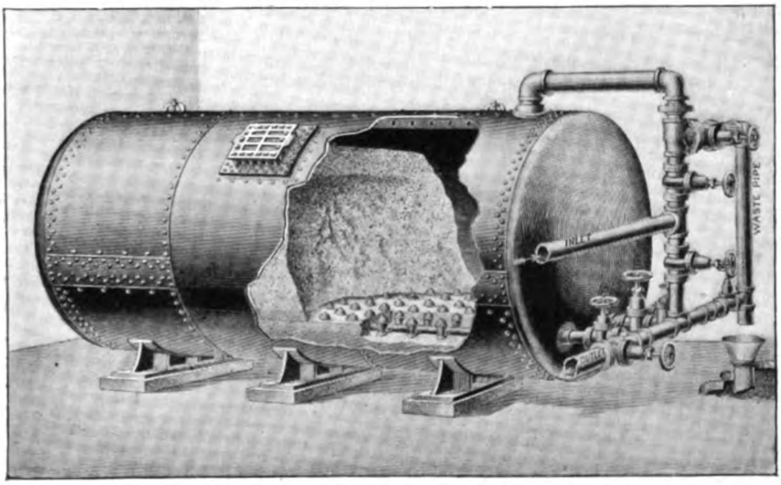
It was supposed that the mere presence of bacteria in a filter was sufficient to condemn the filter. At the present time we know that the reverse is true, and that a sterile sand filter is a worthless one, and that the best sand filter is one in which the bacteria have been cultivated until they are numerous enough to cope with and destroy the decomposable organic matters. But I am speaking of the state of the art of water purification in the United States twelve years ago, and of opinions which, in the light of their knowledge at that time, water works superintendents regarded as wise and conservative.

During this interval of twelve years, public opinion in Philadelphia, recognising the fact that the city is afflicted with a death rate from typhoid fever and kindred diseases far beyond the normal average, has been in incessant ferment, at times inclining to recourse to one of the distant sources above indicated, at times favouring the installation of purifying plants. But the revolution of opinion among hydraulic engineers is indicated in a striking manner by the fact that Mr. John C. Trautwine, the present chief engineer ot the Philadelphia water department, is urging, and, no doubt, will before long obtain, an appropriation for putting in a number of plants, which shall filter 20,000,000 gallons of water per diem and which will afford, on a large scale, a comparison of the mortality of the districts supplied with purified and those supplied with contaminated water.

Opportunity is to be afforded for the installation of a system of intermittent gravity filters, such as has been advocated by those who have operated the experimental plant at Lawrence, Mass.; for a continuous gravity system such as has been used for the past half century at London, and also at Berlin, Frankfort, Hamburg and elsewhere; for the various American systems of mechanical filtration, using alum as a coagulant; and for the Bischoff-Anderson system of oxidation and coagulation by iron, followed by filtration through an ordinary continuous gravity sand filter.

A PRESSURE FILTER PLANT AT OAKLAND, CAL., INSTALLED BY THE NEW YORK FILTER MANUFACTURING CO., NEW YORK.

The installers will have every encouragement and aid to put in plants which will be exponents of the best and latest



A HORIZONTAL PRESSURE FILTER, MADE BY THE NEW YORK FILTER MANUFACTURING CO. DIAMETER, 8 FEET. CAPACITY, 500,000 GALLONS IN 24 HOURS.

features of their several systems; the purified water will be frequently submitted to bacteriological, chemical and microscopic analysis in the laboratory of the city board of health; the statistics of disease in the different parts of the city will be duly collected, and after one or more years of trial the city will finally adopt that system which has proven best.

The city of Louisville is now conducting a similar series of large experiments on a very practical scale, the exploiters and patentees of the various systems receiving all the aid needed to insure the most favourable working of their plants, but their results being for the present retained in possession of Mr. Hermany, the chief engineer, until such time as they have been worked out to an entirely satisfactory demonstration.

The silt-laden waters of the Ohio river, varying, as they do, between very wide limits, both in respect to impalpable clay and burden of mineral matters, and also as to vegetable stains and organic pollutions, are utterly different in character from the waters on the eastern slope of the Appalachian mountains, such as the Mohawk, Hudson, Delaware, Schuylkill and Potomac, and the methods of successful purification will have to be worked out on quite different lines.

But when the results of the comparative trials at Philadelphia and at Louisville will be obtained, there will be available experimental data, which will lay a secure foundation for building up a practice of water purification in the United States that will exactly meet American requirements, and which will render it both unwise and unnecessary for American engineers to resort to English and Continental models that are designed to meet quite different conditions, and, if adopted without appropriate modifications, would lead, in the United States, to inadequate results or damaging failures.

There are no rivers in Europe which drain the entire inland basin of a continent like the Ohio, Missouri and Mississippi. There are none into which the spring and autumn floods may, in the course of a few hours, sweep the vegetable mould and top soil and alluvium of an area equal to that of the whole of Great Britain.

As yet in the United States the factor of temperature in relation to the continuous working of filter beds, is a largely unknown, and altogether unsettled quantity. It has been frequently denied, by those who have recently turned their attention to this subject, that the extremes of heat and cold in the United States will cause any difficulties greater than those which have been encountered in the milder climate of England.

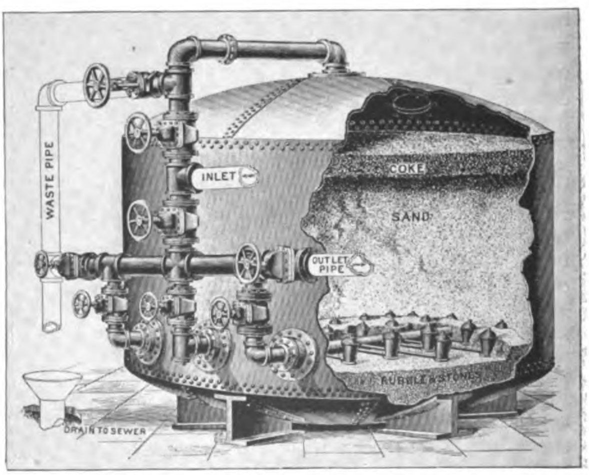
But the communities of Europe are not tormented during the summer, year after year, by such rapid and excessive multiplication of algal growths in their impounding reservoirs and receiving basins, followed by equally unexpected seasons of swift decay, that they fill the press with popular outcry and indignation concerning the intolerable stenches and taste of their drinking waters, as do the majority of towns in New England. Neither do we hear of the river Thames, or the more than a hundred filter beds which supply the city of London with filtered water, being frozen over for months, as is frequently the case with the Hudson, Delaware, the upper Ohio and other great American flowing streams.

These troubles from heat and cold are not unknown in Europe, and to the extent to which they occur, they are both dreaded and duly allowed for. During the course of a visit to the filter beds of the Southwalk and Vauxhill Water Company, located on the Surrey side of the Thames, nearly opposite the House of Parliament, the engineer in charge personally assured me that they were frequently annoyed during the late spring and summer months by vegetable growths, and, in very severe winter, by ice.

To overcome the difficulty, he said, they were compelled to pump all the water off the filter beds, cleanse them and start afresh. In reference to these difficulties, C. Pietke says, in the *Zeitschrift fuer Hygien*, for 1891, that the filter beds of the Berlin water works near the Stralau gate are completely arched over in order to guard against the frost.

If this arching over is done in the way the writer has seen it carried out in connection with the receiving basins of many city filter systems in England, it must be of a very solid and costly nature. The floor of the basin is laid in invert arches of brick masonry. On the spandrils of these arches parallel walls are raised, and from their tops spring the brick arches that roof over the entire basin.

This masonry roof is covered with three or four feet of soil, which is carefully underdrained, and finally a topping of turf is added and so carefully rolled and grassed that in walking over it one might suppose he were standing upon an exquisite green lawn and would have no suspicion that below him was an artificial subterranean well, holding many millions of gallons of cold, limpid water. Pietke insists that the mere arching over of the beds is not adequate to protect the water in them from frost, but that these arches must be covered with soil, equivalent in depth to that which the frost may ever penetrate in the latitude of Berlin.



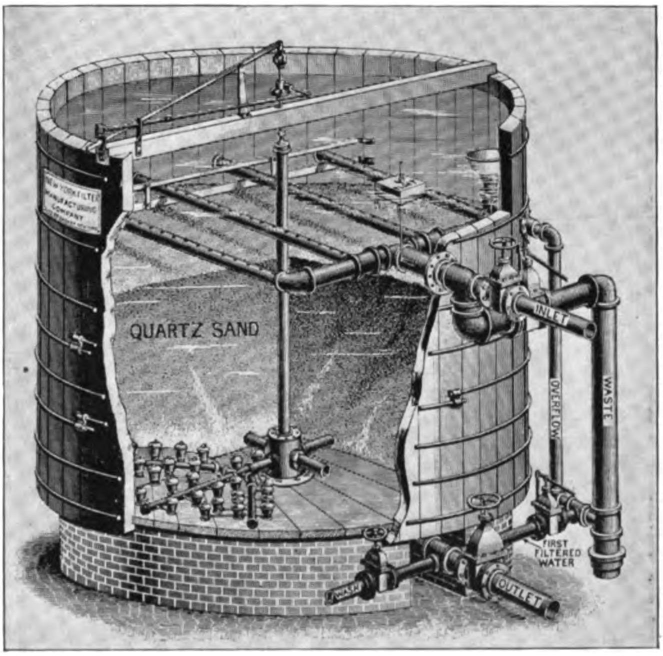
A VERTICAL NEW YORK PRESSURE FILTER.

American engineers, in the author's opinion, should not deceive themselves in this matter, but should face and provide for the greater difficulties which will arise in the United States from algæ and ice, at the very outset of work in the installation of filter plants. The first cost of the works will be vastly greater, but the disappointment and obloquy which will be met with in the working of filter plants, otherwise satisfactory in construction and operation, will be done away with.

Filtered water, one cannot too carefully remember, is not a natural, but an artificial, product of the most sensitive refinement and delicacy. If the filtration has been properly performed, we should have removed 99 per cent. of the bacteria and algal organisms. The spores of the 1 per cent. that remains, having their natural competitors and enemies removed, develop at summer temperature and under the stimulus of light and sunshine with a speed and volume utterly prodigious and astounding, as compared with their multiplication in the same water before filtration, when their numbers are kept down by the savage slaughter incident to the normal struggle of the survival to the fittest.

Reference was made above to the difference of opinion usually existent between the consulting engineer and the consulting chemist, when both are intrusted at the same time with the determination of the problem as to the best future water supply of a particular community. It has been the fortune of the writer to be associated in this regard with a number of engineers, and his experience is that the engineer, speaking from the ground of his professional knowledge and bias, always wants to solve the problem by laying a long pipe, while the chemist declares himself in favour of making the best of what appears to be to him the inevitable cause of things in a country destined everywhere to be so densely populated, and to purify the existent source of supply.

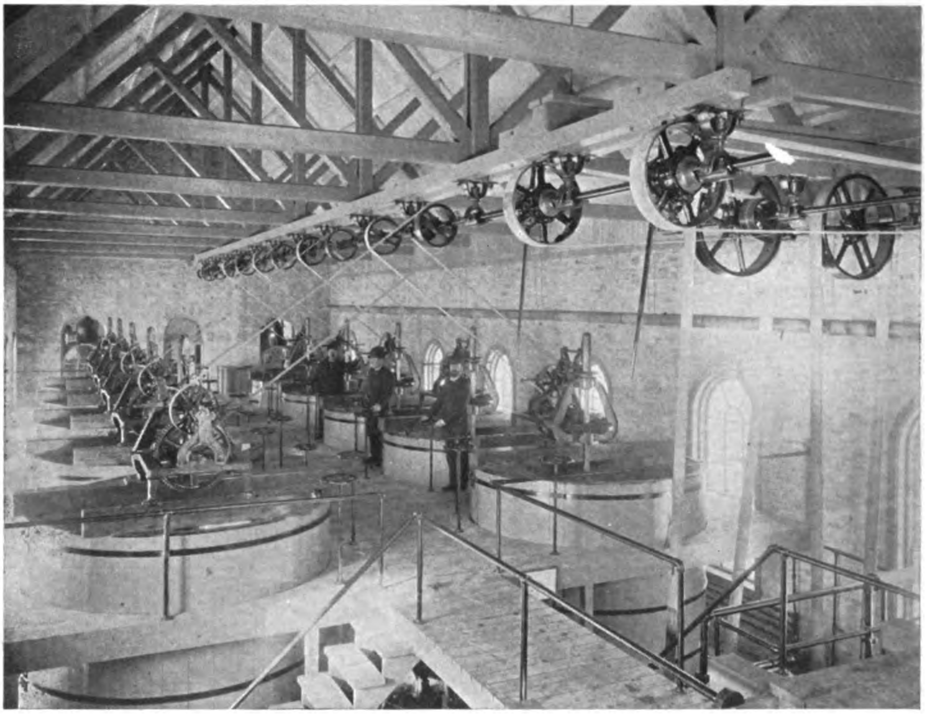
The longer the pipe, the better, the engineer thinks, because not only the work will be more important, enduring and monumental, but also because the farther end of the pipe will be carried as far away from the centre of population as possible. But it is not true that the finest and highest of mountain lakes



A VERTICAL NEW YORK GRAVITY FILTER.

are necessarily safe and pure drinking water. And the same conclusion would be reached by a chemist who would be at the pains to familiarise himself with the impurities which find their way into the upper Hudson, the Delaware above the Water Gap and any similar imagined sources of pure water supply.

Some readers may have possessed themselves of the magnificent blue book and volume of maps in which Mr. Bateman and other renowned English engineers have given the results of their in-

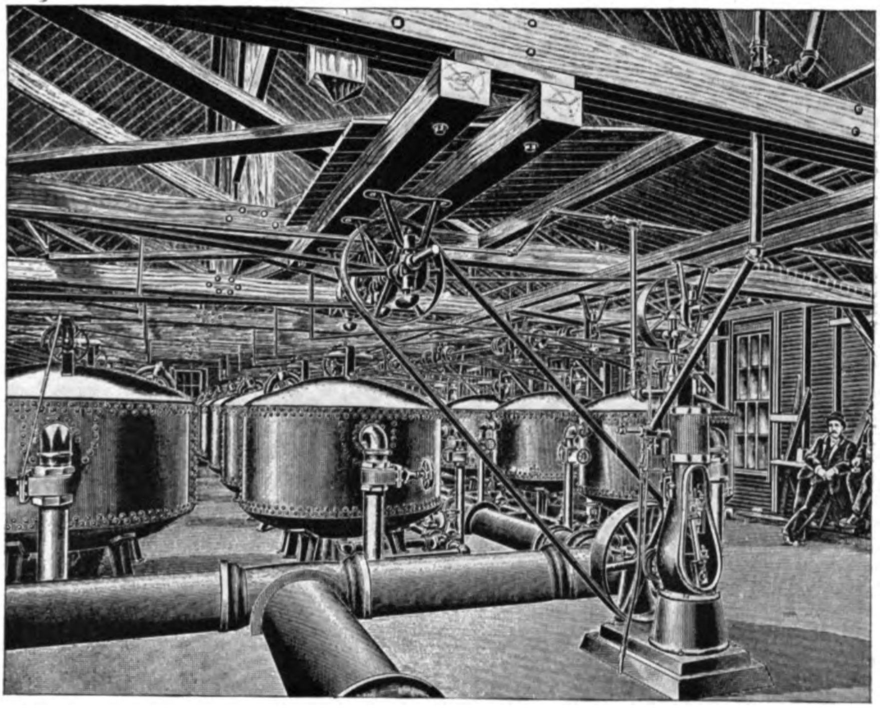


FILTERS AT THE OSHKOSH, WIS., WATER WORKS CO., INSTALLED BY THE CUMBERLAND MANUFACTURING CO., BOSTON, MASS.

quiries into the cost of supplying London with water from the lake district in the North of England or from the mountains of Wales. Although these surveys were spread before the House of Parliament forty years ago, their recommendations and conclusions have not been adopted. On the contrary, the city of London has gone on drawing its water supply from the sewer-polluted Thames, relying on its purification by filtration through sand only.

Meanwhile the population of London has increased from three millions to five and one-half millions, while the death rate and typhoid fever rate have sunk until that city is counted among the healthiest large communities in the world, and no one regards as possible the recurrence of cholera, such as London four times experienced during the first half of this century and before the Thames water was filtered. And while the chemists spoke with great caution and reserve as to the certainty of the causal relation between the immunity from typhoid fever and filtration, as long as they were compelled to rely merely upon chemical analyses, yet, now, after bacteriology has, during the past ten years, put a new instrument of investigation into their hands, and the life present in the water before and after passage through the London filter beds has been constantly and rigorously examined, they do not hesitate to assert that such a causal relation exists and that this immunity is due to the removal of the specific typhoid bacillus along with the 95 to 99 per cent. of other bacteria. To the chemical profession, indeed, the typhoid bacillus has been the greatest benefactor.

Previous to the year 1885, when the chemist reported his interminable catalogue of chemical data, with inferences by no means obvious, drawn by circuitous courses of reasoning from infinitesimal decimals of albuminoid ammonia, organic carbon and organic nitrogen, the lay public was not necessarily much impressed or convinced. But, now,



A PRESSURE FILTER PLANT AT THE CHATTANOOGA, TENN., WATER WORKS. INSTALLED BY THE O. H. JEWELL FILTER CO., CHICAGO, ILL. CAPACITY, 3,000,000 GALLONS A DAY.

that the typhoid bacillus has come to his aid, and the selfish fears of all mankind for personal safety are touched to the quick, his recommendations are listened to with a respect unknown before, and his conclusions are usually adopted.

It may be of interest to note that there has been for several years past in the United States a special committee of water works engineers whose duty has been to urge upon the National Government the passage of a law which shall regulate the emptying of sewage into streams flowing through more than one State, and which are used both as sewage outlets and for water supply. It is doubtful whether general legislation of this sort is desirable, and relief will probably come by decisions in the United States courts, in cases where the lives of people dwelling in cities of one State have been lost by epidemics due to sewage thrown into their water supply by cities located in another State.

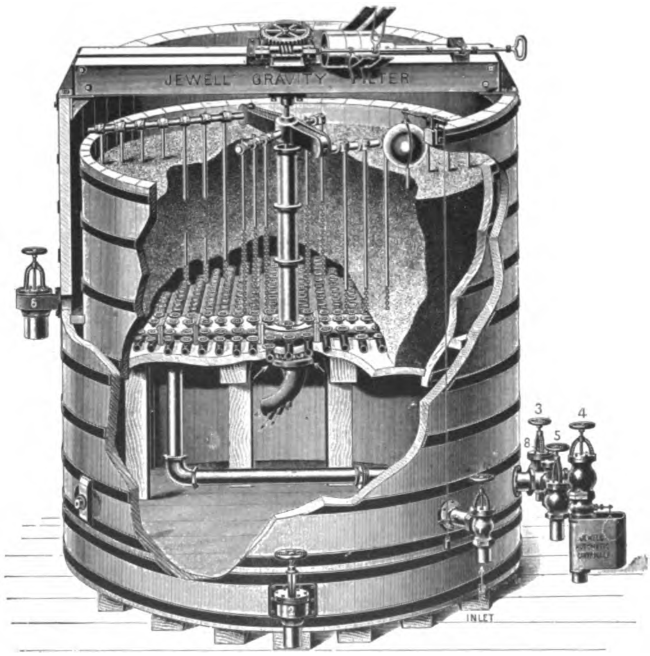
Such decisions may eventually lead up to the formation of interstate boards of conservancy, similar to the board ot conservancy appointed by Parliament in England to conserve within proper limits the purity of the Thames above the intakes of the London water works. It is difficult, if not impossible, to guard against the admission of any contamination whatsoever in flowing streams, or upland lakes and gathering grounds.

Of this difficulty we have appalling testimony in the history of the typhoid epidemic at Plymouth, Pa. The water company inspected and patrolled with care the sides of the mountain streams on which their reservoirs were located. But, nevertheless, one case of typhoid fever in a farm house, located some distance back from the side of this stream, escaped their notice, and in the month of April, 1884, when the dejecta from this typhoid patient were hurried, by the melting of the ice on the bank, upon which they had been thrown, into the stream, they precipitated upon the little town of 5000 inhabitants an epidemic in which 1200 persons were ill of typhoid fever at one time.

But whilst absolute security against pollution is impossible, the amount and character of the contamination can be controlled. The place to look for safety is not at the fountain head, but at the point of consumption, and to purification and careful keeping just before use. The many towns whose sewage find its way directly or indirectly into the Thames, like Oxford and Reading, are compelled by the board of conservancy to purify their sewage by methods previously submitted to, and approved by, the board, and are not allowed to exceed a certain maximum amount of impurity in their effluent sewage water.

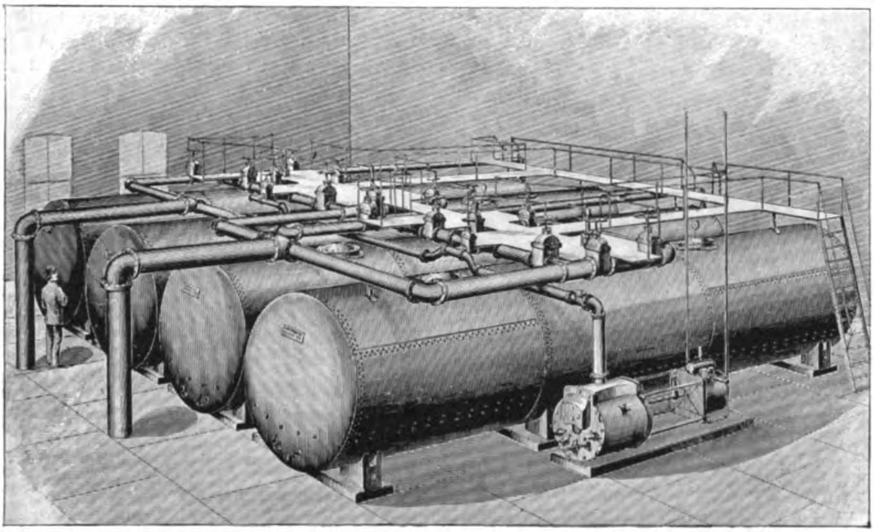
In like manner, the numberless communities now located, and to grow in the future, upon the banks of the Ohio, the Mississippi and the Missouri, will be compelled both to sewer into and drink from those streams. But the burden of impurities carried by those streams will be reduced to such permissible amounts, by compelling all communities to purify their sewage, that the corresponding burden thrown on the purifying plants of the cities will be such that they will be able to remove it at reasonable cost.

In all that precedes I have referred only to one agency of purification, and to one method of such agency, namely to the ordinary gravity sand filter bed as constructed in England and in the United States. Historically this system of purification has the precedence, because its use has grown from small beginnings in England since the time when, in 1830, the London water companies were compelled to abandon direct pumpage from the Thames below Teddington Lock, until the present era, when a system of filter beds is almost invariably installed as a necessary part of a water supply.



A SEVENTEEN-FOOT JEWELL GRAVITY FILTER.

The most conspicuous exceptions are Glasgow, supplied directly by gravity from Loch Katrine, and Liverpool, supplied from Lake Vyrnwy. And yet the latter exception, though this lake is



A PRESSURE FILTER PLANT AT ASBURY PARK, N. J. ERECTED BY THE CONTINENTAL FILTER CO., NEW YORK. NO ALUM OR OTHER CHEMICALS ARE USED IN THESE FILTERS.

usually quoted as exhibiting the highest degree of natural purity of any considerable body of water in Great Britain, is more apparent than real. Mr. Deacon, the engineer in charge of the latter work, told me that he had made all the provision for a filter system at a point located on the Vyrnwy conduit, because public opinion in England demanded such a provision, and he wished to utilise it if the water ever departed from that clear, colourless and odourless condition, which the payers of the water rates thought was their fair due in purchasing potable water.

With the exception of small filter plants at Poughkeepsie and Hudson, on the Hudson river, and of unsuccessful experiments in a few other places, this system, so successful in Europe, was looked at with distrust by American engineers. They were not lacking in knowledge as to the mode of construction and operation of such works. One of the most complete treatises on filtration was the report made by Engineer Kirkwood, of Brooklyn, upon the filter systems of Europe, which was magnificently illustrated by plates and was commonly to be found in the libraries of hydraulic engineers.

The disinclination to install them was due, in part, to the fear of the American climate, but mostly, so far as I have been able to learn, to the dread of the cost of construction, and still more of maintenance, under the unfortunate conditions of political interferences and control that affect the public works of the larger American cities.

Practically, the subject of water purification in the United States was in a hopelessly inert condition, when, in 1884, a patent was taken out by Mr. Hyatt, of Newark, which was the foundation of an entirely new system,—that of mechanical filtration,—which gave the impulse to the incessant agitation of the subject by numberless filter companies and patentees that has finally familiarised the American public with the necessity and possibility of artificially purifying their water supplies. From time immemorial,—the Chinese making use of it before the Christian era,—the device of using alum to clarify a turbid or contaminated water has been one generally known and frequently followed. But the practice was to allow the treated waters to stand and afford time and opportunity for the chemical to react upon the clay and organic matter, and the coagulum of dirt and impurities to settle out by subsidence.

But Mr. Hyatt was led by many experiments to patent and to introduce on a large practical scale what, in 1884, appeared to be a bold, and, indeed, quite chimerical, method of using alum in water purification. His patent was upon the use of a minute dose of alum, applied to the water as it flowed in a continuous stream directly from the pump to the filter, and filtering the aluminated water continuously without affording any time or receptacle for subsidence.

The dose was so proportioned to the impurities and to the carbonate of lime which was present in the water, and which, by its reaction with the alum, set free the alumina hydrate, that no alumina, it was claimed, found its way through the five feet of sand into the filtered water, although the filtration was effected under great pressure and with tremendous velocity.

The essential feature in mechanical filters is the use of alum, the filters themselves, though ingenious in many ways, being useless except when the jelly of hydrate of alumina is employed to make the true filtering medium on the surface and through the pores of the upper portion of the sand bed. This jelly of alumina discharges the same function in the mechanical filter as the jelly which is secreted in the upper part of an ordinary sand filter by the life processes of the countless bacteria that are cultivated therein, and whose multiplication is essential to effect the destruction, through the oxidising processes incident to their vitality, of the organic matters contained in the unfiltered water.

While the coagulum of alumina may be formed instantaneously on the surface of a mechanical filter, it requires a considerable period, — sometimes as much as two weeks,—before the bacteria in a new gravity filter have multiplied sufficiently to bring the filter to its condition of maximum efficiency. And while about four vertical inches an hour is the maximum rate at which water can be passed through an English gravity filter with good result, equally good results, it is stated, have been obtained with alum in an American filter passing forty vertical feet per hour.

After Mr. Hyatt had successfully applied his patents to the operation of filter plants in many cities, and in a very large number of paper and other mills, many patentees, using minor devices in details of mechanical construction, finding that no other material or methods could be substituted advantageously, availed themselves of the use of alum, applied to a continuous stream.

Leaving patent litigation aside, there is already open to chemists and engineers an immense recorded experience in the use of both the English gravity filters and of the American mechanical filters, from which a combined practice is growing up, that will speedily place the United States, not at the bottom, but at or near the top, in the successful purification of city water supplies.

SEBASTIAN ZIANI DE FERRANTI.

By H. Scholey.

ABOUT fourteen years ago the British public began to realise the power of electricity both for good and for evil. It was a time when men spoke glibly of millions, and the public, in its inability to exercise discrimination, supported ill-conceived and badly matured schemes. When enthusiasm is greater than knowledge, disaster is inevitable. There soon followed those commercial failures that set back the electrical industry for at least ten years.

It was at this period that Ferranti, then a lad of eighteen, became a prominent figure in electrical work, and it is a remarkable fact that in spite of the evolution of electrical engineering, modern practice has corroborated Ferranti's early ideas in no uncertain manner. He commenced his practical career when the world was becoming dimly conscious of the great powers of electricity, and a phenomenal insight into the problems rendered him peculiarly fitted for the pioneering of practical electrical work.

Courageous, enthusiastic and original, it was not surprising that he soon became associated with striking developments in practical electricity. He may be aptly described a revolutionary in the practice of electrical engineering. In 1882 he completely altered the construction of alternators. He made use of no new principles, but possessed in a high degree the power of reducing those principles to their most simple form. Not only did he show great originality in the generation of electricity, but chiefly through his efforts, the distribution of high-tension alternating currents ceased to be a difficulty.

The name of Ferranti has been chiefly associated with the idea of lighting large towns by electric currents of high potential from works in outlying districts, and the works at Deptford provide to-day a demonstration of the possibility of such schemes. To transmit electricity at a pressure of 10,000 volts was declared by the foremost living electricians to be an impossibility; yet there are in London to-day 140,000 lamps solely dependent on this "impossible potential."

The adoption of concentric mains and

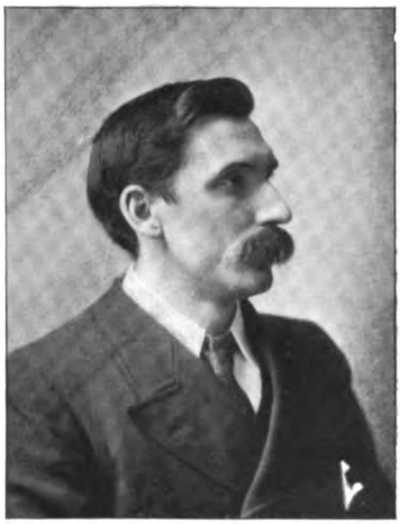
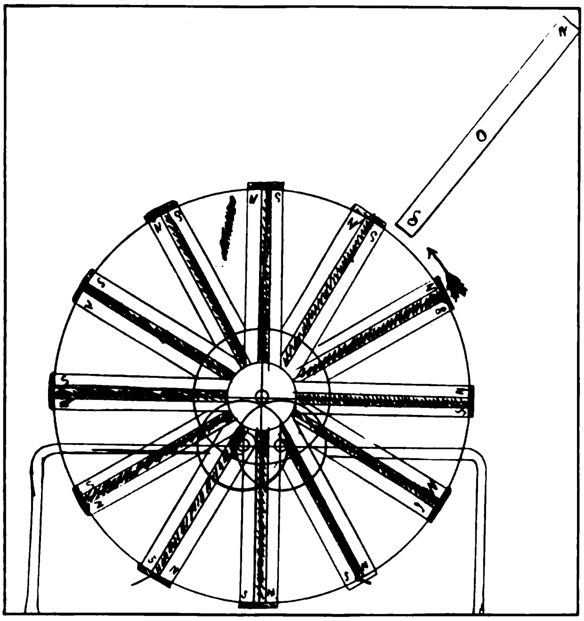


PHOTO BY VAN DER WEYDE, LONDON.

A RECENT PORTRAIT OF FERRANTI.

the earthing of the outer conductor constituted one of the most important suggestions ever made in the distribution of high potential currents, yet the innovation was strenuously opposed by the representatives of the British Government. Mr. Ferranti's courage in acting upon his conviction probably removed the most dangerous element in high-tension



FERRANTI'S FIRST IDEA OF AN ELECTRIC ENGINE.

distribution. His influence on the spread of electric lighting has been as great as that of any one man, and the public attention that was directed to his great schemes had, no doubt, much to do with making electric lighting popular.

Ferranti was born in Liverpool in 1864. It is a curious fact in family history that Ferranti represents four nations, his grandparents being Venetian, American, English and Flemish. He may be said to have commenced his mechanical training when a mere child, for his most cherished toys were an impact and an oscillating engine. He commenced mechanical drawing at a phenomenally early age, and original sketches, made when ten years old, reveal a remarkable grasp of detail. Though unable to read till the age of ten, he was, whenever opportunity offered, a most ardent purchaser of engineering papers, and a scrap-book, compiled at this period, is composed of illustrations from *The Engineer* and *Engineering*, admirably arranged and classified.

As a mere child, he would escape from the custody of his nurse and haunt Lime Street Station, Liverpool, and with keen observation would examine the parts of locomotives, oftentimes aided in his investigation by the explanations of kindhearted drivers. How good an impression he obtained of locomotive design is shown by an original drawing of a locomotive, made when eleven years old and reproduced below. It is a little curious to note that the design is not unlike the present high speed locomotives.

He was led to abandon engines for electrical work through an attempt to make an electric engine which was, to all intents and purposes, based on perpetual motion. The building of this engine was a severe struggle to the young and ambitious boy.

There were great difficulties in the

FROM A PHOTOGRAPH OF AN ORIGINAL COLOURED DRAWING, MADE BY FERRANTI AT THE AGE OF ELEVEN YEARS, AT LIVERPOOL, IN 1876.

way of securing suitable magnets, and after making strenuous efforts to obtain a material that would insulate magnetism, the machine was abandoned.

After staying a short period at a Hempstead school, where he commenced the design of ingenious and impossible engines, he went to St. Augustine's College, Ramsgate, and during his three and one-half years' sojourn there, received much help and encouragement from the masters. The wealth of invention that has since characterised Ferranti was manifested at Ramsgate, where he devised, among other things, arc lamps, some of which were distinctly novel. The most notable was a lamp not unlike the present clutch lamp of the Brush Company, and a pneumatic lamp in which the carbon rod was attached to the end of a piston and held up by the air being retained in a cylinder. A solenoid, controlling a small escape valve, regulated the feed of the carbon.

While at Ramsgate he commenced the construction of his first dynamo. He was then but a lad of fourteen and had no published details to guide him. Although he had never seen a Brush dynamo, his first machine bore a strong resemblance to an early Brush arc lighter with a Weston commutator of spiral segments. The armature was of cast

FERRANTI, THREE YEARS OLD.

iron and the machine, when run at 2000 revolutions, gave a fair arc light of three or four ampères. As money for experimental purposes could be raised only by the most rigid economies, and wire was then five shillings a pound, the making of the machine was necessarily somewhat protracted.

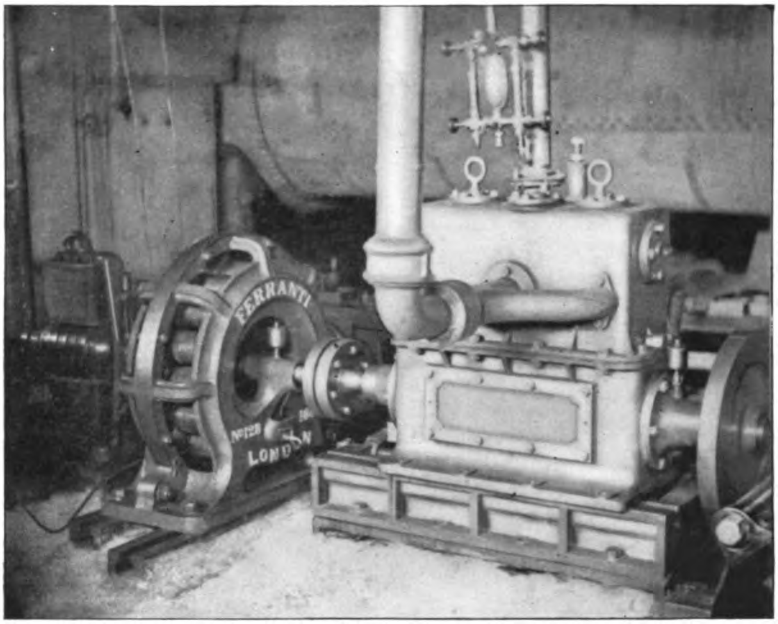
His interest was not confined solely

FERRANTI AT THE AGE OF SIXTEEN.

to electricity, for mechanics claimed a large share of his attention. He designed, about this period, disappearing gun carriages which were, in some respects, not unlike the Moncrieff gun ot the present day.

On leaving Ramsgate he attended University College for twelve months and shortly afterwards obtained his real start in life by selling his first dynamo for a £5 note. He never missed an opportunity of adding to his knowledge, and availing himself of the permission of Mr. Sydney Baynes, who at that time was superintending the lighting of Kings Cross Station for Messrs. Crompton, he worked with the men for several days, gaining, no doubt, considerable insight into the work.

After much persistence he succeeded in obtaining employment at Messrs. Siemens Bros'., Limited. For some



A FERRANTI SHIP LIGHTING DYNAMO, BUILT BY THE HAMMOND CO., AND USED ON BOARD THE STEAMSHIP "TAINUI."

time he worked in the dynamo experimental room and had charge of the lighting installation during the construction of the Mackay-Bennett cables. He was not more than seventeen years of age, when he was sent out to erect and supervise the running of a temporary plant at the Ironmasters' Exchange, Wolverhampton, and this was at a period when electrical plants required considerable humouring.

While at Messrs. Siemens', Ferranti made, at King's College, a series of experiments on electric furnaces for Sir William Siemens, and afterwards made the first tests on the Faure battery in England. He also made at this time a motor-focussing arc lamp, the principle of which was that as the arc required lengthening or shortening, so the motor ran in a different direction. The arc was kept steady by the insertion of a fine steel wire in the centre of the carbons which volatilised and served to keep the arc in the centre of the carbon.

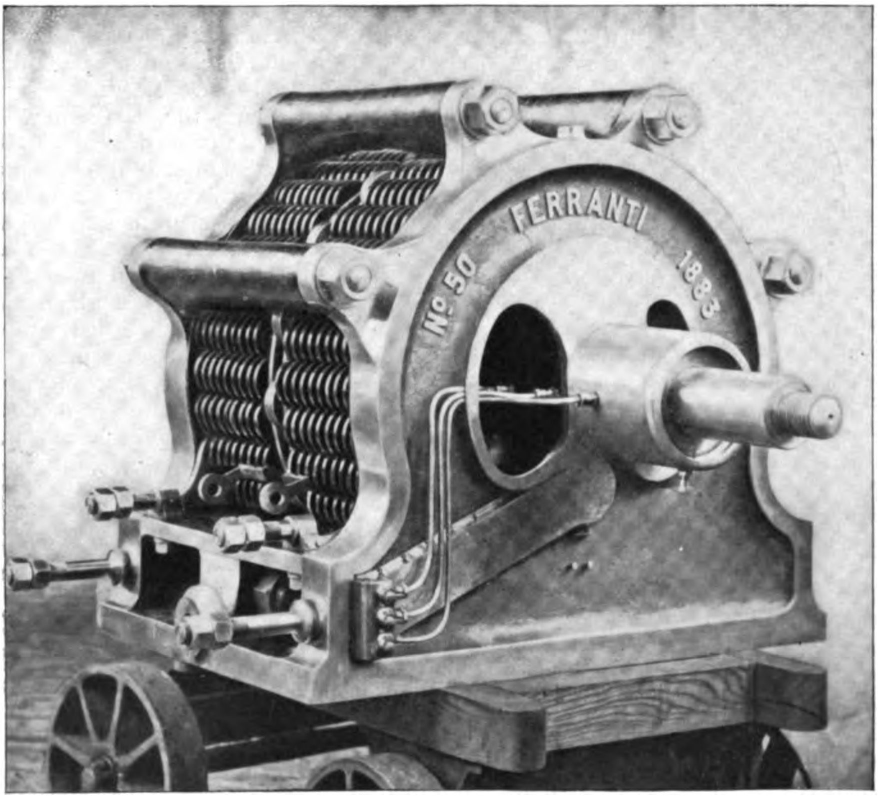
It was at this date that Ferranti made a machine which contained all the elements of a rotary field motor. The machine consisted of a cast iron disc with a coil wound around. It was magnetised in one direction, the electromagnet being fixed on the same stand and set with one pole at an angle of magnetisation to the disc. Had this been supplied with an alternating current, it would have rotated in the same manner as the present rotary field motors, but Ferranti's notion was that the machine might be worked as a commutatorless, continuous-current motor, and as neither an alternating nor an intermittent current was available, the machine was abandoned. He attempted a modification of the incandescent lamp by packing carbon dust into a hole drilled in marble, the idea being to raise the carbon to incandescence away from the air; but gas was formed internally which broke the apparatus.

It was while demonstrating the electric furnace for Messrs. Siemens at the Smoke Abatement Exhibition in London that he showed steel being rotated in the melting pot by passing a current round about the melting crucible. This formed the basis of the present continuous-current meter, which, however, was developed at a much later period.

In quick succession came the invention of the zig-zag armature which constituted Ferranti's first patent. It was taken up by Mr. Alfred Thompson and Mr. Ince, and a company was formed in 1882, Mr. Ferranti being appointed engineer to the company when eighteen years of age. On investigation, it was discovered that Lord Kelvin, then Sir William Thompson, had invented a machine which, in many respects, was identical with the Ferranti alternator, and an arrangement was made to pay royalties to Lord Kelvin, the machine becoming known as the Thompson and Ferranti alternator.

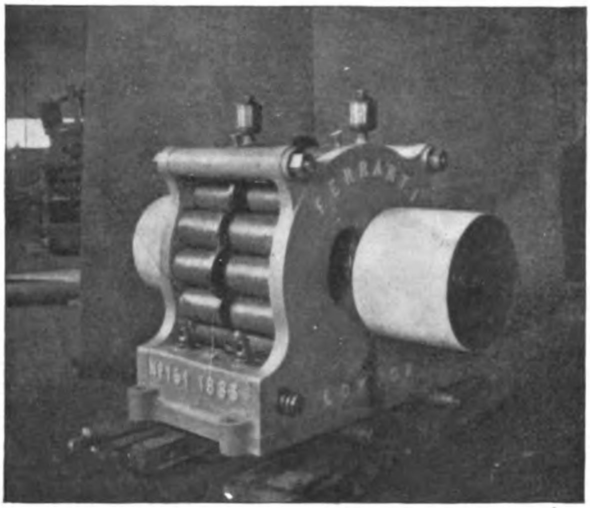
There is little doubt that this machine proved to be a marked advance on what had then been accomplished, and created a sensation among electrical men, and even the public were not unaffected by its performances. The public press of the day was impressed by the fact that the new machine of Ferranti gave five times as much light as other machines of the same size. Genuine alarm was felt among the owners of other electrical machines, the Brush generator being then most prominent. The London *Times* of September 22, 1882, remarked:—"The announcement of this machine has been, we are informed, greeted with incredulity, and naturally some perturbation has been caused among those interested in existing dynamo machines."

The power developed by these original Ferranti machines was enormously greater than anything previously obtained and there was small wonder that



A FERRANTI DYNAMO OF 1883.

the leading engineering paper was struck with the small size and weight of this machine, which, with an armature



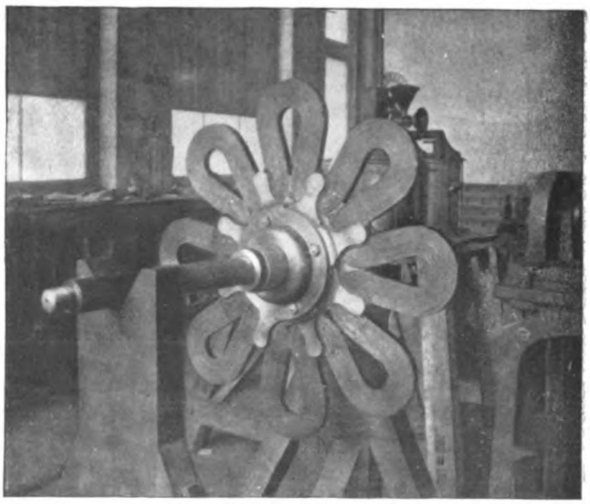
A 1000-LIGHT 16-CANDLE POWER DYNAMO. BUILT BY MESSRS. FERRANTI, THOMPSON & INCE, LTD.

weighing eighteen pounds, could render incandescent 320 Swan lamps,—" nine-tenths of an ounce of moving armature per sixteen candle power lamp." This alternator proved Ferranti to be revolutionary in three things,—the use of high speed; the absence of iron in the armature; and the building of the machine on purely engineering lines.

In order to obtain sufficient driving power without the use of outside bearings, several of these machines were driven by two belts, one on each side. They ran at a peripheral speed of three miles a minute, yet, despite this excessive speed no accident ever occurred,—an unmistakable proof of good mechanical work. Moreover, a number of these machines have run continuously, during the hours of darkness, for the past thirteen or fourteen years. This is an interesting fact, having regard to the present tendency to revert to high speeds without elaboration of bearings.

It was about this period that Ferranti commenced to use oil under pressure for bearings, in place of the lubricating wick and sight-feed lubricators. Though pressure pumps were not actually used, it was unquestionably forced lubrication. Forced lubrication by means of pumps was subsequently employed at Deptford.

At the beginning of 1884 or at the end of 1883 the Hammond Company, which owned Ferranti's patents, went into liquidation. Ferranti, however, succeeded in buying back the patents, and, having purchased a few tools, started manufacturing on his own account and practically founded the extensive concern which exists to-day as S. Z. de Ferranti, Limited.

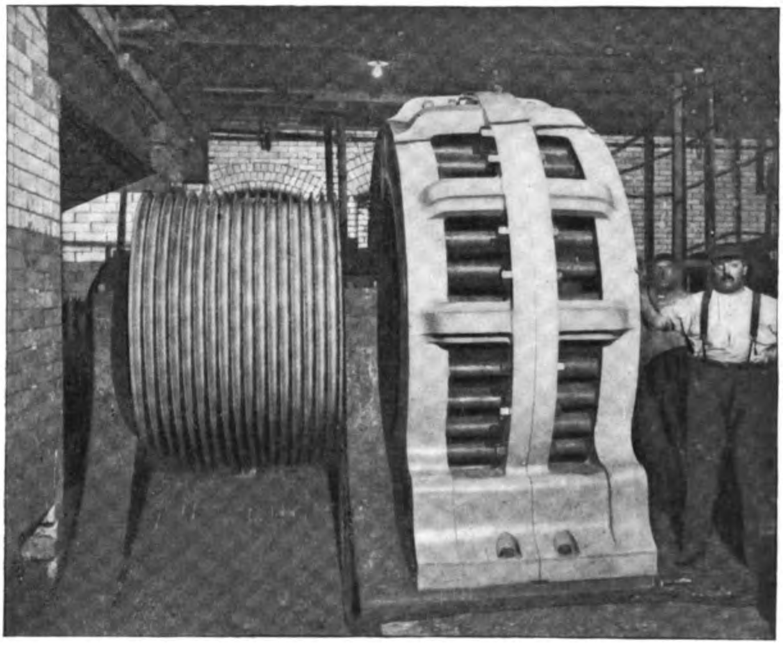


THE ARMATURE.

In 1884, the firm commenced to make unipolar mercury meters, the first being made for the Antwerp central station.

It was at this period that Mr. Ferranti became acquainted with the promoters of the Grosvenor Gallery lighting, an association that was destined to have a far-reaching influence on the public supply of electricity.

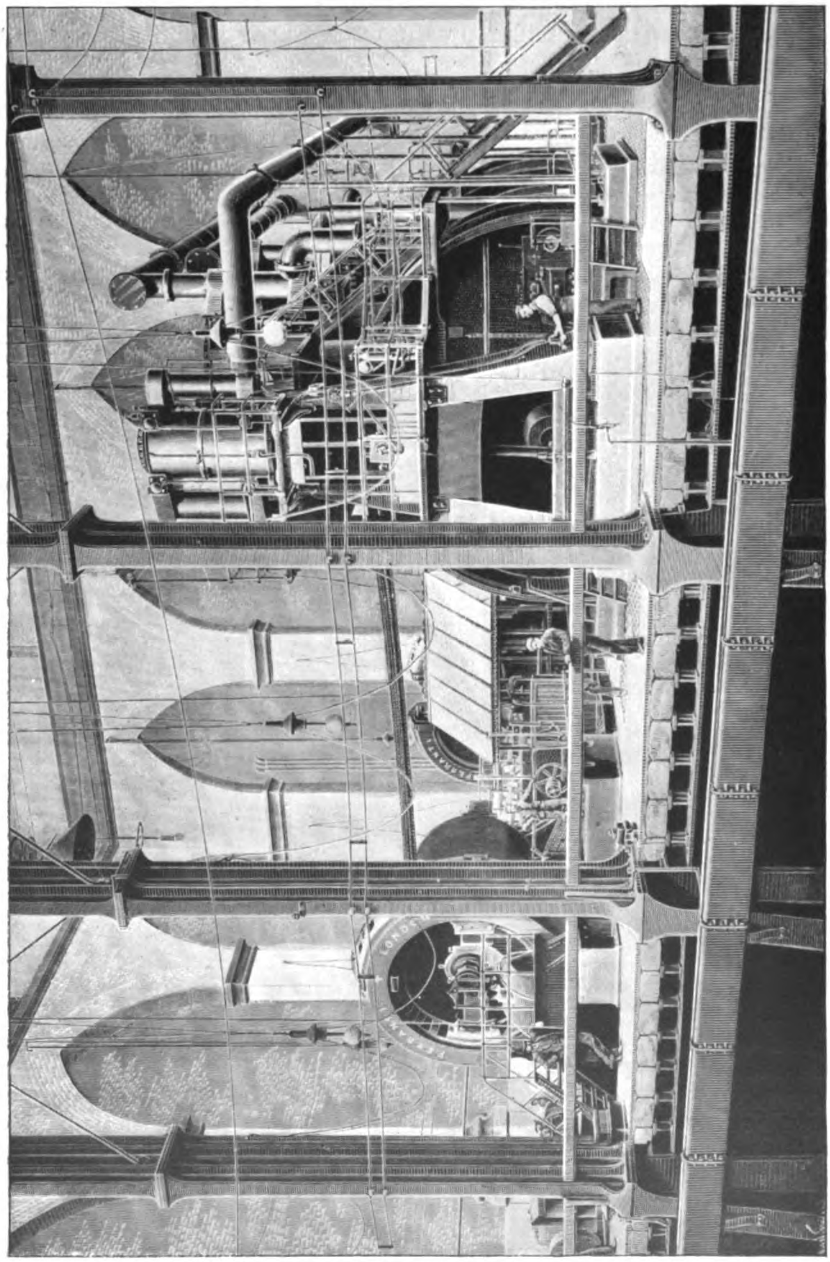
Some two or three years prior to this, an ingenious Frenchman, M. Gaulard, had brought to England a system of electrical distribution which involved the transforming of high-pressure into low-pressure alternating currents. The alternating-current transformer, even in those remote days, was no new thing, for it had been suggested long before; but Gaulard, with whom Gibbs was associated, was probably the first to show the principle in actual practice. The system was received with much incredulity by many scientific men. There were other persons, however, who exhibited enough faith in the apparatus to adopt it for actual work, and the founders of the famous Grosvenor Gallery Station commenced a system of lighting which depended on the Goulard and Gibbs method of distribution.



A 700 H. P. FERRANTI DYNAMO, BUILT IN 1886.

The station originated from Sir Coutts Lindsay's determination to light the Grosvenor Gallery by electricity, but demands from neighbours for current became so great that the plant soon became of considerable magnitude. The system, however, proved to be exceedingly difficult to work, and, after negotiations, Ferranti was called in, at the beginning of 1886, to act as engineer to the Grosvenor Gallery Company. It ought to be observed here, that in the previous year Ferranti had taken out patents practically covering the whole question of alternating current supply which eventually gave rise to many legal disputes.

The young engineer signalled his appointment to the Grosvenor Gallery by immediate measures of reform. The whole system was converted from a series into a parallel one. The Siemens alternators which ran the installation were rearranged, switch gear was designed and erected and a voltmeter, in the shape of twenty-four 100-volt lamps in series, was put into use, a Siemens



THE 1500 H. P. ALTERNATORS AT DEPTFORD. THESE MACHINES ARE GENERATING CURRENT AT 10,000 VOLTS AND ARE PRACTICALLY RUNNING TO-DAY AS THEY WERE FIRST PUT DOWN.

dynamometer measuring the current. The overhead system was entirely remodelled, the leather thong for holding cables from a suspender wire was devised and adopted, oil insulators were used throughout, and eventually, after about a twelvemonth, the first machines were replaced by two Ferranti 700 horse-power alternators which are working to-day at Deptford.

In addition to improving the generating plant, transformers were designed and made in various sizes and erected in the houses. The whole question of danger from fire was exhaustively considered, and by the aid of Mr. Musgrave Heaphy, fire rules were framed which satisfied the fire offices and placed no onerous conditions on the consumer.

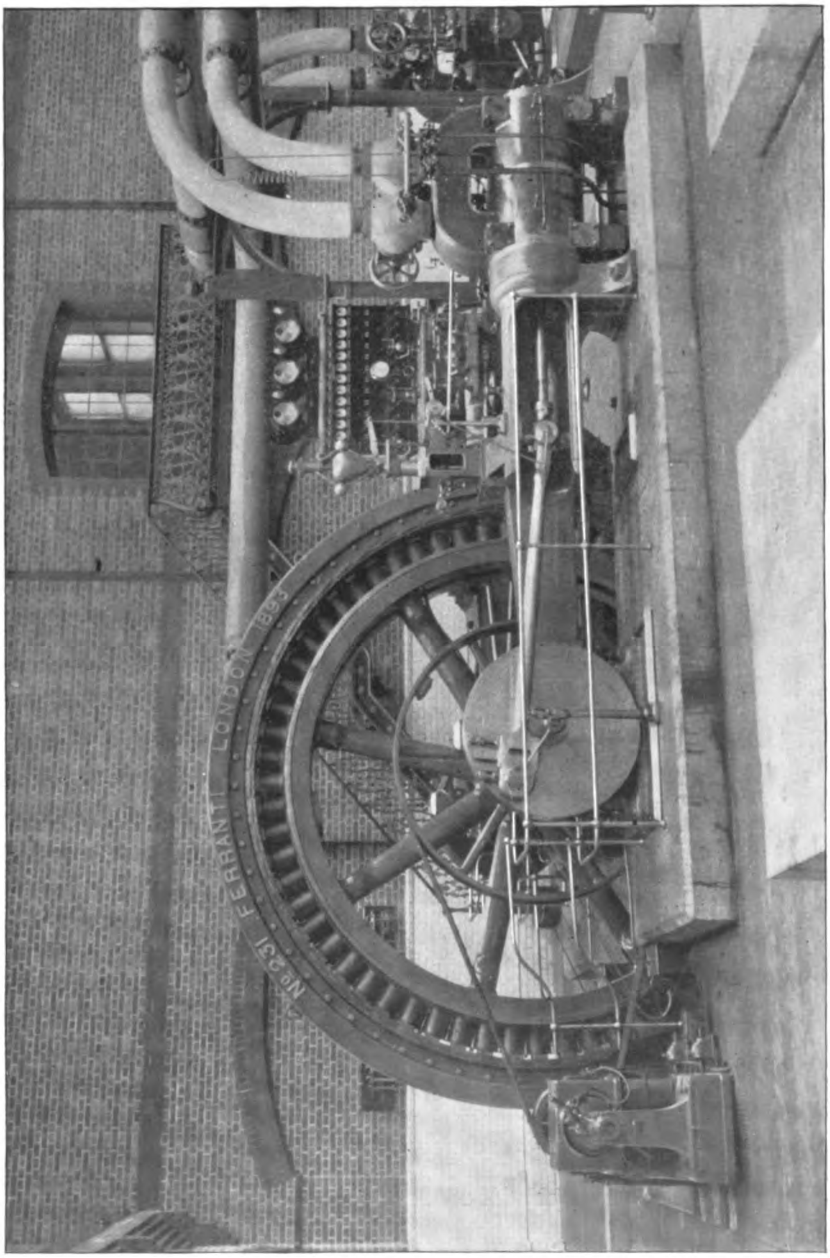
So rapid was the progress of the Grosvenor Gallery Works that, in a very short time 36,000 lamps were connected. In a way, the station was unique. There were 1400 horse-power of high-pressure machines, arranged in a small sub-basement, and a battery of boilers was erected in a similar basement at the other side of the road, steam pipes being taken from one room to another through a subway which passed underneath the roadway.

The plant at the Grosvenor Gallery consisted, in those days, of two Ferranti alternators, each of which was designed for 10,000 ten candle power lamps. One of these machines was driven by a Corliss engine, built by Hick, Hargreaves & Co., while the other was driven from a countershaft which was coupled to three Marshall engines, each of which had previously driven one alternator. It is interesting to observe that the whole of the distribution was done by means of overhead wires, and the fact that 100 miles of mains were maintained in almost perfect condition says much for the skill of the engineering staff.

The phenomenal success of the Grosvenor Gallery system was not unalloyed. The National Society for the Distribution of Electricity by Secondary Generators, the owners of the Gaulard & Gibbs patents, had uttered many threats of injunction until the question became so urgent that the Sir Coutts Lindsay Company had either to contest the claim or to submit to heavy royalties. By a startling and dramatic change the whole position of things became altered. Gaulard & Gibbs were no longer the assailants. They were called upon to show the value of their claims, for on July 10, 1888, Ferranti presented a petition to the chancery division of the High Court of Justice for revocation of the letters patent granted to Gaulard & Gibbs in respect to their system of distributing electricity, on the grounds that the invention was not novel, that the patent would prevent the sale of secondary generators and that it was injurious to the public. Mr. Justice Kekewich, in a most masterly summary of the whole practice of electrical engineering at that date, gave it as his opinion that what Gaulard & Gibbs described as their invention was not the proper subject of a patent and this view was afterwards confirmed by the Court of Appeals and the House of Lords.

Long before the Grosvenor Station had achieved the success already mentioned, Mr. Ferranti had laid down the principle that power generation should be done on a convenient site, outside great cities, where land was cheap, and water and coal were easily available. Impressed with the soundness of Ferranti's ideas and alive to the great future of electric lighting, the owners of the Grosvenor Gallery system determined to embark on an undertaking which, for magnitude, could be compared to the building of the Great Western Railway. The main feature of the scheme was to make electric lighting comparable to gas supply. Beckton, probably the largest gas works in the world, supplied the greater part of the metropolis with gas and it was sought to reproduce a similar state of things in electric lighting.

It was obvious that there was no insuperable difficulty in the way of securing a favourable site. The real difficulty was to find a perfectly safe means of handling the high-pressure currents involved in such a scheme. The solution that presented itself to Ferranti's mind was that it should be done by means of



THE FIRST SLOW SPEED FLY-WHEEL ALTERNATOR AT PORTSMOUTH, 1894.

concentric mains, with the outer conductor connected to the earth. This was rank heresy, but, what was more important, it was entirely contrary to the Board of Trade Regulations. So satisfied was Ferranti, however, that it was the only safe way of working, that he took the responsibility of working contrary to regulations, so as to force home the correctness of the principle, and eventually he succeeded in establishing what is now generally considered the only safe system for all high pressures.

Before saying more about Ferranti's experience with earthing the outer mains, it will be interesting to refer to the scheme of the Deptford Works as they were originally projected. The Grosvenor Gallery Works became merged into the London Electric Supply Corporation, which had been formed to further develop electric lighting business.

There were associated with Ferranti, in carrying out the great scheme, a most able group of men. They were not mere financiers. Lord Crawford, the chairman of the company which had been formed to carry through the project, had already been, at this period, a president of the Institution of Telegraph Engineers, and was widely known as an accomplished electrician, while Mr. Francis H. Ince and the other directors were equally well known as men of ability and experience.

It was not to be wondered at that the scientific world were startled at Ferranti's gigantic plans. The aims of the undertaking were great. It was sought to supply all comers with electric light, and the scheme included plants which would supply energy for 2,000,000 incandescent lamps. In every respect the works were to be a complete departure from existing practice. Electric lighting had scarce achieved commercial success even on the smallest scale, and there were not more than a dozen supply works in England, and the United States, with all its rapid progress, had comparatively few establishments.

Engineers were not very familiar with 500 horse-power engines for electric lighting purposes; yet, at Deptford, it was proposed to employ 10,000 horse-power machines, while 1500 horse-power alternators were spoken of as small units. Moreover, the few stations which, in those days, employed alternating current systems, were experiencing the greatest difficulty, not only in running their machines, but in distributing electric energy. A potential difference of 2500 volts was viewed by many with alarm; yet, on the advice of a man whose age was scarcely twenty-four, a large undertaking was created to work a system at 10,000 volts.

It was at this period that Ferranti not only proposed great changes in electrical engineering, but also in his life, for he married about this time the second daughter of Mr. Francis H. Ince, a gentleman who had taken the greatest interest in Ferranti's early ideas and did much to develop them subsequently. A company was formed to carry out the Deptford scheme with a capital of a million and a quarter, and early in 1888 building operations were commenced at Deptford on the site of an old shipyard.

The distance from the works to the centre of London was eight miles, and the scheme provided for a 10,000-volt current, to be carried to London by means of trunk mains which radiated to different transforming centres where the current was converted down to 2400 volts and then distributed to consumers. The plant was to consist of four 10,000 horse-power engines and dynamos, and two smaller ones of 1500 horse-power each, while the steam-raising plant was capable of supplying steam to the extent of 65,000 horse-power.

As an instance of the enormous size of these machines, it may be said that the diameter of the armature of the large machine was 42 feet, and the alternator, when completed, was to weigh 500 tons. The dimensions of the engine shafts were equally remarkable. Each one was 36 inches in diameter. It was forged from a seventy-five ton ingot, and, when completed, was twenty feet long and weighed twenty-three tons. The illustrations which are given on page 322 of the 1500 horse-power engines and alternators as they were put down, practically represent them as they exist today.

The Deptford scheme provoked one of the fiercest controversies that has ever arisen in the history of electric lighting. Yet, when misrepresentations were rife and criticism was of the keenest, Ferranti, with a commendable spirit of self-control, kept aloof and on no single occasion did he ever reply to critics. Curiously enough, there were few objections urged against the size of the plant. Criticism centred on the transmission of the 10,000-volt current. It was held that cables would not stand the extraordinary difference of pressure, and it has to be conceded that there was a certain amount of truth in the contention, for all known types of cable practically failed and it was not until Ferranti devised and made his own concentric cable that the transmission of 10,000 volts became successful.

Indifferent to the arguments of opponents, the corporation proceeded steadily with the erection of the plant. Colossal, though the undertaking was, it was carried on without Parliamentary powers. But that proved no serious obstacle, for the projectors secured permission from the railway company to lay mains alongside the rails. When some portion of the scheme was almost completed, however, there happened an event which had considerable influence on the future of the great Deptford undertaking. The Electric Lighting Act of 1888 conferred upon the Board of Trade powers of granting provisional lighting orders, and an inquiry was held in the early part of 1888 which resulted in London being parcelled out amongst a number of electric lighting companies.

The promoters of the Deptford scheme had assumed, and perhaps not unreasonably, that the area over which the Board of Trade would grant them powers would be at least as large as the area covered by its overhead mains, which was practically the whole of the best part of London. It was on this assumption that Ferranti decided to use 10,000 horse-power machines, for it was estimated that the progress of lighting in the centre of London would be so rapid that unless large units were employed there must be an excessive number of machines. The area over which powers were eventually granted to the London Electric Supply Corporation, however, was so restricted that there was little justification in proceeding with such excessively large units, and although the machines were partly erected, they were ultimately abandoned.

There have been many misconceptions with regard to these machines, but it ought to be understood that if these huge alternators were to be built to-morrow there would not be the slightest deviation necessary from the original plans. Moreover, the designs are almost identical with the latest machines which are being built for the City of London Electric Lighting Company and other electric lighting works.

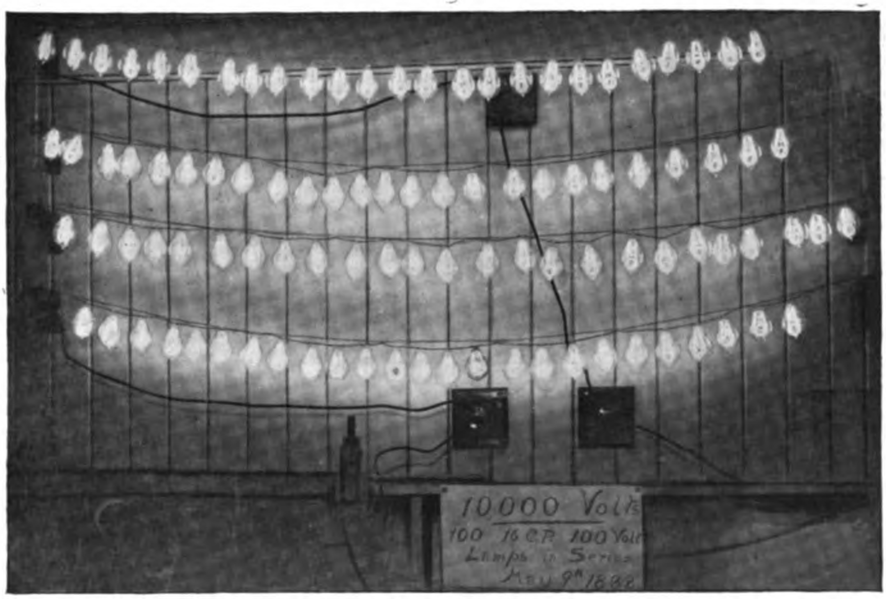
The success of the 10,000-volt transmission had been assured by experiments as far back as 1888, and an illustration is given opposite which shows a bank of lamps through which the first 10,000 volt current was sent. It was not until February, 1891, however, that regular transmission of current at 10,000 volts may be said to have commenced. Many difficulties had to be overcome prior to this. Inductive troubles had arisen from the cables. First the South Eastern Railway complained; then the Post-Office authorities said that the influence of the Deptford current was appreciable in Paris. Mr. Ferranti was convinced that all these troubles would disappear if the outer main were earthed, but it required a good many arguments and experiments before the Board of Trade would sanction such a course.

While speaking on this it is interesting to record one of the experiments that was made to show how perfectly safe concentric mains were, even when conveying currents of 10,000 volts, if the outer was only "earthed." The experiment was made before representatives of the Board of Trade and many of the London vestries and consisted in Mr. Kolle, one of Ferranti's assistants, holding an uninsulated chisel while it was driven by means of a sledge hammer through a concentric main in which a current of 10,000 volts was passing. The chisel short-circuited the main and the supply was cut off by the fuse of the machine burning.

This experiment has been unintentionally repeated over and over again by men, who were working in the roads, driving their wedges through the ground and into the mains. The switching at Deptford has always been done on one pole only and the platforms were originally so arranged as to be completely insulated and to make it impossible, when touching the switch gear, to touch earth at the same time. The result of all these precautions has been that no accident from shock has ever taken place at Deptford.

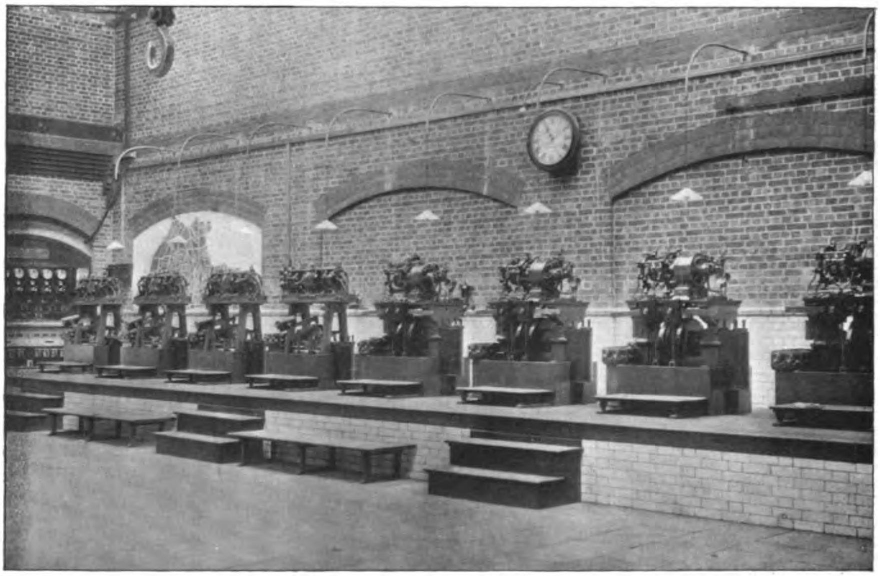
There were many distinctive features about the Deptford system that deserve notice if space only permitted. The most noteworthy were, that the working steam pressure was 200 pounds, and compound, trip-valve engines were employed which constituted a great advance on previous practice. The system of steam pipes was identical with what has been pronounced in the United States to be the very best practice. Swivel bearings were devised by Ferranti, and these are being used on the largest engines of to-day, and about the same time feeding bearings with oil under considerable pressure from force pumps was employed.

The high-tension transformers were ventilated with currents of air passing between the primaries and secondaries and through the iron. Transformers with oil circulation for cooling purposes, such as are used at Niagara, were made about the same period and patented.



A BANK OF INCANDESCENT LAMPS THROUGH WHICH THE FIRST 10,000-VOLT CURRENT WAS SENT ON MAY 9, 1888.

Of the trials and difficulties that beset Ferranti in his magnificent efforts to build up the Deptford scheme, no man can speak without wonder. It was, undoubtedly, a magnificent experiment. There was no experience to guide him, no knowledge to which to appeal. There was simply a deep conviction of success to help him in his single-handed attempts to grapple with a subject full of most subtle difficulties. When engineers of the highest skill, of world-wide reputation, pronounced it an im-



A COMPLETE SET OF FERRANTI RECTIFIERS FOR ARC LIGHTS AT THE PORTSMOUTH STATION.

possibility, how many could have persevered? It was an isolation that would have broken down most men. An expression of opinion that was made in the beginning of 1891 by Mr. Staats Forbes, the chairman of the company, is worthy of recording here:—

"I do not know any man who during the last year has had a more terrible responsibility upon his back than Mr. Ferranti. He pledged his reputation, his fortune, his labour,—day and night—to achieve the result he promised to the directors. He has achieved it greatly and has done so much in redeeming what a year ago seemed a most difficult position and a most uncertain one, that he is justified in his present opinion which is expressed in this paragraph:—'I desire to call attention to the fact that from the commencement of your operations to the present time, no engineering or electrical difficulties whatever have arisen which I have not been able to overcome.'"

A year later Mr. Staats Forbes observed at the meeting of shareholders that "Mr. Ferranti, as everybody knew, was very eminent; his name was European, as was also that of young Mr. Brunel. He supposed that one of the greatest misfortunes was that Mr. Ferranti's ideas, however clever, however sound, had not been realised quite as rapidly as Mr. Ferranti thought they would be, and not quite to the extent he thought."

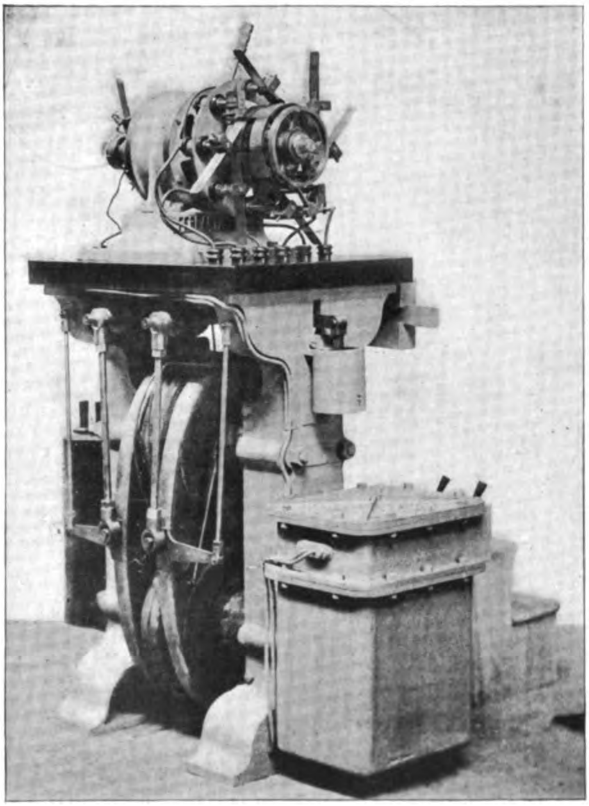
It is clearly recognised that mistakes were made in connection with the Deptford undertaking. It was not within the power of man to avoid errors when building up a system which involved a complete departure from all previous engineering practice. Neither errors of finance nor of engineering could well have been avoided. Beyond the half-dozen able assistants of Ferranti, the labour was unskilled. Moreover, the series of accidents, due to no lack of skill, that dogged the early history of the corporation would have crippled the wealthiest concern.

Yet, how far does the Deptford of to-day differ from the original design of Ferranti? Currents of 10,000 volts pressure are transmitted day after day, with the utmost regularity, and the slightest interruption in the service is practically unknown. Ten thousand volt-alternators are working practically as they were originally laid down, and though Ferranti severed his connection with the Deptford undertaking in the early part of 1892, it ought to be put on record that when the London Electric Supply Corporation sought to increase their machinery and invited tenders from the leading makers of America, Germany and Great Britain, it was Ferranti's tender that was accepted. Consequently, the latest machine put down at Deptford, and so recently as last October, is a Ferranti alternator of 2000 horse-power.

This alternator is probably the largest in Europe, and is the only one in the world that has developed an electric current at 12,500 volts. Its usual output is 120 ampères at 10,000 volts, and it is direct-coupled to a compound vertical engine having three cranks at 120 degrees. The armature wheel, or fly-wheel, weighs twenty-six tons, of which fourteen tons are in the rim, and it runs at a peripheral speed of 11,000 feet per minute. The building up of the fly-wheel is on Ferranti's own methods and there is little doubt that it is well calculated to stand the action of such an abnormally high speed.

With Ferranti's name so closely associated with Deptford, it may surprise those who are not in direct touch with electrical work to know that Ferranti has made engines and machines for electric lighting works in Great Britain, apart from Deptford, representing over 100,000 horse-power. He is one of the large contractors in England and employs over 700 people.

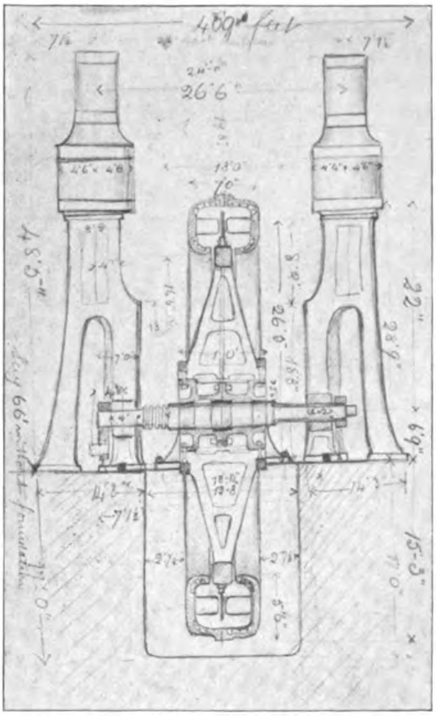
The influence of Ferranti on the design of modern stations has been very great, and in one of the most recent works it has been shown in a most striking manner. The Corporation of Portsmouth, about two years ago, commenced the public supply of electricity on methods so radically different to anything else in England that an illustration of one of the principle features is worth noting in this article. Originally, the Portsmouth corporation decided to adopt ordinary rope-driven alternating plant, but on Ferranti's recommedation combined engines and alternators were substituted. Although continental engineers had used this type of plant long before, it was the first occasion on which slow-speed alternators had been used in



A FERRANTI ALTERNATING CURRENT RECTIFIER

England, and the success of the plant was immediately followed by the erection of other similar machines. One of the Portsmouth fly-wheel alternators is illustrated on page 324, and gives an excellent idea of the apparent strength and elegance of these machines.

It was not only in alternators, however, that the Portsmouth Works exhibited great variation from ordinary practice. It was perhaps chiefly remarkable as being the first place where the commutation of alternating current was employed for arc lighting. Without minimising in the slightest degree



A ROUGH SKETCH, MADE BY FERRANTI, OF A DIRECT-CONNECTED ALTERNATOR.

the work of Hutin and Leblanc, Pollak and others, it can be fairly conceded to Ferranti that he was the first to use commutators, or rectifiers, for practical work.

The Ferranti rectifier, shown on page 329, consists, in its simplest forms, of a synchronous motor, driving a special form of commutator. There is little doubt that the device has had an important bearing on electricity supply. Alternating arc lamps had proved to be a comparative failure for street lighting, and the necessity of employing special engines and dynamos somewhat handicapped the high-tension alternating station. The use of the rectifier immediately changed all that and placed one system in as good a position as the other for outside lighting. The rectifier now forms a very distinctive feature of English work and it is being rapidly adopted in all parts of the country.

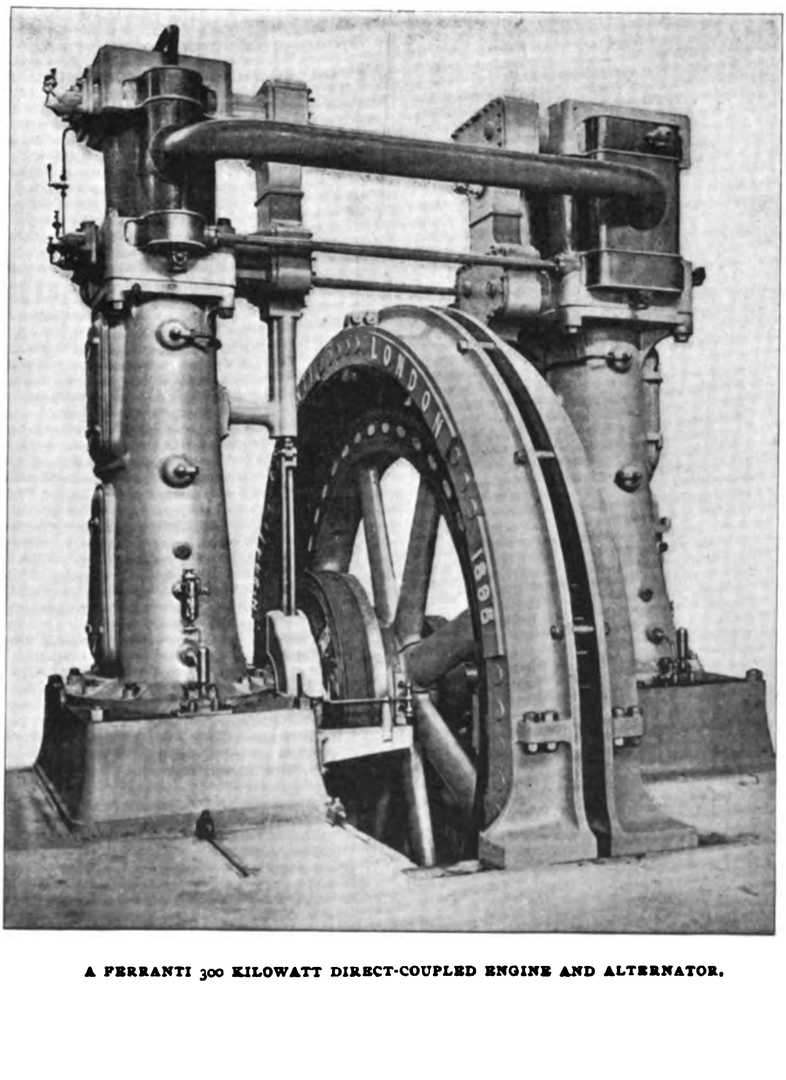
A modern rectifier is usually made to feed about fifty twelve-ampère arc lamps, and occupies a space of less than four square feet, which is in striking contrast to the space taken by an ordinary arc lighter and its engine. A further illustration of the Portsmouth station, on page 328, shows what little room a complete set of rectifiers take. The whole of the public arc lighting of Portsmouth, about 300 lamps, is done by the plant which is illustrated, and there is sufficient reserve in case of breakdown. Having regard to the fact that the Portsmouth system constituted a radical change, it is important to notice that the running costs for the first six months are about the lowest that have ever been achieved by an electrical concern in the first half year of its existence. The total cost per kilowatt hour was 2.3d. and excellent though this figure was, it has since been improved upon.

In all branches of electrical engineering Ferranti's aim has been in the direction of strength and solidity. His switching devices, which are now widely used, are remarkable for their strength, safety, and simplicity. It is not only in large plants that Ferranti has achieved distinction; the humbler duty of measuring current owes much to him, and there are to-day 25,000 Ferranti meters used throughout Great Britain,—an eloquent testimony to their excellence and general reliability.

Ferranti to-day is building the largest engines and alternators in Europe; indeed, they are inferior in size to the Niagara machines only, and when completed will run at a higher surface speed. They are of 2500 horse-power and are intended for the City of London Electric Lighting Company. The engines will embrace all the latest developments of the enclosed vertical type, and the alternator will be suspended between the high and low-pressure cylinders. The illustration on this page shows this type of plant which has been in use at Sheffield for some time and was patented as far back as 1885.

It is a fact not generally known, though it was mentioned in the Niagara Number of CASSIER'S MAGAZINE, that Ferranti was interviewed in the eighties by Dr. Coleman Sellars and Professor Riedler on the subject of the utilisation of Niagara, and his trenchant remarks on the subject had, no doubt, much influence on the eventual use of electrical methods. It is worthy of record that a syndicate, composed of Ferranti, Mr. Ince and Colonel Shaw, secured, in 1886 or 1887, the original concession on the Canadian side for utilising the Niagara Falls. The idea was to transmit electrical energy to Buffalo, and, indeed, anywhere within 500 miles. It was proposed to employ Pelton water wheels, placed just below the flood level of the lower water, and to drive single-phase alternators of low periodicity. The idea received little support in England and the scheme eventually died of inanition.

It is not surprising that Ferranti should have clear and distinct views on



A FERRANTI 300 KILOWATT DIRECT-COUPLED ENGINE AND ALTERNATOR.

the future of electrical engineering. He holds that the essence of improvement lies in the cheapening of the supply to bring it within the reach of all, and to adapt it to the many purposes for which it is so admirably suited. In his opinion the "business of distributing electrical energy must be done upon a large scale to be commercial, and to attain this we must supply a large area, not limited by the exigencies of systems, and we must do this from a site not in the congested heart of a big city, but from a position best suited by its natural advantages to the carrying on of such an undertaking."

He maintains that we must still look for improvement in transformers, and that the apparatus of the modern station must be less complicated before it can run cheaply. He is emphatic in his opinion that the solution of cheap motive power, which is essentially what is necessary for the production of cheap electrical energy, is to be found in the internal combustion engine.

When a man has achieved a world-wide reputation at the age of thirty-two, it is reasonable to assume that he will have considerable influence in moulding the future of electrical engineering. With all his brilliant achievements, his great attainments, and his vast experience, Ferranti remains the most modest of men. He has a clear and generous appreciation of other men's work and is not enthusiastic about his own. His life is spent in hard work, but though his days are filled in carrying on the large works in Lancashire and London he still finds time to develop improvements in plant and machinery. As to the advances that are made during the next decade, it will be surprising if Ferranti is not concerned in many of them.

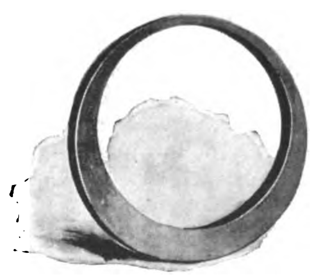
Current Topics.

REMOVING old paint from metal surfaces, in structural steel and iron work,—bridges, for example, and the like,—previous to repainting, involves an expenditure of time and money quite beyond the conception of any one who has never given the matter serious consideration. Whether the sand blast, which is so efficient in cleaning castings, would perform satisfactorily in this direction is, therefore, a question of considerable economic interest. Whatever experiment has thus far been made has shown, what was to be expected, that when the paint is reasonably new and the oil is in a slightly elastic state, it is exceedingly difficult to remove it by sand blast, though later, when the oil has become more oxydised from longer exposure to the air, it yields more readily to the attack of the process. Paint, therefore, which is old enough to warrant its removal and replacing by a fresh coat, would probably give way before the sand grains in an encouraging manner. In one instance the sand blast was used to clean between decks of a cattle steamer, which was in exceedingly bad condition, with many coats of old paint on the iron work. The results were highly satisfactory as to quality of work done, but the time consumed was excessive. The air pressure used was, however, only about ten pounds per square inch, and it is, therefore, reasonable to suppose that if, say, from forty to fifty pounds pressure had been used, the results might have been satisfactory in point of both quality and economy of work. At any rate, it would seem worth trying the process further. The promise of money saving that it holds out is certainly seductive.

In engineering work, as in some other things, phenomena are constantly encountered which lack satisfactory explanation and which, regretfully, have to be relegated to the class known as mysterious. Sir Benjamin Baker, touching upon this matter some time ago, in an address before the British Institution of Civil Engineers, made the point that many of the things which appear mysterious to the engineer, appear so because the assumptions made by him in ordinary work are rough generalisations rather than particular truths. We know that iron expands with heat, and therefore jump at the conclusion that this expansion will go on from the solid to the molten state; and when we see a piece of solid cast iron, immersed in molten iron, rise to the surface and float, like ice on water, we term it mysterious, whereas the flotation is a necessary consequence of the molecular changes which went on in the iron. We assume, again, that a red hot bar of steel will cool gradually and steadily, and then style the curious wriggling of a flat bottomed steel rail, when cooling, mysterious, whereas, as a matter of fact, a red hot steel bar does not cool gradually, but cools down to a certain point, then becomes hotter again, and then resumes the cooling process, only to make further oscillations of temperature which affect the thin flange and the thick head of the rail at different times, and so cause considerable cambers in opposite directions before the rail ceases to be red hot. We know now, from the researches of physicists, that changes in thermal condition and changes in the arrangement of the metallic and other elements, and even of the atoms in the molecule, occur simultaneously, and that between the temperatures of 1200 degrees to 1600 degrees there are several so-called critical points where the cooling process is arrested, and thus the wriggling of the rail ceases to be mysterious.

The effects of hardening, tempering and annealing, familiar to the world, doubtless, for several thousand years, have only recently been partially lifted out of the mysterious class by researches of a like nature to the preceding. There are many other mysteries of an analogous kind waiting to be cleared up. We should like to know, for example, what is going on month after month in a hardened steel armour-piercing projectile which frequently leads finally to a violent disruptive explosion of the mass, and also what causes a sword to lose temper by lapse of time, whilst the edge becomes sharper. Why, again, should the tough and flawless bar iron suspension links, which had carried the Hammersmith bridge successfully for over sixty years, snap in two by the dozen during simple transport to Edinburgh, although in every case the halves of the broken links, on being thrown down 300 feet from the top of the Forth Bridge on to the rocks below, bent like a corkscrew without fracture? Practical engineers have been aware for forty years past from Fairbairn's experiments that at temperatures of 60 degrees and of 320 degrees the strength of wrought iron was practically constant, whilst at 30 degrees the strength was slightly increased; but until Professor Dewar's recent researches they could never have conceived that when immersed in liquid air at a temperature of — 320 degrees the strength of iron wire would be raised from thirty-four tons to sixty tons per square inch. The chemical constituents of iron and steel do not change, but the molecular arrangement and intercrystalline cohesion must change, and it is to mathematical investigation and laboratory work rather than to practical engineering that we must look for an elucidation of the process.

THE uncertainty of cast iron steam pipe was recently well illustrated in *The Locomotive*, published by the Hartford Steam Boiler Inspection and Insurance Company, from which the accompanying little sketch has been reproduced, which tells a good part of the story. It appears that at a certain large manufacturing establishment a line of 8-inch cast iron pipe had been in use for a number of years, carrying about seventy-five pounds pressure. That part of the pipe which was in the boiler room had failed on several occasions, but each time there was some very fortunate circumstance about the accident, so that no great damage was done. It was feared, however, that this continued run of good fortune might not always prevail, and as a matter of precaution it was decided to take out the cast iron and put in something better. The pipe in the boiler room was removed and broken up for old iron, and was replaced by a modern wrought iron pipe with riveted flanges. The cast iron that had been in the boiler room was entirely discarded; but those lengths that were in the engine room, were supposed to be of superior quality, inasmuch as they were extra heavy, and were made "on honour," and so it was thought best to preserve this part of the piping for possible future use. Not long after the pipe had been changed, the company wanted a cast iron column for some purpose or other, and bethinking themselves of the high grade piping that they had reluctantly taken out of the engine room, they put a section of it in a lathe to cut it off to the right length; and when they made the cut, they made a discovery also. The nature of the discovery is shown in the sketch. On one side the pipe was $1\frac{1}{4}$ inches thick, and on the other its thickness was a scant quarter of an inch. It is hardly necessary to say that the firm that had used this pipe as a steam main for many years, has had enough experience with cast iron steam pipe, even when it is "made on honour."



SECTION OF AN IMPERFECT CAST IRON STEAM PIPE.

THE makers of the pipe described most probably believed it to be sound, and perfect; and one must therefore look to the process by which such pipe is made, continues *The Locomotive*, if we wish to find the most likely explanation of the defect. In casting large pipe, a hollow iron core is used, which is perforated with numerous holes, and also studded, on the outside, with little points or projections. The core is coated to the proper thickness with a composition of flour, coarse sand, and molasses, which is held in position by the projections or studs, and the whole is placed in an oven and baked. When the covering is hard and dry, the core is placed in the mould, and the casting is made. Now the core, being hollow, and being immersed in the melted iron, will be buoyed up powerfully, and means must be provided to hold it in position. Yet even if the ends of the core are held firmly in position, there is danger of the middle springing upward by a sensible amount, unless it is quite stiff and rigid. A small amount of yielding will be sufficient to destroy the uniformity of thickness that is essential to good pipe. In the case described above, the core must have been about ten feet long, and a "spring" of half an inch at the middle (which is not at all impossible), would have been quite sufficient to account for the observed inequality in thickness. The general conclusion to be drawn from this example is, that cast iron should not be used for steam pipe. This is a corollary to the more general proposition that cast iron should not be used in any place where it will be exposed to a tensile stress. It is good enough material for resisting compressive strains, but it is altogether too uncertain in its behaviour to be trusted under tension.

IF report be true, the Buda-Pesth underground railway has developed a very curious defect. There are not enough ventilating apertures in the tunnel, and the trains rushing through it compress the air in it like that in the tube of a Zalinski pneumatic gun. On some occasions the cars are said to have been lifted from the track and the passengers have been almost suffocated. One stretch of tunnel, two miles long, has only a single ventilating aperture, making it almost an airtight compartment.

THE reversibility of the physical processes of nature has latterly been the subject of interesting comment. Lord Kelvin, for example, has been credited with saying that all of them, no matter how complex they might appear to the human senses, consist in reality of the motions of invisible molecules, and if, therefore, by some means, all these molecules could, at the same time, be made to move in exactly the opposite direction, and each with the same velocity that it possessed at the moment, all the world would begin, and continue, to move backward; waterfalls would flow up the sides of cliffs; rivers would run upward from the sea; rain would rise; full-blown flowers would shrink into buds, and plants dwindle into seedlings, man himself would become young again, passing from old age to infancy. Just what kind of picture such a topsy-turvy world would present may be seen with a kinetoscope running backward. Professor Queroult, according to report, has made observations in this line, and some time ago communicated them to the French Academy of Science.

FROM one of the published accounts of his lecture it appears that during some of his experiments he hit upon the idea to turn around photographic records and also the series of pictures seen through the kinetoscope. Having photographed a plant at regular intervals and shown in the kinetoscope the growth, the development of the stem, leaves, buds, flowers and fruit, the same consequence of photographic pictures reversed was presented to the eyes of the astonished spectators, who wondered at the fruit turning into flowers, flowers into buds, buds drawing back into themselves and disappearing, the leaves closing, getting smaller and disappearing, the stem getting shorter and shorter, until the earth closed over it.

REVERSING even the most ordinary series of pictures affords startling views. A drinker takes up an empty glass and replaces it full upon the table; a smoker sees the stump of a cigar flying at him from the floor, takes it to his mouth and sees the smoke originate in the room, draws it into his mouth and into his cigar, which is gradually lengthened and finally replaced in the pocket. A wrestler, who has probably thrown away his garments, is recovered with them by their, so to speak, walking up on him into their places, while he himself performs motions of which one can understand nothing, because these most ordinary motions, performed backward, are rarely seen. A man, for instance, seated at a table before an empty plate, works hard taking bite after bite from his mouth, until the chicken is whole again on the dish before him, and the side dishes also are returned full to their respective places. All these things, however, are, for the present, not likely to find counterparts in the operations of nature.

WHAT is occurring or what will occur to the metallic portions of the many tall buildings that are in process of erection at the present time, under great dissimilarity as regards temperature, humidity, and other climatic conditions, but of one characteristic sameness—viz., being sealed in solid masonry or other coverings beyond the ken of inspection? Probably no engineering question to-day is entitled to more serious consideration than this one. In discussing it recently, before the American Society of Mechanical Engineers, Mr. M. P. Wood maintained that while inspection of some of the buildings now in progress, as well as some of those lately erected, reveals possibly a slight improvement in the means of preservation adopted over those apparent a short time ago, yet the improvement is a hollow mockery, and will bear fruit for repentance before many years have passed. These structures, though more carefully painted than those erected before, with more and heavier coatings of some kind of stuff called paint, do not appear in a single case to have received any attention or consideration as to the condition of the metallic surfaces before applying the protective coating beyond a possible sweep with a dirty broom to get rid of the rough dirt from the workshop yard, and a possible wipe with a piece of old sacking to remove the grease due to machining processes. There has been nothing like a washing down of the parts with soda ash or lye water to remove the grease, and then pickling with weak acid to remove the mill scale, and a subsequent washing with lime water to neutralise the acid bath, warming the work before painting it, and taking care to apply the paint only on clear, bright days, when no sweating can occur, or applying the paint in warm paint rooms. It is safe to say that not in a single case out of the many skeleton structures of modern skyscrapers can this be found to have been the procedure. There would seem to be no better possible assurance than all this of trouble ahead for coming generations.

NO less than 106 different kinds of car couplers are enumerated by the United States Interstate Commerce Commission in a table giving a summary of equipment fitted with automatic couplers in each year, commencing with 1889. During the seven years covered, many varieties of couplers have dropped out of use and many new ones have come forward. In 1889, the number of kinds reported in use was thirty-nine, of which fourteen do not now appear, while the varieties in use in 1895 have increased to seventy-eight. The number of automatic couplers of all kinds reported used has increased from 80,540 in 1889 to 408,856 in 1895. One type that had 11,808 in use six years ago had dwindled down to a solitary one; while another that reported only 952 six years ago now boasts of 105,725 in service.

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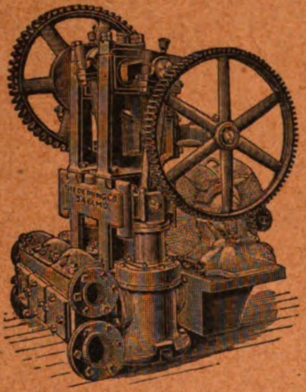

Fig. 55. Electric Pump.

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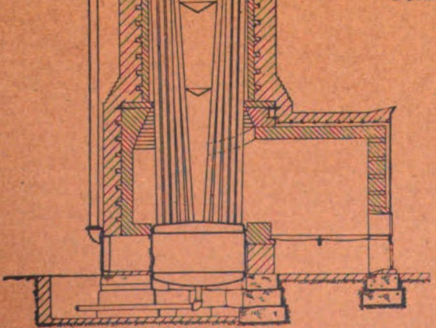

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Ambrose Swasey.

(SEE PAGE 403.)

CASSIER'S MAGAZINE.

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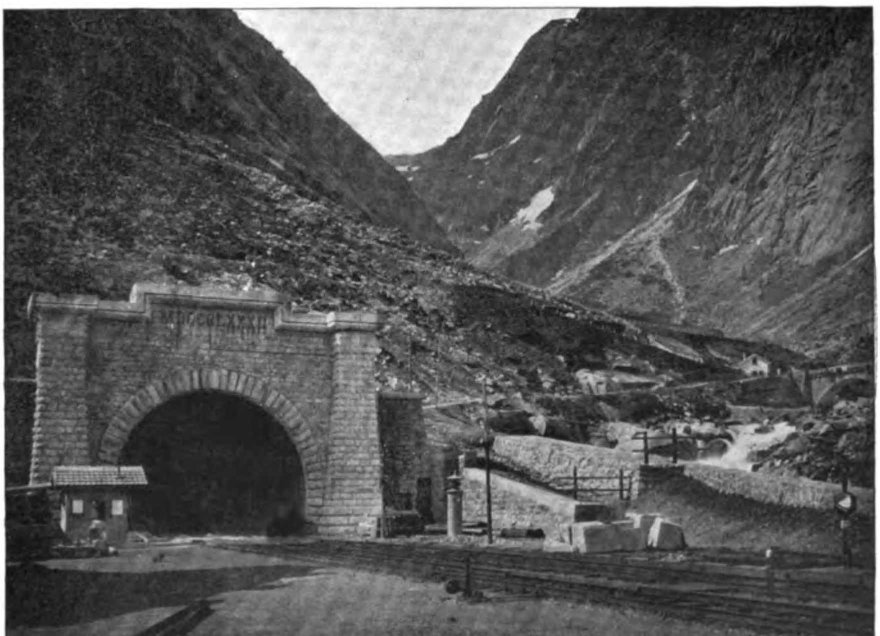
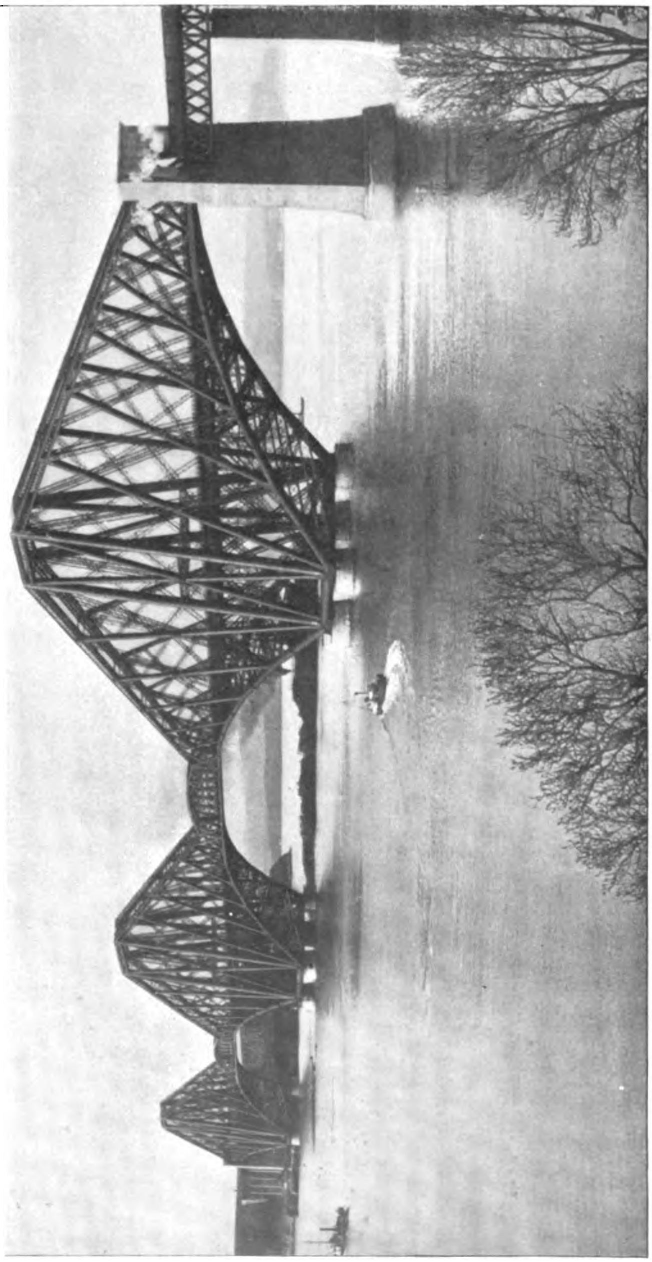
TWENTY-FIVE YEARS OF ENGINEERING PROGRESS.

By Sir Douglas Fox, Vice-Pres. Inst. C. E.

IN a recent presidential address at Liverpool, before the Mechanical Science section of the British Association for the Advancement of Science, the author, reviewing the progress of the past quarter century, pointed out that during this period the railway system of the British Isles has extended from 15,376 miles, at a capital cost of £552,680,000, to 21,174 miles, at a capital cost of £1,001,000,000. The railway system of the United States has more than trebled in the same period, and now represents a total mileage of



AT THE MOUTH OF THE ST. GOTHARD TUNNEL.



THE FORTH BRIDGE. LENGTH, 8296 FEET. HEIGHT, 354 FEET. SPANS, 1700 FEET.

181,082, with a capital cost of $11,565,-000,000.

The Forth and Brooklyn, amongst bridges, the Severn and St. Gothard, amongst tunnels, the gigantic works for the water supply of towns, are some of the larger triumphs of the civil engineer; the substitution of steel for iron for so many purposes, the perfecting of the locomotive, of the marine engine, of hydraulic machinery, of gas and electric plant, are those of the mechanical branch of the profession.

The city of Liverpool and its sister town of Birkenhead have witnessed wonderful changes during the period under review. Great and successful efforts have been made to improve the water-gate to the noble estuary, which forms the key to the city's greatness and prosperity; constant additions have been made to the docks, which are by far the finest and most extensive in the world. The docks on the two sides of the river have been amalgamated into one great trust. In order properly to serve the vast and growing passenger and goods traffic of the port, the great railway companies have expended vast sums on the connections with the dock lines and on the provision of station accommodation, and there have been introduced, in order to facilitate intercommunication, the Mersey railway, crossing under the river, and carrying annually nearly ten millions of passengers, and the Liverpool Overhead railway, traversing for six miles the whole line of docks, and already showing a traffic of seven and one-half millions of passengers per annum. A very complete waterside station, connected with the landing stage, has been lately opened by the dock board in connection with the London and Northwestern railway. In addition to this, the water supply from Rivington and Vyrnwy has now been made one of the finest in the world.

To the hydraulic engineer there are few rivers of more interest, and presenting more complicated problems, than the Mersey and its neighbours, the Dee and the Ribble. They all possess vast areas of sand covered at high water, but laid dry as the tide falls, and in each case the maintenance of equilibrium between the silting and scouring forces is of the greatest importance to the welfare of the trading communities upon their banks. The enclosure of portions of the areas of the respective estuaries for the purposes of the reclamation of land, or for railway or canal embankments, may thus have far-reaching effects, diminishing the volume of the tidal flow and reducing the height of tide in the upper reaches of the rivers.

Some idea of the magnitude of these considerations may be derived from the fact that a spring tide in the Mersey brings in through the narrows between Birkenhead and Liverpool 710 millions of cubic yards of water to form a scouring force upon the ebb. The tidal water is heavily laden with silt, which is deposited in the docks, and, at slack water, upon the sandbanks. The former is removed by dredging, and amounts to about 1,100,000 cubic yards per annum; the latter is gradually fretted down into the channels and carried out to sea before the ebb. Whilst a considerable portion of the narrows is kept scoured, in some places right down to the sandstone rock, there is a tendency, on the Liverpool side, near the landing stage, to silt up,—a difficulty counteracted, to some extent, by the extensive sluicing arrangements introduced by Mr. George Fosbery Lyster, the engineer of the Mersey Docks and Harbour Board.

Very extensive and interesting operations have been carried on by the board in connection with the bar at the mouth of the river. Dredgers, specially designed for the purpose, have been employed for some six years, with the result that 15,142,600 tons of sand and other dredged matter have been removed, and the available depth of water at low water has been increased from 11 to 24 feet in a channel 1500 feet in width.

Those who have made the transatlantic passage in former years can more readily appreciate the very great advantage accruing from this great improvement. Formerly vessels, arriving off the port on a low tide, had to wait for

THE PROMENADE ON THE BROOKLYN BRIDGE.

some hours for the water level to rise sufficiently to enable them to cross the bar. The result of a large vessel lying outside, rolling in the trough of the sea with her engines stopped, was that not infrequently this proved to be the worst part of the voyage between New York and Liverpool, and passengers who had escaped the malady of seasickness throughout the voyage were driven to their cabins and berths within three or four hours of landing.

Owing to the very successful dredging operations, ships of the largest size can now enter or depart from the Mersey at any state of the tide, and they are also able to run alongside the landing stage without the intervention of a tender. Such vessels as the *Teutonic* or *Majestic*, of nearly 10,000 registered tonnage, 566 feet in length, 57 feet wide, and 37 feet deep; or the still larger vessels, the *Campania* or *Lucania*, of nearly 13,000 tons register, 601 feet in length, 65 feet in width, and 38 feet in depth, can be seen, on mail days, lying alongside.

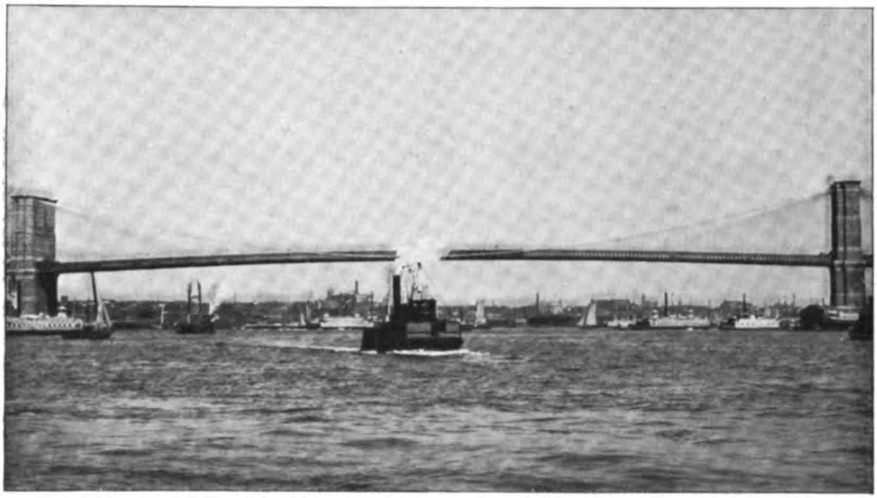
Whilst the estuary of the Mersey presents a narrow entrance with a wide internal estuary, the Dee, owing to extensive reclamation of land in the upper reaches, has a wide external estuary leading to an embanked river of very limited width, up which the tide rushes with great velocity, laden with silt, rising in some two hours, then, during a short time of slack water, depositing the silt, which is not removed by the ebb tide, spread over some ten hours, and therefore having comparatively little velocity. In this case, also, the outer estuary shows a great tendency to silt up beyond the reach of any but the highest spring tides.

The reclamation of the Ribble has not yet proceeded so far as to so seriously affect the general conditions of the estuary; but here, also, there is a constant tendency in the channels to shift, and the erosion which takes place when a high tide and wind combine is very remarkable.

A most important improvement was introduced in 1886, by Mr. G. F. Lyster, when it was decided to raise the water level in certain of the docks by pumping, the wharves being heightened in proportion, and half-tide basins, or locks, made use of to compensate for the difference of level. The area of the docks so treated in Liverpool is 78 acres, whilst at Birkenhead the whole area ot the docks on that side of the river, amounting to 160 acres, is so raised.

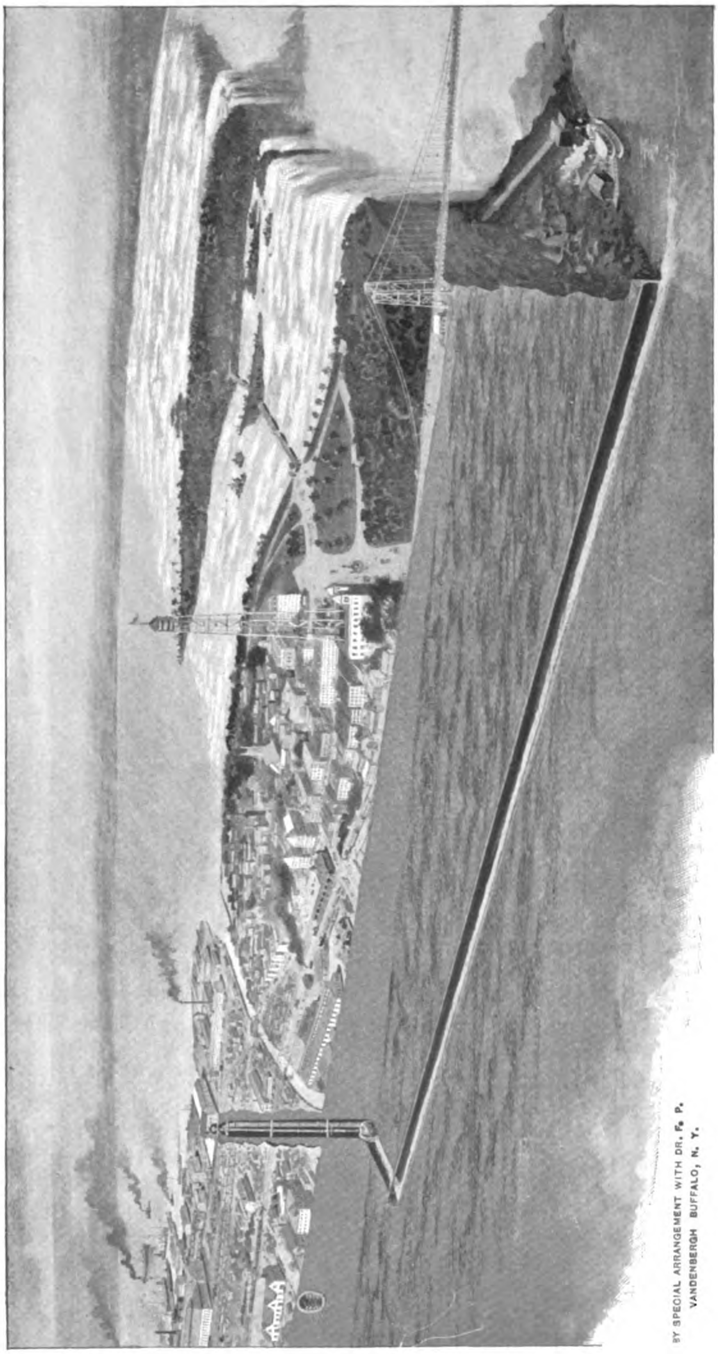
The hydraulic power used in the docks is very large, the indicated horse-power of the engines amounting to 1673 in case of Liverpool, and 874 in that of Birkenhead, whilst the Hydraulic Power Company are supplying some 1000 horse-power to railways and private firms. The direct-acting hydraulic lifts of the Mersey railway have now been at work for ten years, and through these, at St. James' station, no less than 75,000,000 to 80,000,000 of passengers have passed with regularity and safety.

It is remarkable that, whilst Great Britain led the van in the introduction of steam locomotion, she has lagged in the rear as regards electric and other mechanical traction. This arose, in the first instance, from mistaken legislation, which strangled electrical enterprise. This is still much hampered by the reluctance of public authorities to permit the introduction of the necessary poles and wires into towns.



THE BROOKLYN BRIDGE SEEN FROM NEW YORK HARBOUR. LENGTH OF SPAN, 1595 FEET. CLEAR HEIGHT IN CENTRE OF SPAN ABOVE HIGH WATER, 135 FEET.

At the date of the latest published returns there were at work in the United States no less than 12,133 miles of electric, in addition to 599 miles of cable, tramway. Hardly a large village but has its installation, and vast have been the advantages derived from these facilities. In Brooklyn one company alone owns and works 260 miles of overhead trolley lines. With the exception of some small tramways at Portrush, Brighton, Blackpool, South Staffordshire, Hartlepool, etc., the only exam-



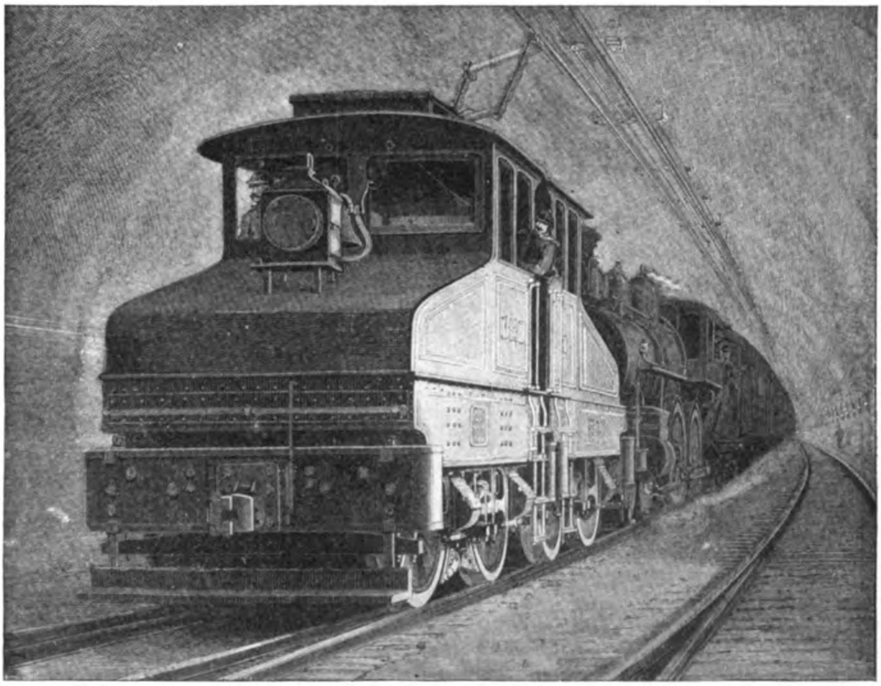
BY SPECIAL ARRANGEMENT WITH DR. F. P. VANDENBERGH BUFFALO, N. Y.

A BIRDS'-EYE VIEW AND SECTION OF THE NIAGARA FALLS POWER INSTALLATION.

ples in Great Britain of serious attempts to apply electro-motive force to the carriage of passengers are the City and South London railway and the Liverpool Overhead railway, the latter being the latest constructed, and having, therefore, benefited by the experience gained upon the London line.

This railway is over six miles long, a double line of the normal, or 4 feet 8½ inch, gauge, running on an iron viaduct for the whole length of the docks; the installation is placed, for convenience of coal supply, about one-third of the distance from the northern end. A train service of three minutes each way is readily maintained, with trains carrying 112 passengers each, at an average speed of twelve miles per hour, including stoppages at fourteen intermediate stations. During the last year, as before stated, seven and one-half million passengers were carried, the cost of traction per train mile being 3.4d. The Hartlepool tramway is proving successful, overhead trollies and electric traction having taken the place of a horse tramroad, which was a failure from a traffic point of view.

Careful researches are being prosecuted, and experiments made, with the intention of reducing the excessive weight of storage batteries. If this can be effected, they should prove very efficient auxiliaries, especially where, in passing through towns, underground conductors are dangerous, and overhead wires objectionable.



BY COURTESY OF THE "SCIENTIFIC AMERICAN."

A 100-TON ELECTRIC LOCOMOTIVE IN THE BELT LINE TUNNEL OF THE BALTIMORE & OHIO RAILROAD AT BALTIMORE.

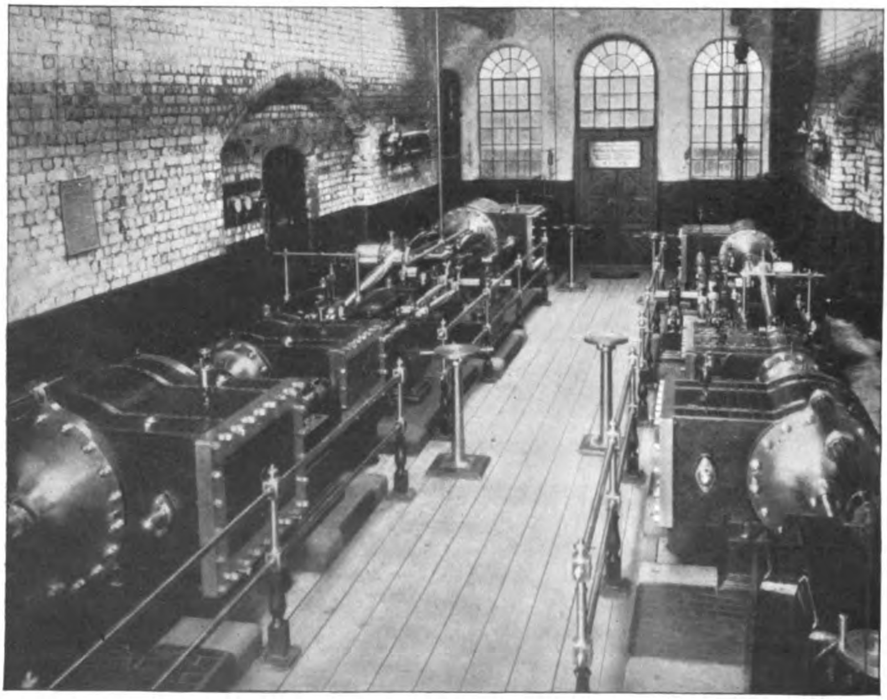
In connection with electric traction, it is very important to reduce, if possible, the initial force required for starting from rest. Whether this will be best attained by the improvement of bearings and their better lubrication, or by the storage, for starting purposes, of a portion at least of the force absorbed by the brakes, remains to be seen, but it is a fruitful field for research and experiment.

In the United States there is a very general and rapid displacement of the cable tramways by the overhead wire electric system. The latter has many opponents, owing, probably, to causes which are preventible. Many accidents were caused by the adoption of very high tension currents, which, on the breakage of a wire, were uncontrollable, producing lamentable results. The speed of the cars, too, was excessive, resulting in many persons being run over.

The cable system, therefore, found many advocates, but the result of experience is in favour of electrical traction under proper safeguards.

The cable system can compete with the electric system only when a three minute, or quicker, service is possible, or, say, when the receipts average £20 per mile per day; it is impossible to make up lost time in running, and the cars cannot be "backed." If anything goes wrong with the cable the whole of the traffic is disorganised. The cost of installation is much greater than in the case of electricity, and extensions are difficult.

On the other hand, electricity lends itself to the demands of a growing district, and extensions are easily effected; it satisfies more easily the growing demands on the part of the public for luxury in service and car appointment. It is less expensive in installation, and works with greater economy. By placing the wire at the side of the street, and using a current of low voltage, the objections are greatly minimised, and the cars are much more easily controlled and manipulated. Electric cars have been worked successfully on gradients of 1 in 7.



VENTILATING ENGINES FOR THE MERSEY TUNNEL AT LIVERPOOL. BUILT BY MESSRS. WALKER BROS., WIGAN.

The conduit slot system can be adopted with good results, provided care is taken in the design of the conduit, and allowance made for ample depth and clearance; a width of ¾-inch is now proved to be sufficient. Where, how-

FROM A COPYRIGHTED PHOTOGRAPH BY LOEFFLER, NEW YORK.
THE TALL DOMED BUILDING AT THE LEFT IS THE HOME OF THE AMERICAN EDITION OF CASSIER'S MAGAZINE.

A GROUP OF TALL NEW YORK BUILDINGS.

ever, there are frequent turnouts, junctions, and intersecting lines, the difficulties are great, and the cost excessive. Attempts have been made to obviate the necessity of the slot by what is known as the closed conduit; but at present the results are not encouraging.

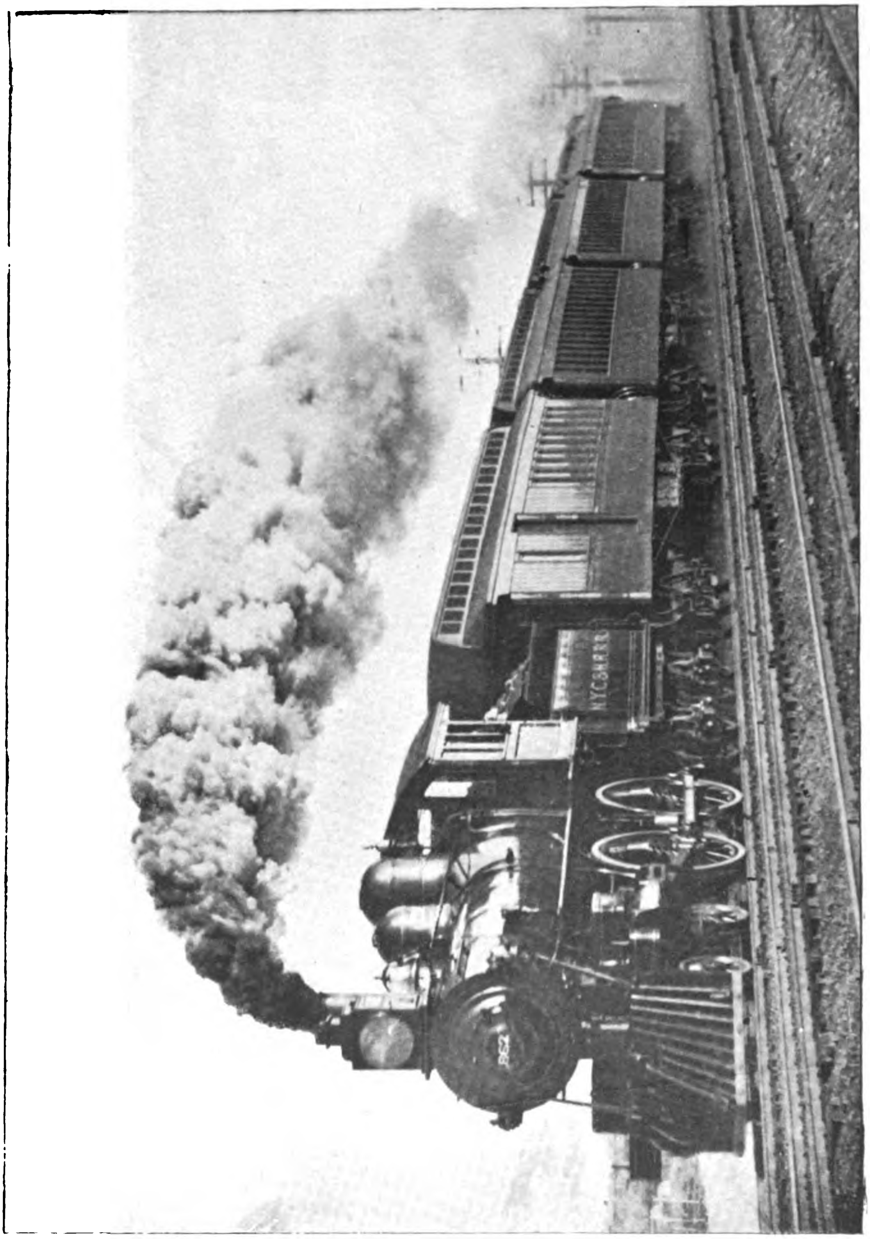
In addition to the application of electricity for illuminating purposes, and for the driving of tram cars and railways, it has also been applied successfully to the driving of machinery, cranes, lifts, tools, pumps, etc., in large factories and works. This has proved of the greatest convenience, abolishing, as it does, the shafting of factories, and applying to each machine the necessary power by its own separate motor. The economy resulting from this can hardly be overestimated. It is also successfully employed in the refining of copper, and in the manufacture of phosphorus, aluminium, and other metals, which, before its application, were beyond the reach of commercial application. The extent of its development for chemical purposes in the future no one can foresee.

It is hardly necessary to call attention to the successful manner in which the falls of Niagara, and the large falls of Switzerland, and elsewhere, are being harnessed and controlled for the use of man, and in which horse-power by thousands is being obtained.

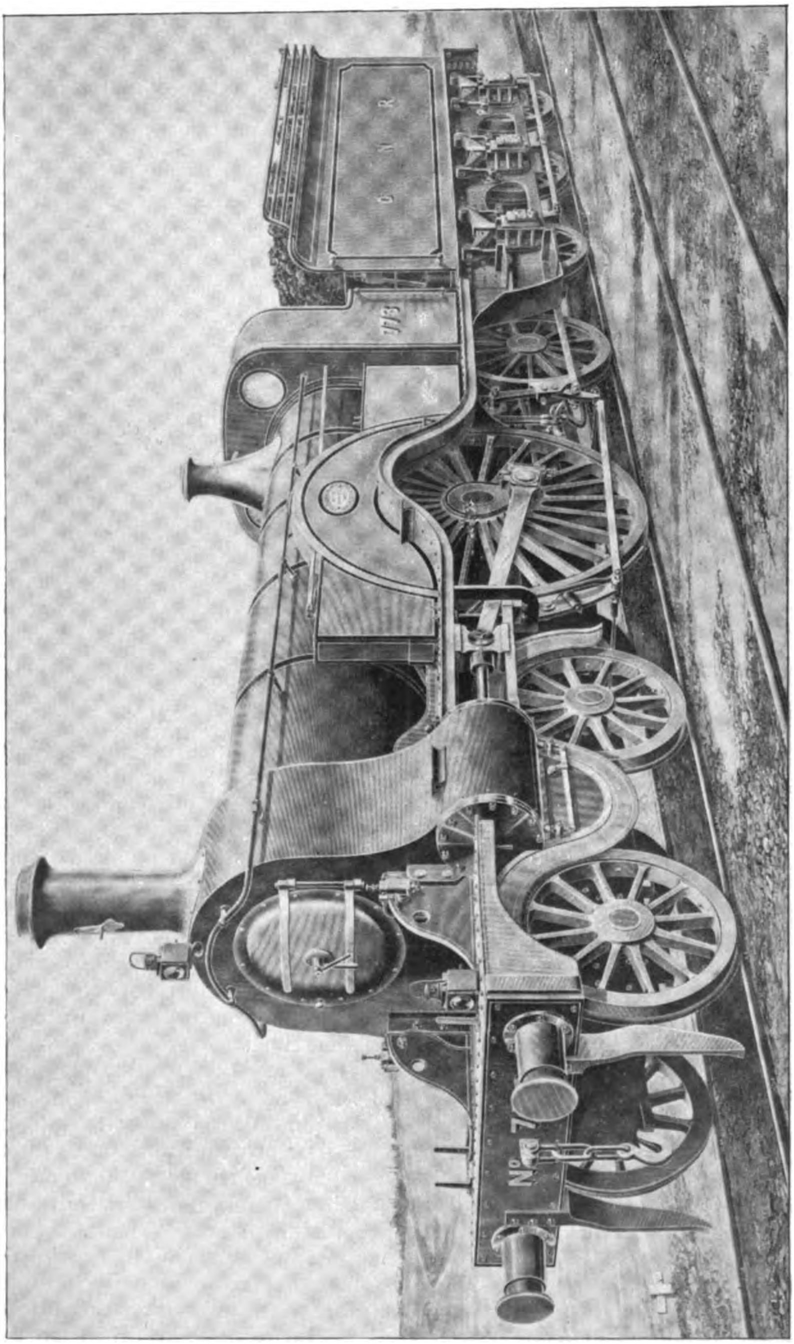
At Niagara, single units of electrical plant are installed, equal to about 5000 horse-power output. These units are destined to be utilised for any of the purposes previously suggested, and it is computed that one horse-power can be obtained from the falls, and sold for the entire year day and night continuously, for the sum of £3 2s. 6d. per annum.

The use of compressed air and compressed gas for tractive purposes is at present in an experimental stage in England. The latter is claimed to be the cheapest for tramway purposes. Combination steam and electric locomotives, gasoline, compressed air, and hot water motors are all being tried in the United States, but definite results are not yet published.

The first electric locomotive practically applied to hauling heavy trains was put into service on the Baltimore



THE EMPIRE STATE EXPRESS, RUNNING BETWEEN NEW YORK AND BUFFALO—THE FASTEST TRAIN IN THE WORLD.



BY PERMISSION OF THE ENGINEER, LONDON.

LOCOMOTIVE USED ON GREAT NORTHERN RAILWAY EXPRESS BETWEEN LONDON AND GRANTHAM. WHEEL DIAMETER, 8 FT. 1 IN. DESIGNED BY P. STIRLING, DONCASTER. 105¼ MILES IN ONE HOUR AND FIFTY-FIVE MINUTES. FASTEST REGULAR SHORT DISTANCE TRAIN IN THE WORLD.

A VIADUCT ON THE RIGI ROAD IN SWITZERLAND.

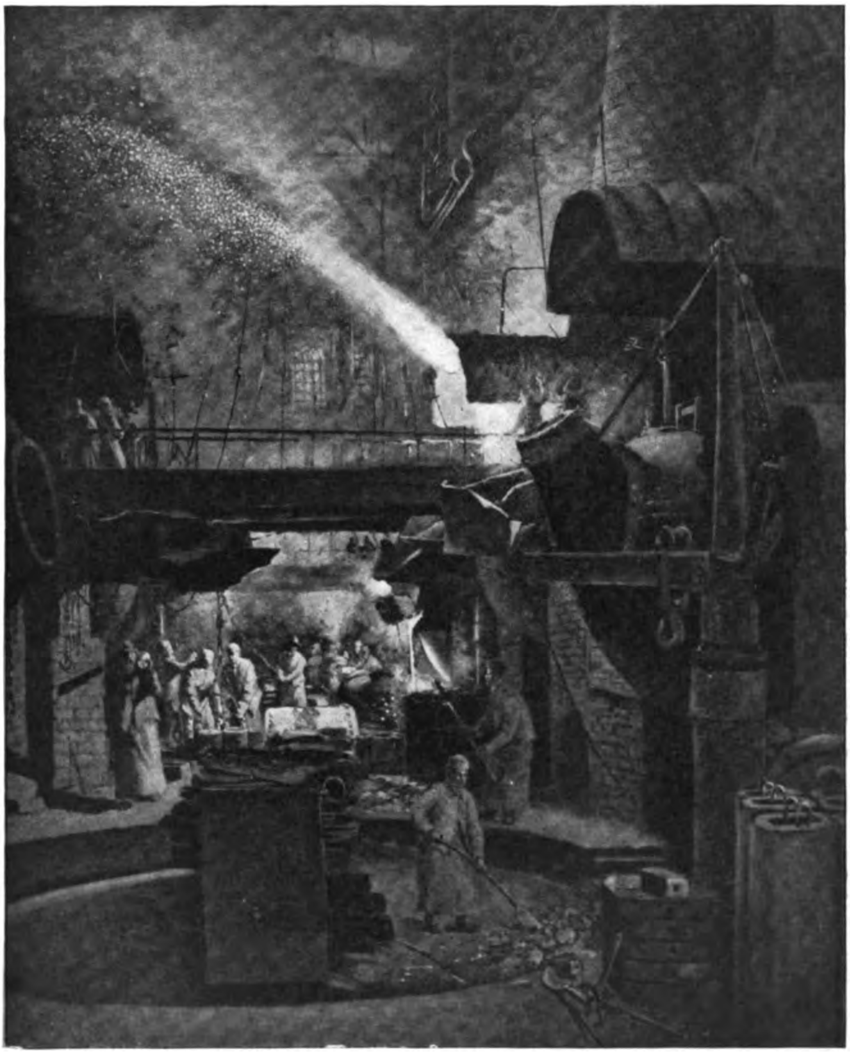
and Ohio railway in 1895 to conduct the traffic through the Belt Line tunnel at Baltimore. It is stated that, not only was the guaranteed speed of thirty miles per hour attained, but, with the locomotive running light, it reached double that speed.

On the gradient of 8 per cent. a composite train of forty-four cars, loaded with coal and lumber, and three ordinary locomotives—weighing altogether over 1800 tons—was started easily and gradually to a speed of twelve miles an hour without slipping a wheel. The voltage was 625. The current recorded was, at starting, about 2200 ampères, and, when the train was up to speed, it settled down to about 1800 ampères. The drawbar pull was about 63,000 pounds. The actual working expense of this locomotive is stated to be about the same as for an ordinary goods locomotive—viz., twenty-three cents per engine mile.

The rapid extension of tunnel construction for railway purposes, both in towns and elsewhere, is one of the remarkable features of the period under review, and has been greatly assisted by the use of shields, with and without compressed air. This brings into considerable importance the question of mechanical ventilation. Amongst English tunnels, ventilation by fan has been applied to those under the Severn and the Mersey. The machinery for the latter is, probably, the most complete and most scientific application up to the present time.

There are five ventilating fans, two of which are 40 feet in diameter, and 12 feet wide on the blades; two of 30 feet, and 10 feet wide; and one quick running fan of 16 feet in diameter, all of which were ably installed by Messrs. Walker Bros., of Wigan. They are arranged, when in full work, to discharge 800,000 cubic feet of air per minute, and to empty the tunnel between Woodside and St. James' street in eight minutes; but, unfortunately, it is found necessary, for financial reasons, not to work the machinery to its full capacity.

The intended extension of electrical underground railways will render it necessary for those still employing steam by belts or ropes instead of direct from the engine. The duties now usually required for mining purposes are about 300,000 cubic feet of air per minute with a water gauge of about 4 inches; but

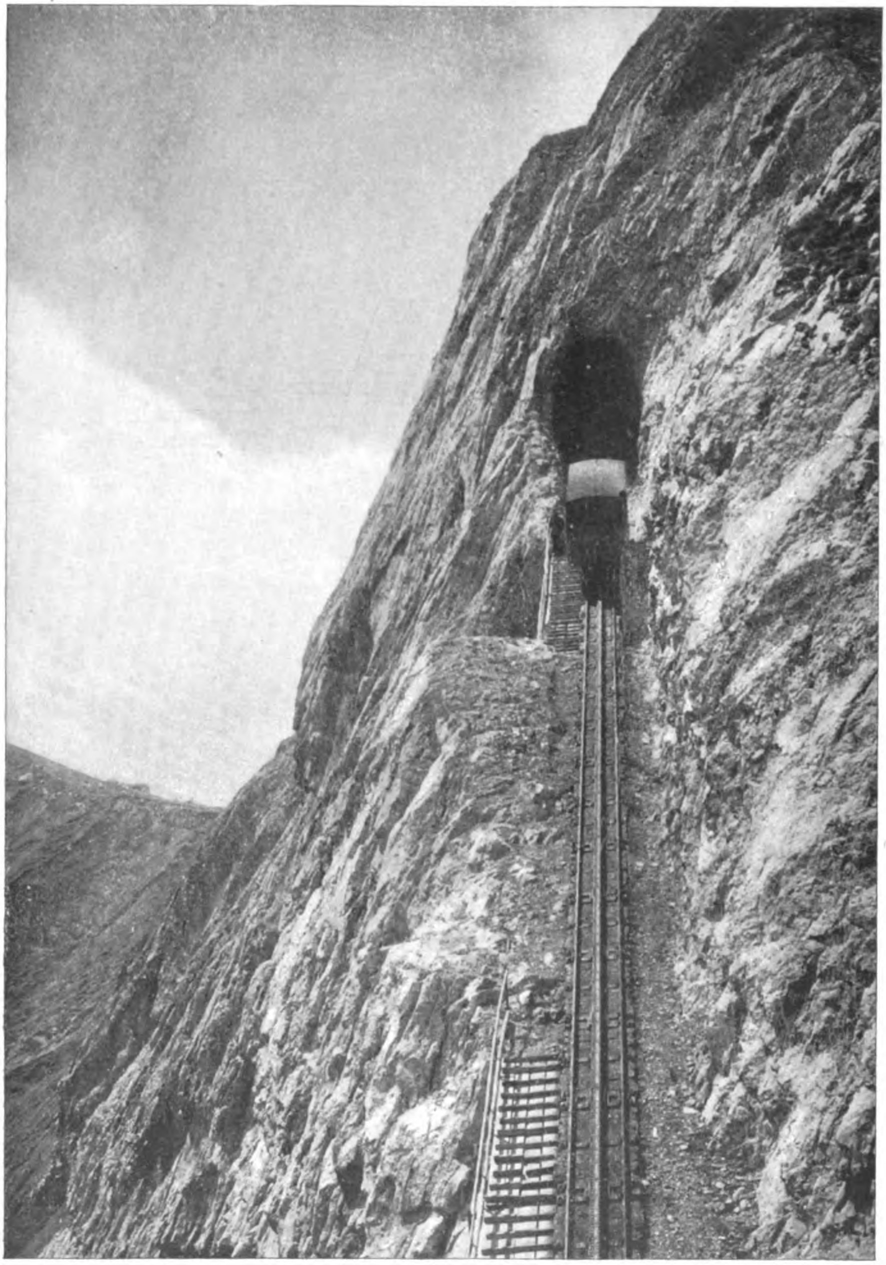


BY PERMISSION OF AUGUST BAGEL, DUSSELDORF, GERMANY

BESSEMER CONVERTERS IN THE KRUPP WORKS AT ESSEN, GERMANY.

traction either to ventilate by machinery or to substitute electro-motive force. Great improvements have been lately made in the details of mechanical ventilators, especially by the introduction of anti-vibration shutters, and the driving one installation is in hand for 500,000 cubic feet of air per minute, with a water gauge of 6 inches. Water gauge up to 10 inches can now be obtained with fans of 15 feet diameter only.

An interesting installation has been



NEAR THE SUMMIT OF MT. PILATUS, SWITZERLAND.

made at the Pracchia tunnel on the Florence and Bologna railway. The length of the tunnel is 1900 metres, or about 2060 yards. It is for a single line, and is on a gradient of 1 in 40. When the wind was blowing in at the lower end, the steam and smoke of an ascending train travelled concurrently with the train, thus producing a state of affairs almost unimaginable except to those engaged in working the traffic.

Owing to the height of the Apennines above the tunnel, ventilating shafts are impracticable; but it occurred to Signor Saccardo that, by blowing air by means of a fan into the mouth of the tunnel, through the annular space which exists between the inside of the tunnel arch and the outside of the traffic gauge, a sufficient current might be produced to greatly ameliorate the state of things. The results have been most satsfactory, the tunnel, which was formerly almost dangerous, under certain conditions of weather, being now kept cool and fresh, with but a small expenditure of power.

In an age when, fortunately, more attention is paid than formerly to the well-being of the men, the precautions necessary to be observed in driving long tunnels, and especially in the use of compressed air, are receiving the consideration of engineers. In the case of the intended Simplon tunnel, which will pierce the Alps at a point requiring a length of no less than twelve and one-half miles, a foreign commission of engineers was entrusted by the Federal Government of Switzerland with an investigation of this amongst other questions.

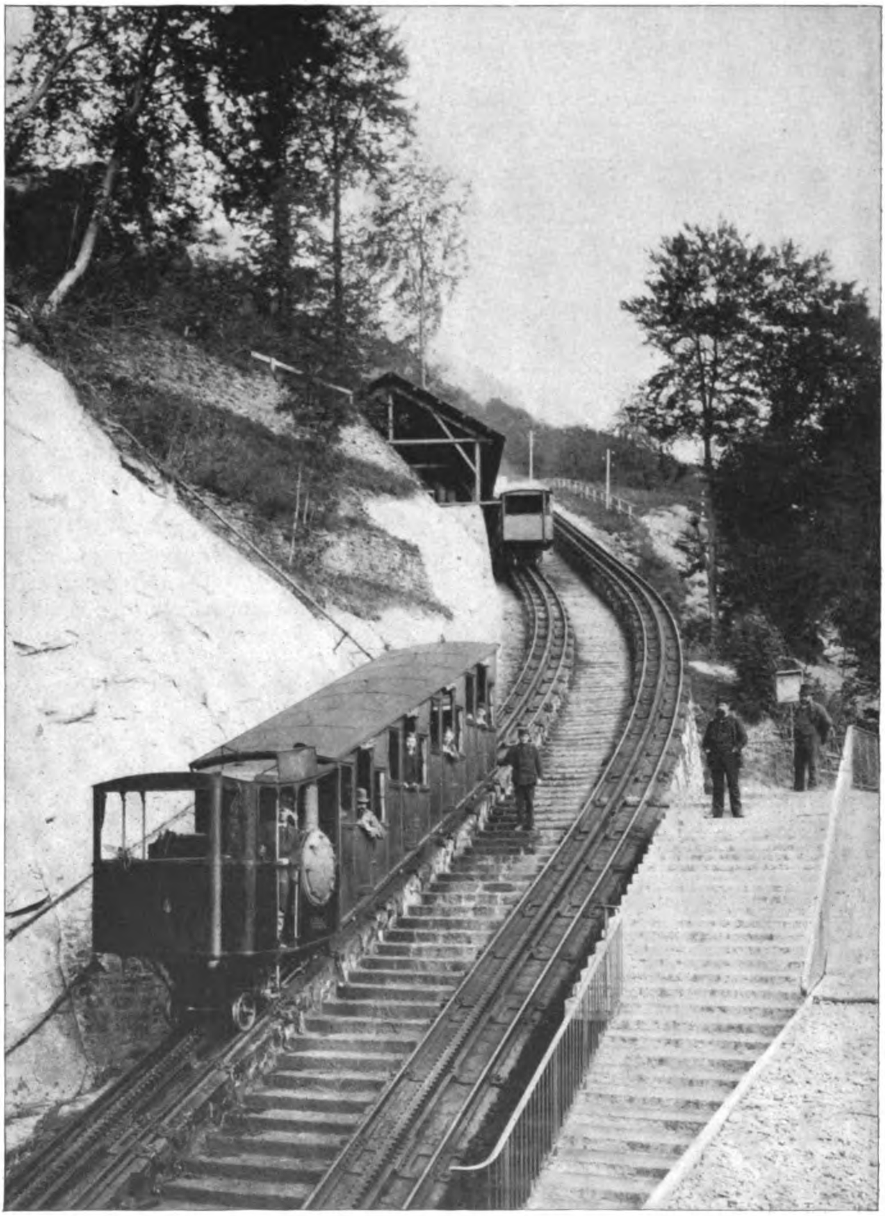
During the construction of the St. Gothard tunnel, which is about ten miles in length, the difficulties encountered were, of necessity, very great. The question of ventilation was not fully understood, nor was sanitary science sufficiently advanced to induce those engaged in the work to give it much attention. The results were lamentable, upwards of 600 men having lost their lives, chiefly from an insidious internal malady not then understood. But the great financial success of this international tunnel has been so marked, as to justify the proposed construction of a still longer tunnel under the Simplon.

The arrangements which are to be adopted for securing the health of the employees are admirable, and will surely not only result in reducing the death rate to a minimum, but also tend to shorten the time necessary for the execution of the undertaking to one-half.

The quantity of air to be forced into the workings will be twenty times greater than in previous works. Special arrangements are devised for reducing the temperature of the air by many degrees; suitable houses are to be provided for the men, with excellent arrangements for enabling them to change their mining clothes, wet with the water of the tunnel, before coming in contact with the Alpine cold; every man will have a bath on leaving; his wet clothes will be taken care of by a custodian, and dried ready for his return to work; suitable meals of wholesome food will be provided, and he will be compelled to rest for half an hour on emerging from the tunnel, in pleasant rooms furnished with books and papers. This may appear to some as excessive care; but kind and humane treatment of men results, not only in benefit to them, but also in substantial gain to those employing them.

The great improvements in subaqueous tunnelling can be clearly recognised from the fact that the Thames tunnel cost £1150 per lineal yard, whilst the Blackwall tunnel, consisting of iron lined with concrete, and of 25 feet internal diameter, has, by means of Greathead's shield and grouting machine, been driven from shaft to shaft, a distance of 754 yards, for £375 per yard.

Tunnels have been successfully constructed through the most difficult strata, such as waterbearing silt, sand, and gravel, and, by the use of grouting under pressure, subsidence can be almost entirely avoided, thus rendering the piercing of the sub-strata of towns, underneath property without damaging it, a simple operation, and opening up to practical consideration many most important lines of communication hitherto considered out of the question.



A STATION ON THE MT. PILATUS RACK ROAD.

On the other hand, very little improvement has taken place in the mode of constructing tunnels in ordinary ground, since the early days of railways. The engineers and contractors of those days adopted systems of timbering and construction which have not been surpassed. The modern engineer is, however, greatly assisted by the possibility of using bricks of great strength to resist pressure, combined with quick setting Portland cement, by the great improvements which have taken place in pumping machinery, and by the use of the electric light during construction.

A question which is forcing itself upon the somewhat unwilling attention of great railway companies, in consequence of the continual increase of the population of cities, is the pressing necessity for a substantial increase in the size of the terminal stations in the great centres of population. Many large terminal stations are not of sufficient capacity to be worked properly, either with regard to the welfare of the staff, or to the convenience of the travelling public.

The discussion, both in and out of Parliament, of the proposals for light railways has developed a considerable amount of interest in the question. Experience only can prove whether they will fulfill the popular expectations. If the intended branch lines are to be of the standard gauge, with such gradients and curves as will render them suitable for the ordinary rolling stock, they will, in many cases, not be constructed at such low mileage costs as to be likely to be remunerative at rates that would attract agricultural traffic.

The public roads of Great Britain (very different from the wide and level military roads of Northern Italy and other parts of the Continent) do not usually present facilities for their utilisation, and, once admitted the necessity for expropriating private property, the time-honoured questions of frontage, severances and interference with amenities will force their way to the front, fencing will be necessary, and, even if level crossings be allowed at public roads, special precautions will have to be taken. Much must then depend upon the regulations insisted upon by the Board of Trade. If, in consideration of a reduction in speed, relaxation of existing safeguards are permitted, much may, no doubt, be effected by way of feeders to existing main lines.

If, on the other hand, the branches are of narrower gauge, separate equipment will be necessary, and transhipment at junctions will involve both expense and delay. It is very doubtful whether the British farmer would benefit much from short railways of other than standard gauge. He must keep horses for other purposes, and he will probably still prefer to utilise them for carting his produce to the nearest railway station of the main line, or to the market town.

It would seem quite probable, that motor cars may offer one practical solution of the problem how best to place the farms of the country in commercial touch with the trunk railways, seaports, and market towns. They could use existing roads, could run to the farmyard or field, and receive or deliver produce at first hand.

Such means of locomotion were frequently proposed towards the end of the last century, and in the early part of the present one, and it was not until the year 1840, that the victory of the railway over steam upon common roads was assured, the tractive force required being then shown to be relatively as 1 to 7.

The passing of the act of 1896, superseding those of 1861 and 1865, will undoubtedly mark the commencement of a new era in mechanical road traction. The cars, at present constructed chiefly by German and French engineers, are certainly of crude design, and leave much to be desired. They are ugly in appearance, noisy, difficult to steer, and vibrate very much with the revolutions of their engines, rising as they do to 400 per minute; those driven by oil give out offensive odours, and cannot be readily started, so that the engine runs on during short stops. There would seem to be arising here an even more important opening for the skill of mechanical engineers than in the case of bicycles, in which wonderful industry the early steps appear also to have been foreign.

It is claimed for a motor car that it costs no more than carriage, horse, and harness, that the repairs are about the same, and that, whilst a horse, travelling twenty miles per day, represents for fodder a cost of 2d per mile, a motor car of two and one-half horse-power will run the same distance at ½d. per mile. The highway authorities should certainly welcome the new comer, for it is estimated that two-thirds of the present wear and tear of roads is caused by horses, and one-third only by wheels.

Perhaps no invention has had so widespreading an influence on the construction of railways as the adoption of the Bessemer process for the manufacture of steel rails. This has substituted a homogeneous crystalline structure, of great strength and uniformity, for the iron rails of former years, built up by bundles of bars, and therefore liable to lamination and defective welds. The price has been reduced from the £13 per ton, which iron rails once reached, to £3 15s. as a minimum for steel. There are, however, not infrequently occurring, in the experience of railway companies, the cracking, and even fracture of steel rails, and the British Government has lately appointed a Board of Trade committee for the investigation, incidentally of this subject, but specially of the important question of the effect of fatigue upon the crystallisation, structure, and strength, of the rail. Experience proves, at any rate, that it is of great importance to remove an ample length of crop end, as fractures more frequently take place near the ends, aided by the weakening caused by bolt holes. Frequent examination by tapping, as in the case of tyres, seems, at present, the most effective safeguard.

The average and maximum speeds now attained by express trains would appear to have reached the limit of safety, at any rate under the existing conditions of junctions, cross-over roads, and other interferences with the continuity of the rail. If higher speeds are to be sought, it would seem to be necessary to have isolated trunk lines, specially arranged in all their details, free from sharp curve and severe gradient, and probably worked electrically, although a speed of 100 miles per hour is claimed to have been reached by a steam locomotive in the United States.

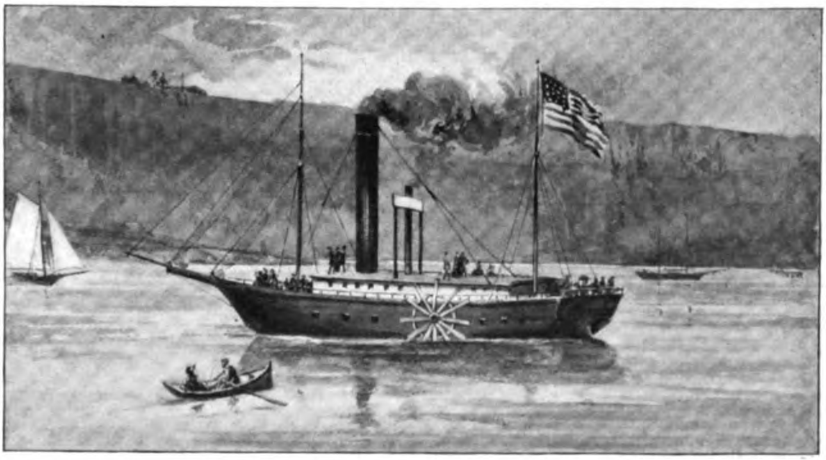
The period of twenty-five years under review has indeed witnessed great advances, both in scientific knowledge and practical application. It is impossible to forecast in what direction the great advances since 1871 will be equalled and exceeded in the coming quarter of a century. Progress there will and must be, probably in increased ratio. The mechanical engineer may fairly hope for still greater results in the perfection of machinery, the reduction of friction, the economical use of fuel, the substitution of oil for coal as fuel in many cases, and the mechanical treatment of many processes still dependent upon the human hand.

The electrical engineer may surely look forward to a wonderful expansion in the use of that mysterious force, which he has already learned so wonderfully to control, especially in the direction of traction.

The civil engineer has still great channels to bridge or tunnel, vast communities to supply with water and illuminating power, and (most probably with the assistance of the electrician) far higher speeds of locomotion to attain. He has before him vast and ever-increasing problems for the sanitary benefit of the world, and it will be for him to deal from time to time with the amazing internal traffic of great cities. China lies before him, Japan welcomes all advance, and Africa is great with opportunities for the coming engineers.

SOME EARLY AMERICAN STEAM CRAFT.

By Professor F. R. Hutton.



THE "CLERMONT," BUILT BY ROBERT FULTON IN 1807.

THE American Society of Mechanical Engineers a little more than a year ago became the possessor of some very interesting historical material. At the annual meeting of 1895, by the interested kindness of Miss Louisa Lee Schuyler, of New York City, there passed into the possession of the Society an original drawing, which had been in the possession of her father, Mr. George L. Schuyler, representing the plans of the steamboat *Robert Fulton*.

The paper is yellow with age and still retains the stains of its original use in the drawing room and shop, but is particularly interesting by reason of bearing the autograph signature of Robert Fulton himself, and the date March 1, 1813.

It will be remembered that James Rumsey, in 1774, and John Fitch, in 1785, in the United States, and Patrick Miller and William Smyington, in 1787, and Henry Bell, in the beginning of the present century, in England, are historical names connected with early pioneering in the development of steam navigation. Yet it is the *Clermont* of Fulton which first passed the line between antecedent experiment and assured success, making so long a trip as between New York and Albany, so unmistakably with certainty and reliability that the vessel was regularly advertised thereafter for the passenger service between New York and Albany. Fare, seven dollars (£1 8 sh.), including five or six meals; time, thirty-six hours.

The launching of the *Clermont* was in 1807. In 1808 she was enlarged, and two new steamboats, the *Raritan* and the *Car of Neptune*, were built between 1808 and 1811. The *Paragon*

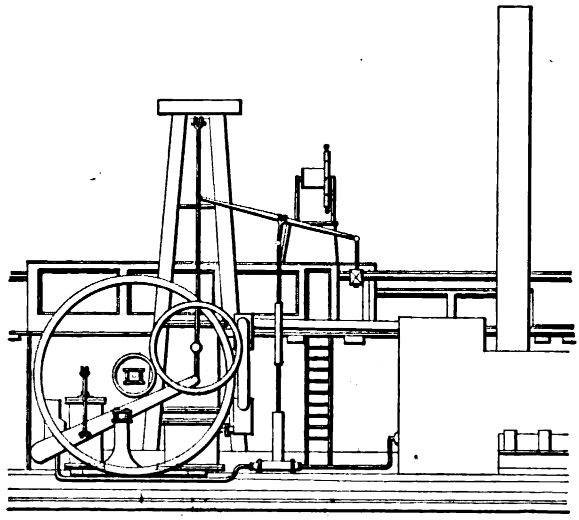


FIG. 1. THE ENGINE OF THE "ROBERT FULTON."

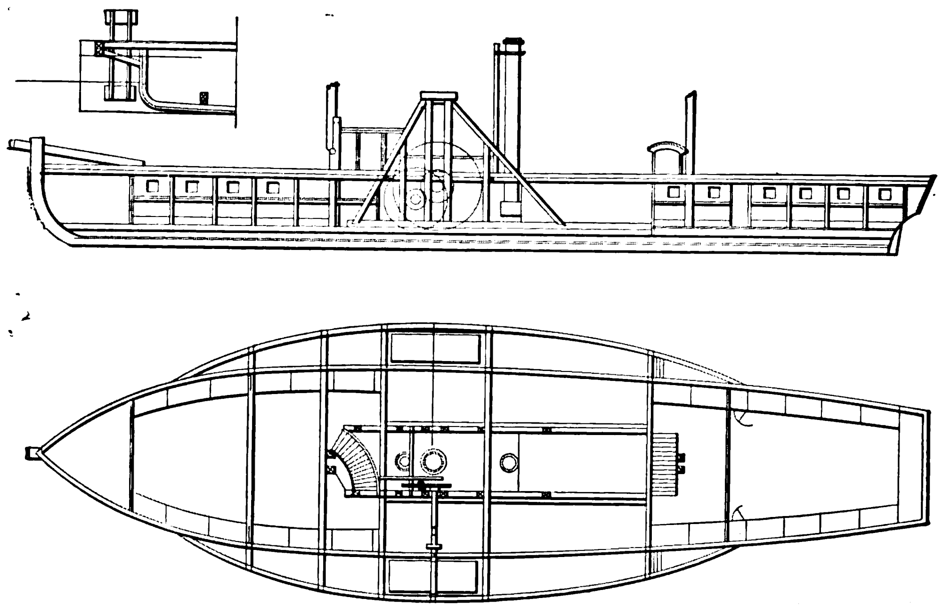


FIG. 2. ELEVATION AND PLAN OF THE "ROBERT FULTON," 1813. ENGRAVED AFTER THE ORIGINAL SHOP DRAWING.

of 1811, a group of steam ferry boats in 1812 and 1813 to connect New York city with Jersey City and Brooklyn, respectively (*Nassau* was the name of one of these), seem to be the structures which intervene between the first *Clermont* and this boat of 1813 which was called the *Robert Fulton*.

In pencil upon the drawing are these memoranda :—"The Sound steamboat called the *Fulton*, navigating the sound between Long Island and Manhattan Island, passing the dangerous strait called Hellgate, in which she was often exposed to the current, running among rocks on every hand, at the rate of six miles an hour." She cost $87,000 (£17,400). Her boiler, of copper, cost more than $30,000 (£6000). The boat was of 327 tons, Custom House measure. The New York *Evening Post*, of June 14, 1814, contained the first announcement of her sailings, and states that until the cessation of hostilities (war of 1812) she was to be employed between New York and Albany, instead of for the intended purpose of running between New York and New Haven.

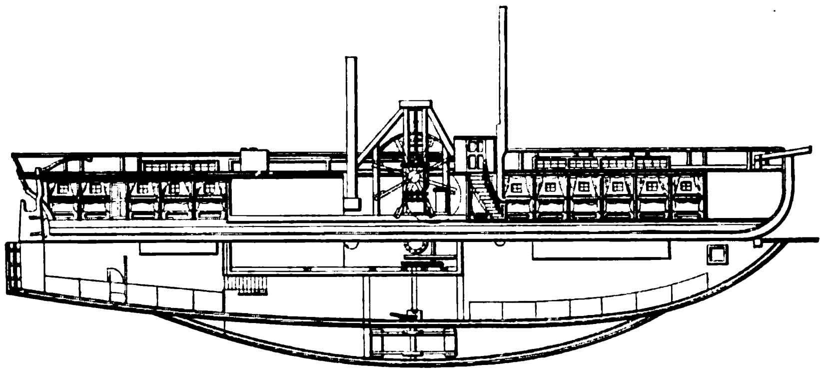


FIG. 3. MARESTIER'S DRAWING OF THE "ROBERT FULTON."

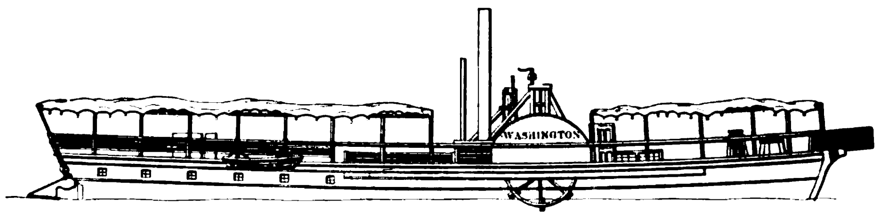


FIG. 4. THE "WASHINGTON." THE FIRST STEAMBOAT ON THE POTOMAC RIVER, 1815.

She carried only 60 persons, and while she was to make the trip to Albany in 13 or 14 hours, she never seemed to do better than 16 to 17 hours. The fare was ten dollars (£2), of which three were to go to Mr. Fulton as his royalty.

The first trip to New Haven was in March, 1815, and occupied from five in the morning to half-past four in the afternoon. Afterward she ran to New London, and later to Providence (June, 1822). She had a fore and aft sail on a foremast—all the early steamboats had sails, which were not abandoned until 1829 for boats of this class—and the mast was rigged with a hinge at its heel, so that in head-winds the whole could be lowered.

The *Clermont* was 133 feet long, 18 feet wide and 9 feet deep ; the *Fulton*, from the drawing, was 134 feet long and 26 feet wide (43 feet over the paddle-wheel guards), with a hull 13 feet deep, planned to draw 4 feet 6 inches of water. The wheels were 14 feet in diameter, over all, the floats being 4 feet 6 inches by 2 feet. The drawing does not make it clear how many of these floats, or buckets, the wheels carried. The *Clermont* appears to have had eight, but some of the early engines were fitted with only four.

The engine of the *Fulton*, as shown in Fig. 1, is by no means completely drawn, and all that is presented is rather an outline for avoiding interference than to give any detailed information. The cylinder, 3 feet in diameter, is located in the vertical plane through the water wheel shafts. Four feet 6 inches in front of it is the vertical axis of the air-pump. The water wheel shaft for each side is separate and terminates in the engine room in a toothed wheel, 5 feet in diameter; into the face of each is inserted a crank pin. This gear drives a 3 feet 3 inch pinion upon a shaft which carries a fly wheel, 9 feet 6 inches in diameter, by means of which shalt it would appear probable

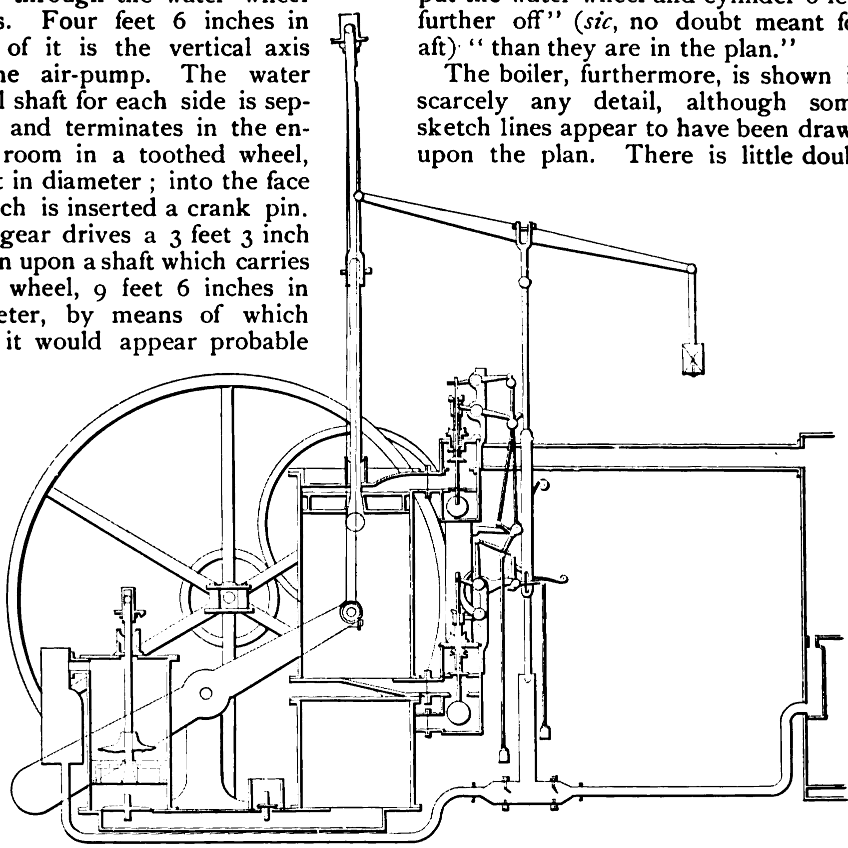


FIG. 5. THE ENGINE OF THE "WASHINGTON."

that the water wheel shaft on the other side was similarly connected by gear to the other fly wheel.

The gear and fly wheel are shown on one side only in detail, the other side being represented by a centre line. The radii of the toothed wheels would indicate that the fly wheel, turning at higher speed than the water wheel shafts, was a scheme to equalise the variable resistance which would be afforded when so small a proportion of the circumference of the water wheel was occupied by the driving buckets.

The gallows frame of the engine was of wood, apparently 12-inch by 9-inch timbers, strongly braced to the keelson by diagonals, 9 inches square. The pencil memorandum says that in building the boat "it was found necessary to put the water wheel and cylinder 6 feet further off" (*sic*, no doubt meant for aft) "than they are in the plan."

The boiler, furthermore, is shown in scarcely any detail, although some sketch lines appear to have been drawn upon the plan. There is little doubt that its construction was a usual one of that period in which a horizontal flue, shaped like a letter U in plan, made the boiler into a return flue design, the fire being at one end of a leg of the U, and the products of combustion passing out at the other. The stack is 3 feet 6 inches in diameter.

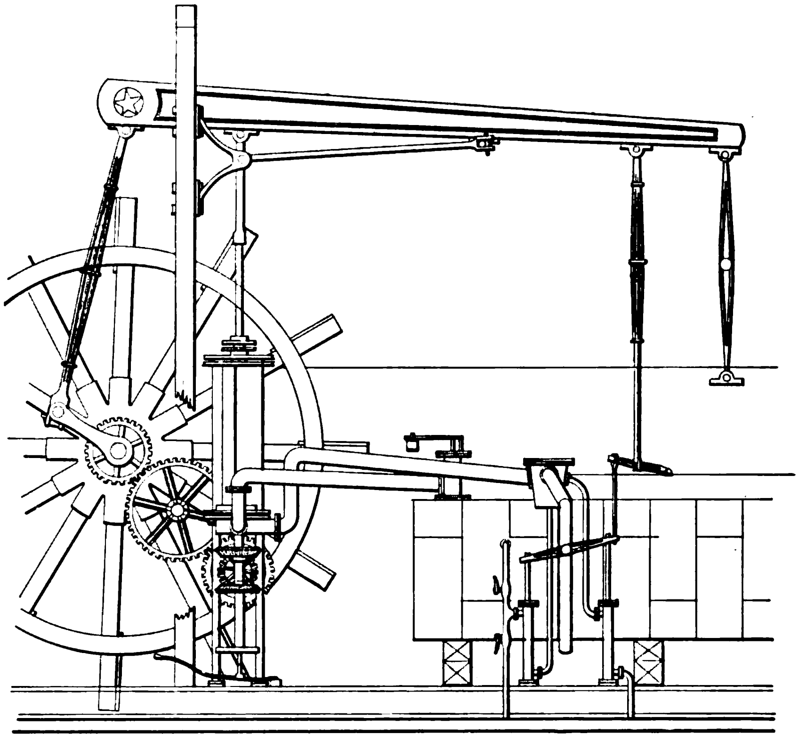


FIG. 6. AN EARLY BEAM ENGINE.

For its other details of construction and arrangement we will be compelled to go to other sources of information, as to what was the practice of the engine builders at that time.

For the student who cares to trace the growth and progress of the early years of American engineers, it is to the highest degree unfortunate that these modest men were filled so completely with the idea of doing something, rather than with that of telling about it, that it is very difficult to get hold of records. The technical newspaper and magazine were unknown in those days. The technical school had not been thought of and achievements of this sort were entirely outside of the scope of the public museums and scientific collections. It is, therefore, to sources outside of America that both at this early date and at a considerably later time, we have to look for any consecutive record of American growth and achievements in those early days.

The longer standing of engineering as a profession in the older countries had made them more quick to perceive what there was of value to progress in these new problems which the new country was presenting, and therefore we have to depend upon either French or British authorities for the information desired. The writer considers himself most fortunate in having been able to obtain, in the autumn of 1894, a series of plates, published in Paris at the Royal Printing Establishment, illustrating a memoir on the steamboats of the United States of America, with an appendix on various machines belonging to marine engineering. This memoir was written by M. Marestier, Engineer of the Royal Navy, and Chévalier of the Legion of Honour.

This atlas contains fifteen plates, 15 by 19 inches, and one large double one, the last presenting a drawing, in great detail, of a hull and engine which might easily be assumed to be a sister ship to the *Fulton* (Fig. 3). The second plate is so exactly a reproduction of the *Fulton* that were it not for the name *Washington* upon the wheel house it might be assumed to have been repro-

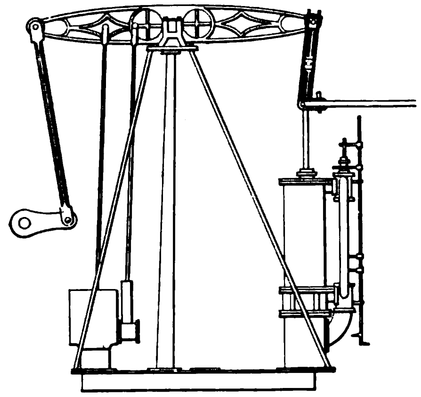


FIG. 7. ENGINE WITH OPEN-WORK BEAM.

duced from the earlier original which has been under consideration. (Fig. 4). The *Washington*, however, was the first boat on the Potomac River, and ran from Washington to Norfolk in

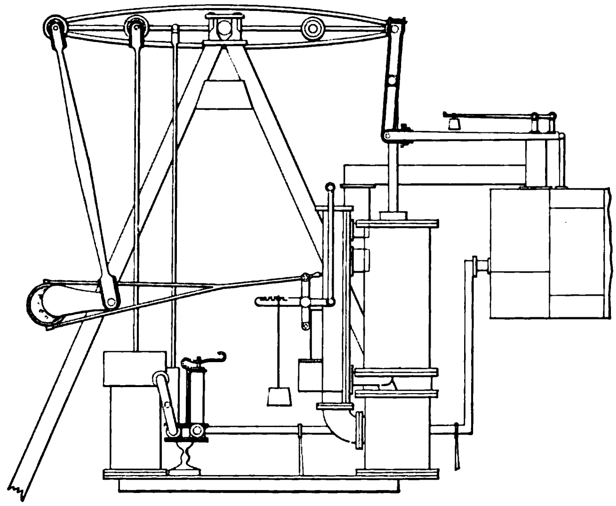


FIG. 8. AN EARLY FORM OF THE CHARACTERISTIC AMERICAN RIVER BOAT ENGINE.

1815. Her first engine-runner was a black slave, who was taught his art by Mr. I. B. Calhoun, who was sent by Mr. Fulton with the boat.

It is apparent from these French drawings that the modern construction which puts the condenser directly at the bottom of the cylinder, had been thought of at this early date. The piston rod passed out of the top of the cylinder to a cross head, guided in the timber framing, from which the two connecting rods came back, as in a back-acting engine, to the crank pins on the large gears. Two rods, depending from the cross head, one on each side of the cylinder, came downwards to the end of a side lever, beyond whose centre was the air pump rod. The boiler feed pump was operated from a second lever, driven also by symmetrical links from the cross head. The boiler seems to have been of the general wagon-top shape which became, afterwards, the standard type of Martin marine boilers.

The valve motion of this type of engine was like that of the Cornish pumping engine with which the engineers of that day had been brought up (Fig. 5), but already the upper and lower valve chest and the side pipes had begun to take shape, the only difference being that the side pipes, instead of resembling columns, as in the American river boat engine of to-day, were real copper pipes entering the valve chests from the side.

The valves were tripped from two rockshafts, the tappet connections being made from the rod driving the boiler feed pump. The air-pump was single-acting and discharged at its top

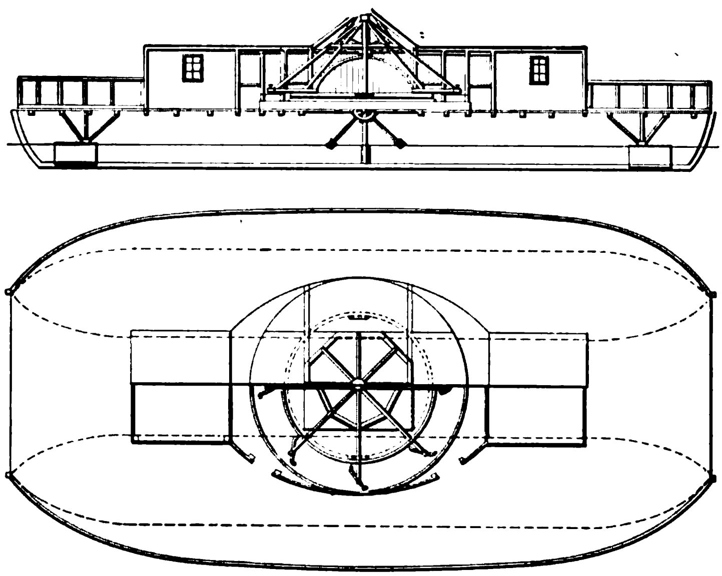


FIG. 9. AN EARLY CATAMARAN HORSE-POWER FERRY BOAT.

into a hot well. The hand lever, pivoted upon the rockshaft, with which all controlling of river boat engines is still done, is present in one of these early engines for the purpose of starting the gear by hand. There is nothing to indicate the method by which there was

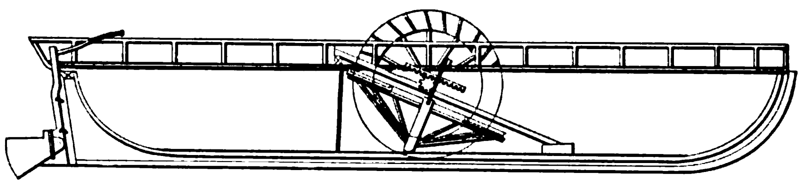
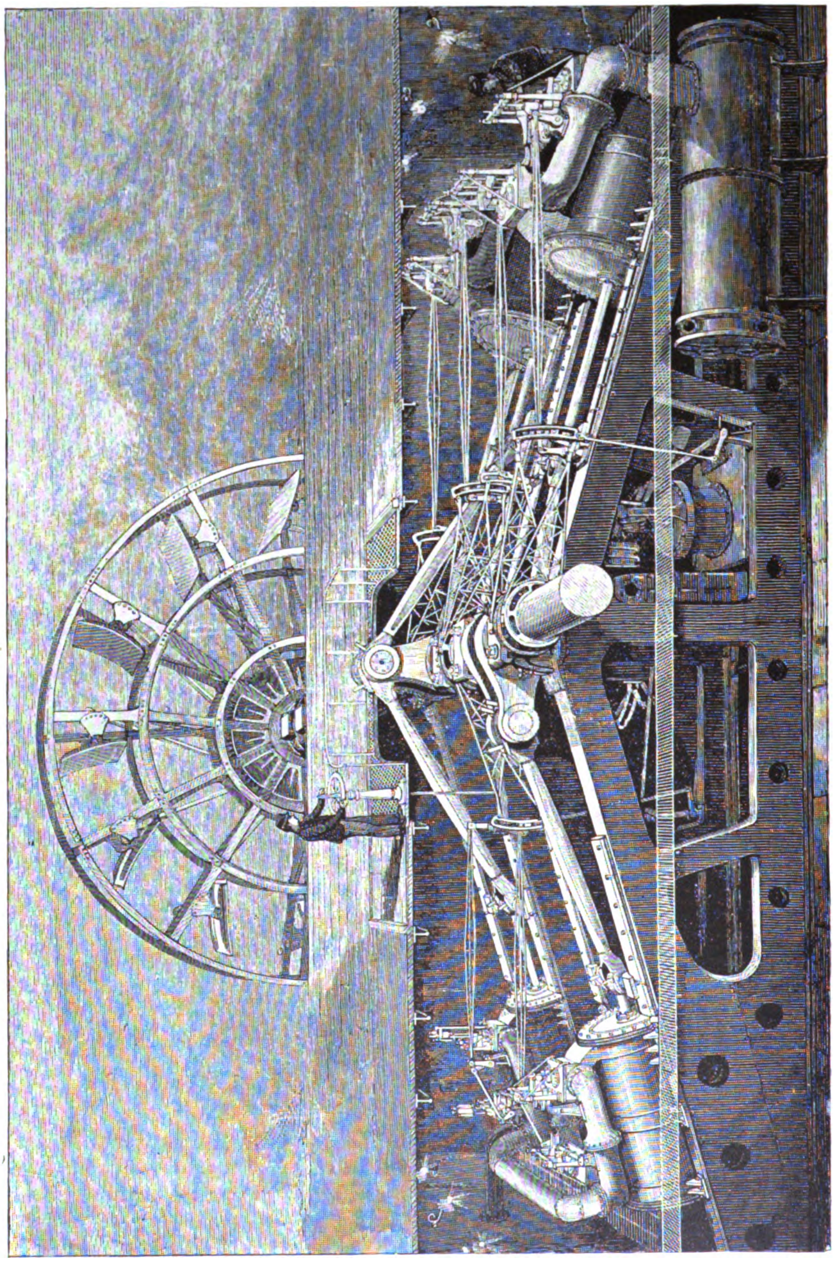


FIG. 10. A HORSE-POWER FERRY BOAT WITH INCLINED HORSE PATH.

any provision for a reversal of the engines.

Side by side with the sketch of the trip motion valve gear is a sketch of a valve rod, lifted by a toe the latter driven by a hanging arm and gab hook after the method to which later use has made all engineers so thoroughly accustomed.

Still previous to 1824 is presented a design of engine with four valve seats in the bottom of the cylinder and a rotating valve, driven by gears from the engine shaft. The piston-rod ascends from the top of the cylinder, but the beam has replaced the gallows frame construction. The floats have been increased from eight to twelve, the connecting rod is an open work braced structure, and the engine will reverse. (Fig. 6.) This is accomplished by having the rotating seat driven from the main shaft by a set of box gears upon its axis, which can be drawn in and out of gear by means of a clutch, and within a year or two is the *A* frame with the beam of open work, lozenge shape, and the construction was inaugurated which we have grown accustomed to consider as characteristic of the American



BY COURTESY OF THE "SCIENTIFIC AMERICAN"

FOUR-CYLINDER, TRIPLE-EXPANSION, DOUBLE INCLINED ENGINE OF THE STEAMER, "PLYMOUTH." 5000 H. P. BUILT BY THE W. & A. FLETCHER CO., HOBOKEN, N. J.

river boat engine. (Figs. 7 and 8)

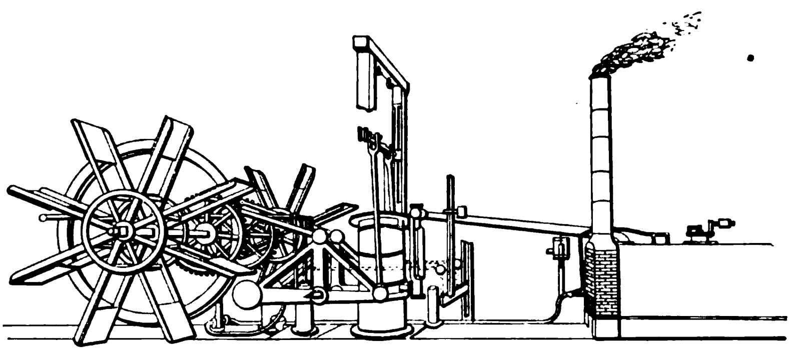
Going back a little to somewhat earlier history, the horse boats, between the cities of New York and Brooklyn may also be cited as early attempts to solve the problem of transport by water. An interesting feature of these early constructions was the use of a water wheel, 12 feet or so in diameter, with twenty-four floats, the latter inclined slightly to the radius, so as to avoid the lifting of the water which is so troublesome a feature of the radial float. These horse boats appear to have been of three general designs. In the first a frame, shaped somewhat like the letter *A*, or an inverted *U*, was mounted to turn around its vertical axis. (Fig 9.) Four of these frames, dividing the circle into eight parts, made a sort of skeleton cone, and this cone was caused to revolve by eight horses moving in a horizontal circular path, about twenty feet in diameter. The face gear, 15 feet in diameter, drove a three-foot pinion mounted upon the axis on the water wheel shaft, and the wheels were within the frame, in an opening between half hulls.

The second plan was of a conical skeleton frame at an incline of about 1 in 2, so that the horses had to travel up this inclined surface, causing it to rotate with their weight and traction.

In the third plan,—a smaller design,—the paddle wheels were brought into a well between the two half hulls of the boat, catamaran fashion, as in the first arrangement, and the frame was mounted above the wheels and its rotating motion was transmitted by intermediate idle wheels to the water wheel shaft. Boats of the first and second class seem to have been about seventy-five feet long.

It is interesting, also, to observe that the swinging bridge for ferry boat service had been already thought out by Fulton, with its counterweight construction and its windlass for making the boats fast. Such boats seem to have drawn a little over two feet of water and to have had perfectly flat bottoms like scows.

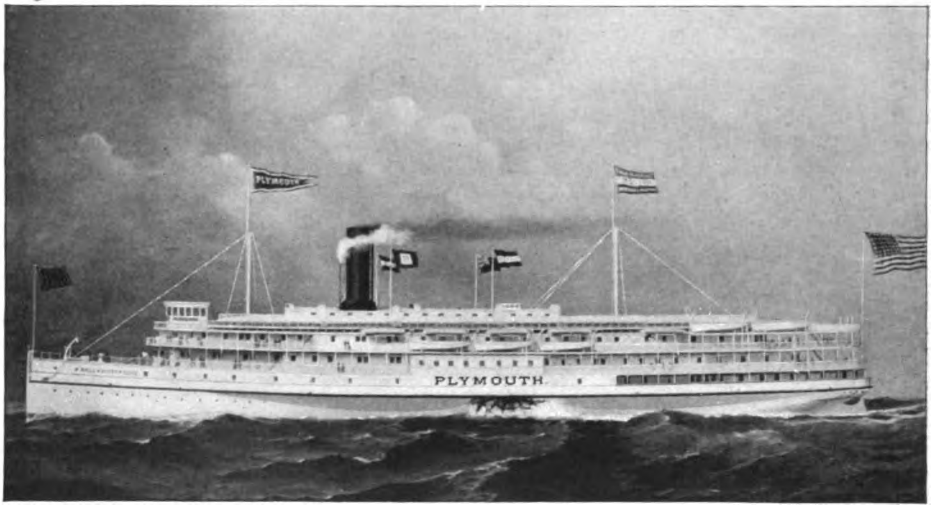
It cannot fail to interest every student of these earlier beginnings of marine engineering to observe the contrast between the flower and fruition of these latter days, and the promise and blossom of that elder day of beginnings. While the warship and the transatlantic greyhound are the most advanced types of naval art, yet the early designers were not harvesting in that field, and, moreover, these achievements belong to a class in which very valuable lessons have been learned from the successes and failures of European countries.



THE MACHINERY IN FULTON'S BOAT "CLERMONT," 1807.

But in the field of river boat and Sound boat engineering, America is unique, both in its conditions and in its solution of its problems, and it is in this field that America began with the *Clermont* and the *Fulton*.

The French transportation engineer has no conditions parallel to those which call for night transport of passengers on the Hudson river or Long Island Sound,



THE "PLYMOUTH," 1890.

nor is there a freight business for him to provide for to anything like the extent which there is upon these same waters and the shallower western American rivers. The British engineer, likewise, has entirely other conditions for coastwise business, as the vessel must be distinctly a sea-going craft, so that development along this line is peculiarly American, and a comparison of the two ends of the series is of special interest. As a means of presenting this to the eye as well as to the mind, four illustrations are reproduced on pages 357, 364, 365 and above. They present the hulls and the engines of the *Clermont*, and of the *Plymouth* of the Fall River Line, between Boston and New York. It is the story of the pigmy and the giant. Some of the further particulars of the pair are:

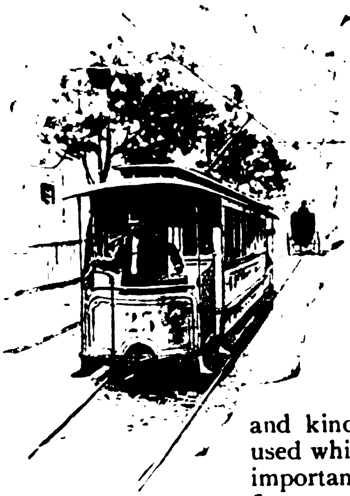
	Clermont	*Plymouth*
Length on water line, feet	133	351.8
Tons measurement	160	3100.
Speed in miles per hour	3	20.
Revolutions per minute of engine	10	24.
Horse power of engine	12	4500.

And there is more growth before us, in that future of which even these of to-day are but the beginnings.

MODERN OVERHEAD TROLLEY ROAD CONSTRUCTION.

By Benjamin Willard.

A partial reprint of a paper recently read before the American Street Railway Association.



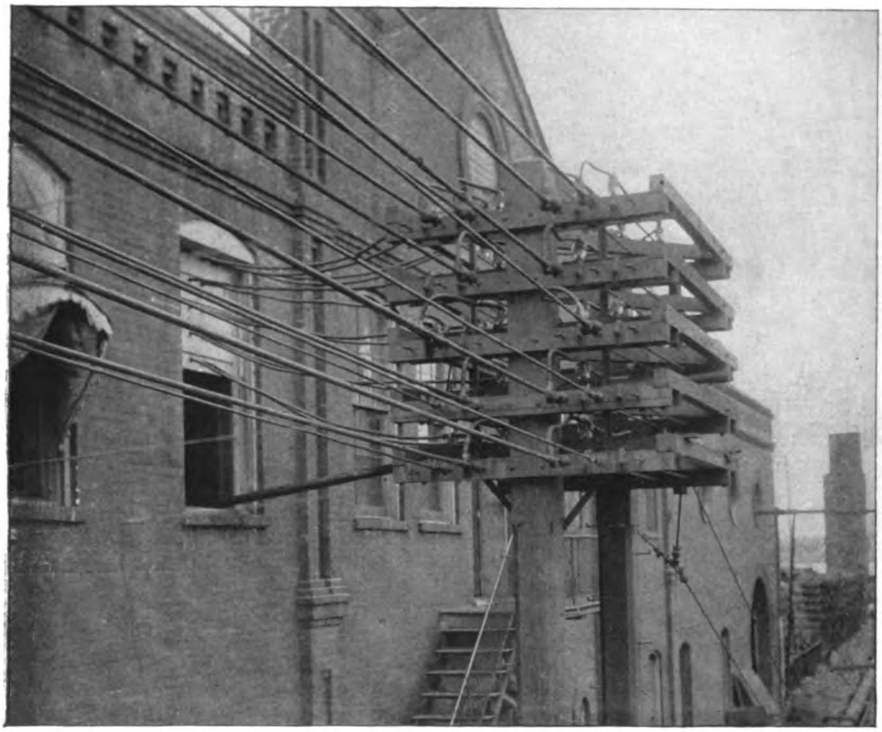
TROLLEY line construction can be erected in various ways and still conform to good practice, one difference being in the kind and cost of poles to be erected. There are various requirements governing the selection and kind of poles to be used which determine an important factor in the first cost. Municipal requirements may compel you to erect steel or wood poles, or you may be allowed to make your own selection.

In the first instance the price is fixed and you have only one thing to do; in the second instance you have opportunities which are left for your own discretion. The steel pole presents a neat and attractive appearance, and also takes up a small amount of space, which are the chief points in its favour. The insulating qualities are not as good as with the wood pole, and although I am not prepared to say positively as to its lasting qualities, I have made some observations of deterioration on wrought iron coulmns that have been in the ground for several years, and estimating that this deterioration would take effect in the same proportion on steel poles, I am convinced that in a moist climate a limit on the practical life of such poles would not be over thirty years. While I am not strictly an advocate of wood poles, I am of the belief that from a practical and financial standpoint, wood poles should be used in many instances.

Through the business sections of cities steel poles are in some respects better, as they are not affected by being willfully or accidentally mutilated. In suburban or residence districts the wood poles, when properly dimensioned, answer every purpose, and appear fully as well as the steel poles. A heart pine or cedar pole will, if properly selected and kept painted, last in some climates twenty years. This is a known fact from observation of poles that are now in sound condition after having been erected for that length of time.

Suppose we select New Orleans as a suitable location to build a road and base our estimates on cost of material there. The cost of steel poles would be greater than in Northern cities, owing to freight rates and distance from the manufacturers of such poles. Wood poles can be furnished for less in New Orleans, owing to their near production, so that I think an estimate covering cost at that point would be a fitting proposition elsewhere.

Steel poles for one mile of span wire construction, 104 poles at $15 each would cost $1560, and assuming their life to be thirty years, the interest on the investment for thirty years at 5 per cent. per annum would be $2340, or a total first cost and interest of $3900. The setting of steel poles necessitates the use of concrete which is an expense to be figured over the cost of wood pole setting; so we must figure at least the cost of such material and labour which would be $4.50 per pole, or $468 per



ANCHOR AND TERMINAL POLES AT A POWER STATION.

mile; figured with interest for thirty years at 5 per cent. per annum, this would be $1170, or a total for interest and first cost of material and labour of $5070, which is to be considered against the cost of one mile of wood pole construction covering the same period.

Assuming the life of wood heart pine poles to be twelve years, instead of twenty years, I will base a comparative proposition on that basis, taking the interest on each investment and carrying it through to the expiration of thirty years. Wood heart pine poles for one mile of span wire construction, 104 poles to the mile, at $4.50 each, would cost $468; also suitable labour and material for erecting at $2.50 per pole, $260, or a total first cost of $728; to this must be added interest for thirty years at 5 per cent. per annum, $1098, making the first investment at the end of thirty years $1820. At the expiration of twelve years the construction must be renewed at a cost of $728, and to this must be added interest for eighteen years at 5 per cent. per annum, $655.20, making the second investment at the end of thirty years cost $1,383.20.

At the expiration of twenty-four years the construction will be renewed for a third time at a cost of $728, and to this will be added the interest for six years at 5 per cent. per annum, $218.40, making the third investment at the end of thirty years cost $946.40,—a grand total for wood pole construction of $4,149.60.

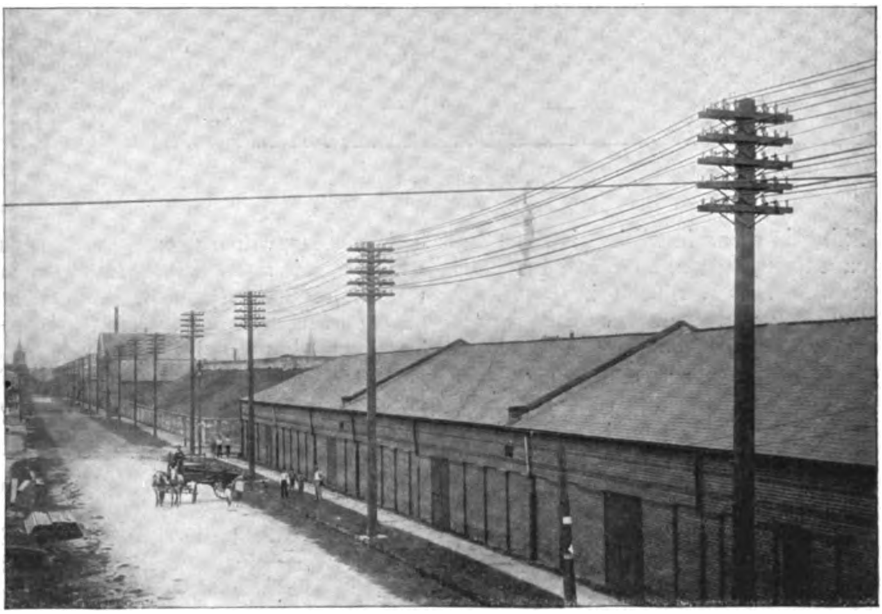
The difference between total costs of steel and wood pole construction for a period of thirty years would be $920.40 per mile, which would be more than a liberal allowance for changing span wires and other work, but assuming that it would take this amount, we would stand even at the end of thirty years and still have six years more paid for on wood pole construction.

If steel span poles are used, I would recommend for the average span of forty feet a pole weighing about 700 pounds, made in two parts, the lower section to be constructed for six-inch extra heavy, and the upper section of five-inch standard steel pipe, swaged at the joint for a distance of eighteen inches; such a pole to be twenty-eight feet long, eighteen feet for the lower and ten feet for the upper section, and provided with a cast iron and wood pole top for the attachment of the span wires.

Such poles should be provided with a wood filling to fit the bottom of the lower half to prevent it from sinking, and should be set six feet in the ground with a rake of ten inches from the perpendicular to allow for being straightened when under strain.

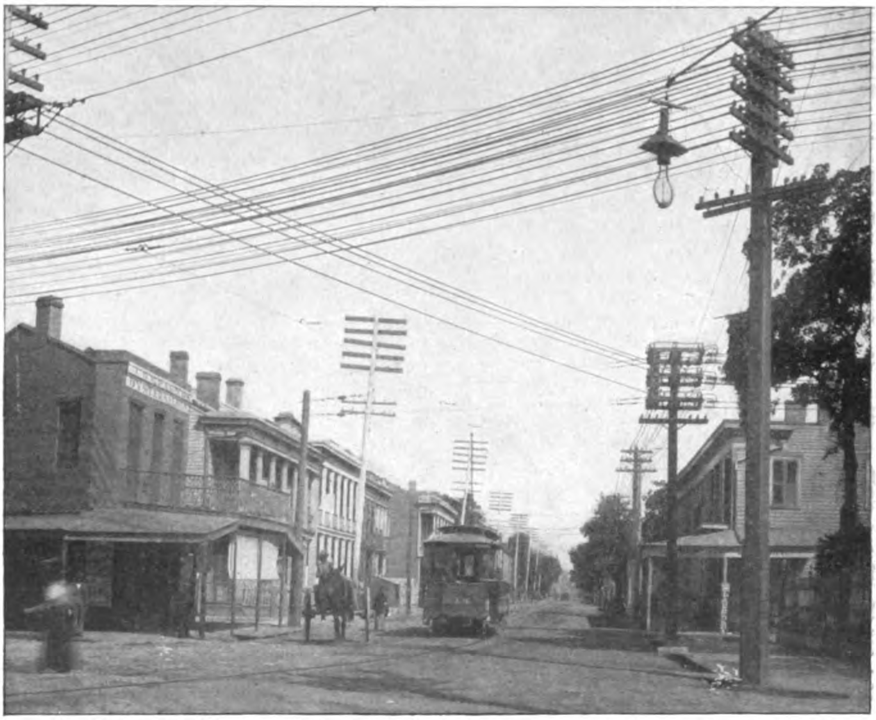
The average size of hole to be dug should be twenty inches in diameter with a depth of a little over six feet, requiring (after the pole is inserted) a mixture of about one-half cubic yard of concrete, composed of one part of Portland cement, two parts of sharp sand, and four parts of broken rock. The cement should be given at least three days in order to set firmly before attaching the span wires. Whenever it is practical to allow poles to bear against the curbing this should be taken advantage of, as it affords an efficient stay to assist the pole in resisting the strain. Should it not be possible to secure use of the curb, or paving, a good-sized rock, having a bearing surface of about one square foot would assist very much, and keep the pressure from cracking the cement.

If wood poles are used where it is necessary to make neat appearing and substantial construction, I would recommend for the average span of forty feet a long leaf, yellow pine pole, dressed and chamfered, thirty feet long, sawed square, 11x11 inches at the base, and 7x7 inches at the point, free from sap, rot or knots, and corners chamfered 1½ inches, beginning at a point fourteen feet from the base, and terminating in an octagonal form and roofed evenly for a space of three inches.



AN EXAMPLE OF A FEED LINE CONSTRUCTION.

In setting wood poles where concrete is not used (and I do not consider it necessary) a great deal depends upon the soil encountered. Whereas it is necessary to use very little prepared material



A DISTRIBUTING CENTER.

for filling in some localities, it will take a quantity in others, so I will mention what would be required in a soil of medium clay and character which would probably meet the average condition. Poles should be set six feet in the ground with a rake of twelve inches from the perpendicular to allow for being straightened when under strain, and the hole should be dug to a vertical depth of six feet (or more if necessary to allow the pole to stand a given height above the track) in the ground and should be about two feet square at the top and not less than eighteen inches at the bottom.

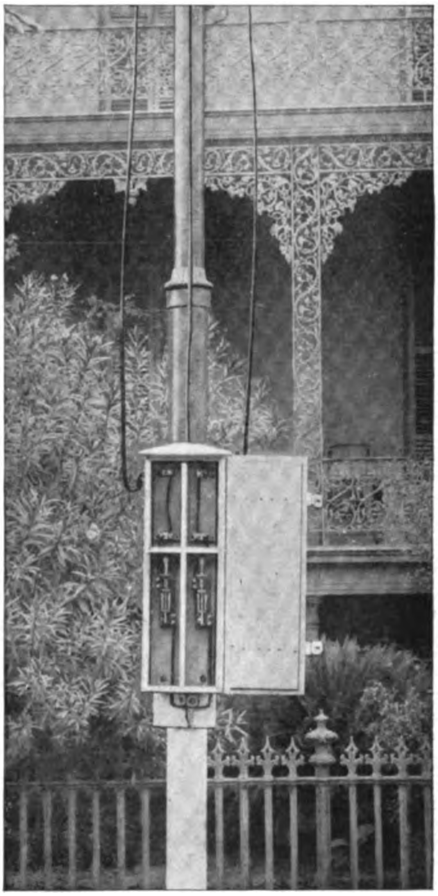
Where it is practical to allow poles to bear against the curbing, or paving, this should be taken advantage of, and it will not be necessary to use other material near the surface as in iron pole construction, but it will be necessary to place a substantial bearing at the heel to prevent the pole from pressing through the earth; for this purpose a small quantity of coarse broken stone, or brickbats, will answer every purpose; where this is not easily obtainable, and the earth is soft, a piece of plank, twelve inches wide by three inches thick, four feet long, sharpened and driven in the earth to a depth of about two feet at the back and base of the pole, will give good results.

Whenever it is necessary to erect poles in the absence of substantial material at the surface, such as paving or curbing, I would recommend that the base of the pole be well rammed with broken rock for a distance of eighteen inches, taking pains that the greater quantity is placed at the back where the pressure is greatest, and leaving a small quantity in front where no pressure takes place. The space to within twenty inches of the top may be filled with earth taken from the hole and well rammed. To prevent the pole from yielding at the surface, a breast plank of oak or cypress timber, 3x12 inches x6 feet, should be placed and spiked in front and at right angles to the pole about eight feet under the surface of the ground, which would make a suitable bearing surface, and resist the span wire strain. About twenty inches from the top and in front of the breast plank, the hole should be filled and well rammed with the same material as is used at the base of the pole. The necessary quantity of broken rock required would be about two-tenths of a cubic yard to the pole.

Poles of wood or steel which may be used for holding strains at curves should necessarily be heavier than those used for straight line construction and should also be set at greater depth in the ground. Steel poles of proper dimensions for curve construction should be made in two joints and constructed on the same principle as the straight line pole, except with heavier dimensions of pipe. A steel pole for curve construction should be twenty-nine feet long, made of six-inch and seven-inch extra heavy pipe, the larger section to be nineteen feet long, and the smaller section to be ten feet long and made to weigh 1050 pounds. Such poles should be set seven feet in the ground, and raked ten inches from the perpendicular in a direction radiating from the central point of the curve to where the strain is required. The filling necessary would be the same as specified for straight line iron pole construction.

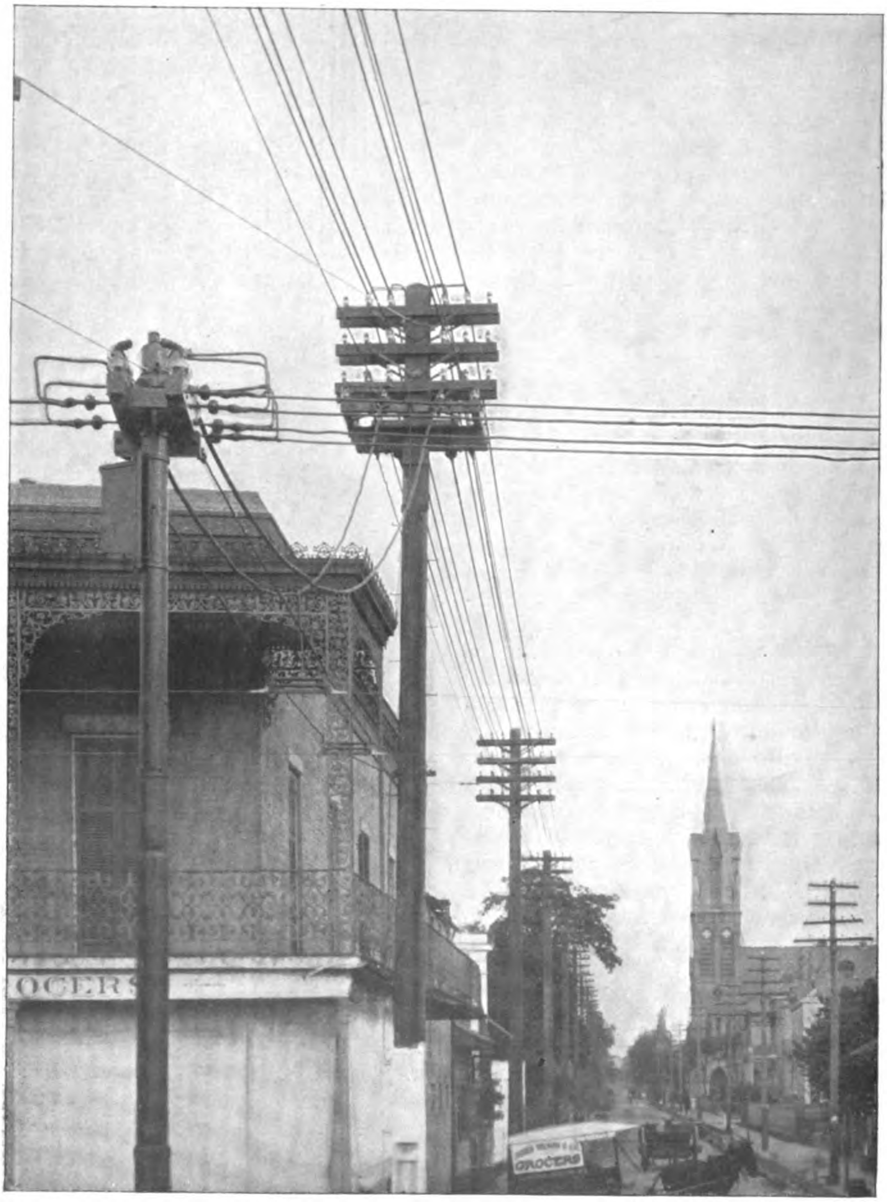
Wood poles for curve construction should be made similar to those specified heretofore for straight line construction, excepting that the dimensions of such poles should be 31 feet long, 14x14 inches at the butt, 9x9 inches at the top, chamfered from a point fourteen feet from the base to the point, terminating in an octagonal form and roofed evenly for a space of three inches. Such poles should be set seven feet in the ground and raked twelve inches from the perpendicular in a direction radiating from the centre of curvature where the strain is required. The hole should then be entirely filled with about seven-tenths of a cubic yard of broken rock and well rammed.

The holes for eyebolts should be bored in wood poles before their erection and should be bored so that the bolt will incline slightly downward towards the eye to prevent water from following in and rotting the top of the pole. The correct location for eyebolt holes would be determined by the height at which the trolley wire is to be placed; twenty-two feet from the base of the pole would be correct, assuming that we allow two feet for drop in the ear body and ear and also



A SWITCH BOX.

dip in the span which would make the height of the trolley wire about twenty feet. To facilitate the setting of poles to a uniform height, it is a good plan to place grade stakes near the location selected for poles indicating a given



A SECTIONAL FEEDING POINT.

height relative to the grade of the track.

Centre pole construction is required in many locations and may be more adaptable than other methods, but I consider span construction better, owing to its flexibility and for being less unsightly. There are now on the market appliances for making bracket suspensions flexible, which are an improvement over the old style of rigid construction. One of the most practical which I am familiar with is an attachment to receive a short span of flexible wire and the ordinary straight line hangers.

Poles used for centre and bracket construction should be made according to the same specifications as those used for span construction, excepting that an ornamental pole top would be required for the steel pole instead of an insulated one. Much can be spent on ornamentations on centre and bracket construction, but it always occurred to me that the most practical is ornamental enough and places the cost where it will do the most good. For the bracket arm a 1½-inch pipe of the required length, attached to a malleable iron collar, made in halves and encircling the pole and supported by truss rods leading from the end and centre of the arm to near the top, makes excellent and neat construction.

Wherever guard wires are required, it will be necessary to leave about two feet additional space on the top of the pole above where the trolley span wires are attached, for the attachment of the guard wire span. It would hardly be practical to provide an insulated pole top to provide for both span wires, so the trolley span would be supported by means of a wrought iron clamp collar encircling the pole at the proper point, and provided with suitable insulating fastenings. I do not especially approve of this method of construction, as I do not favour guard wires, but I would recommend it where it is compulsory to erect guard wires.

All poles should be painted with one coat before their erection, as it affords better opportunities to carefully apply the priming coat and at less expense than after the poles are set. A paint of dark green, composed of graphite mixture, I find to wear well, and although it costs more than some other paints, it has better lasting qualities, especially in iron work. A second coat of this paint after the poles are erected will cover marred places, made necessary in setting, and will look well and last for at least two years.

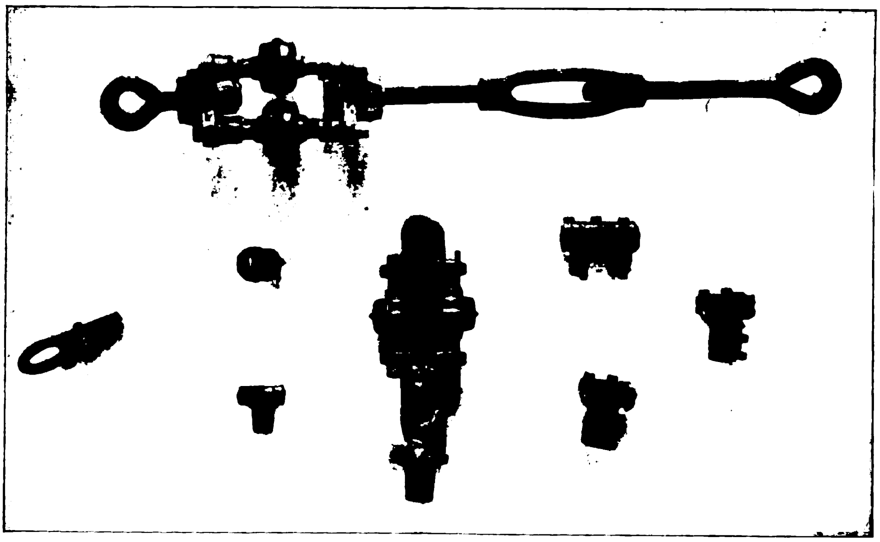
Span wires, necessary for trolley suspension, should be flexible steel, 5-16-inch in diameter, composed of seven strands of No. 12 galvanised wire, and when under strain with conditions of pole setting as I have stated, would have a tension of about 750 pounds when erected. Whereas I have allowed eighteen inches for sag in the span, it probably would not be over twelve inches at the time the wire is first suspended, but will gradually sag more as the wire stretches and the poles spring or yield in the ground, so that if a forty-foot span is attached twenty-two feet above the rail surface, the trolley wire, within the course of a year, would be, approximately, twenty feet above the rail.

Where wood poles are used, or wood pole tops for steel poles, the ordinary ⅝x12-inch eyebolt, threaded about four inches, answers every purpose for the attachment of the span wires, and other devices, more expensive, used for the same purpose are not necessary. Poles, when properly set, will bear a given strain on the span wires for many years without much yielding; consequently an adjustable device is rarely if ever used.

Hard drawn copper trolley wire of No. 0 B. & S. gauge has been found to be the most practical and is generally considered a standard for most trolley construction; therefore, overhead appliances are made, of various manufacture, to meet such requirements. There has been a trolley wire recently manufactured in the form of a figure 8, which is now in use on some roads and has given very good results. Where this wire is used, it leaves a perfectly unobstructed surface for the trolley wheel and gives greater current-carrying capacity, but in modern construction the hanging appliances have reached such a degree of perfection that the round wire can be used with equally good results, and as the trolley wires on large systems are relied upon but little as conductors for current capacity, I can hardly recommend anything that would be more practical than the round wire.

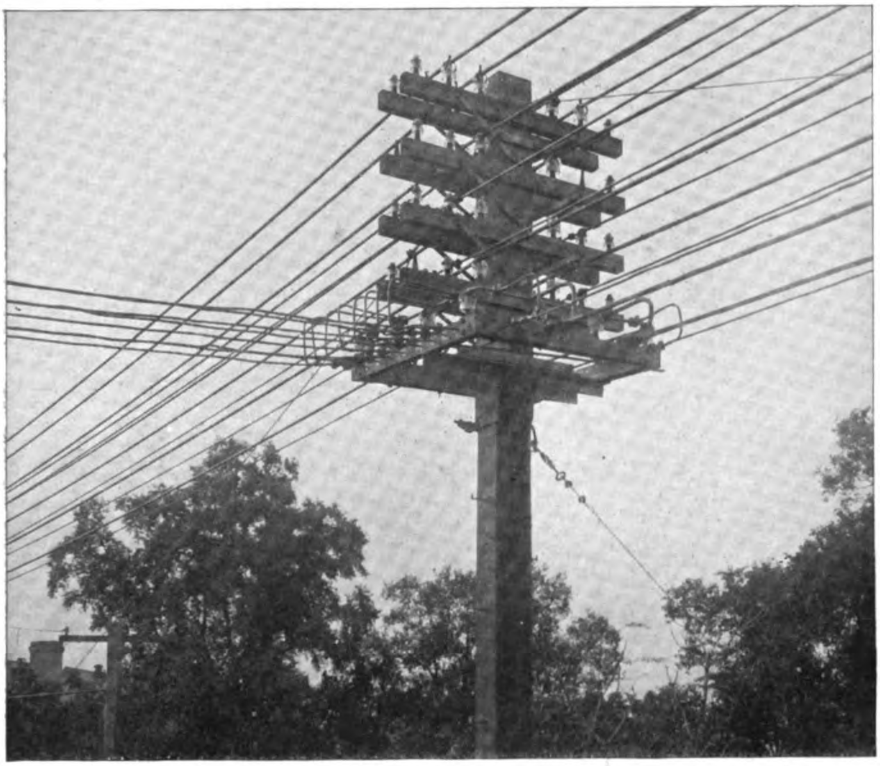
Span wire hangers and insulators are of various forms and compositions, and many possess equal merit. I would recommend, for straight line work, those most indestructible and possessing the best insulating qualities. The best forms of such hangers are those where the insulation is concealed from the weather as much as possible, and having a metallic covering to prevent them from being broken by accidental contact of the trolley pole. Brass hangers are more expensive than iron, but resist the moisture and are maintained at much less expense. Iron hangers should be painted at least once a year, as the oxidition, if allowed to accumulate, will form a conductive contact between the conductors and span wires, and, in course of time, will cause the escape of current by leakage. Hard rubber insulation for hangers is more expensive than many other compositions, but from my experience I must say it has fine insulating qualities, and stands different conditions of climate with little or no deterioration.

Suspension ears are of as many varieties as hangers. I have experienced the use of many such appliances, and have concluded that a little modification of the old brass solder ear is the most practical and lasting of all, if properly attached. A solder ear should be fifteen inches in length, tapped for a ⅝-inch cap bolt and provided with thin lips at either end, so dimensioned as to encircle but little more than half the trolley wire, and one point which should be observed very particularly is to have the ends of the ears ground to a thin tapering end, so that they will become flexible with the vibrations of the wire. If the ends are made heavy or unyielding, the vibrations will have a tendency to detach the ear at the points, and when this takes place it is a question of a short time before the ear is wholly detached.



STRAIN INSULATORS AND CONNECTIONS.

Insulators and hangers for curve construction, like straight line material, are of many designs and permit of wide selection. However primitive may seem my ideas of this particular part of construction, I can give only good results from my experience. I favour what is known as the gooseneck hanger, which is simply a ⅝-inch steel forging, formed of such dimensions as to allow good clearance for the trolley wheel, and fastened to the soldered ear in a manner to permit it to swivel, also provided with an eye for the attachment of pull-over wires. Such devices are strong and do

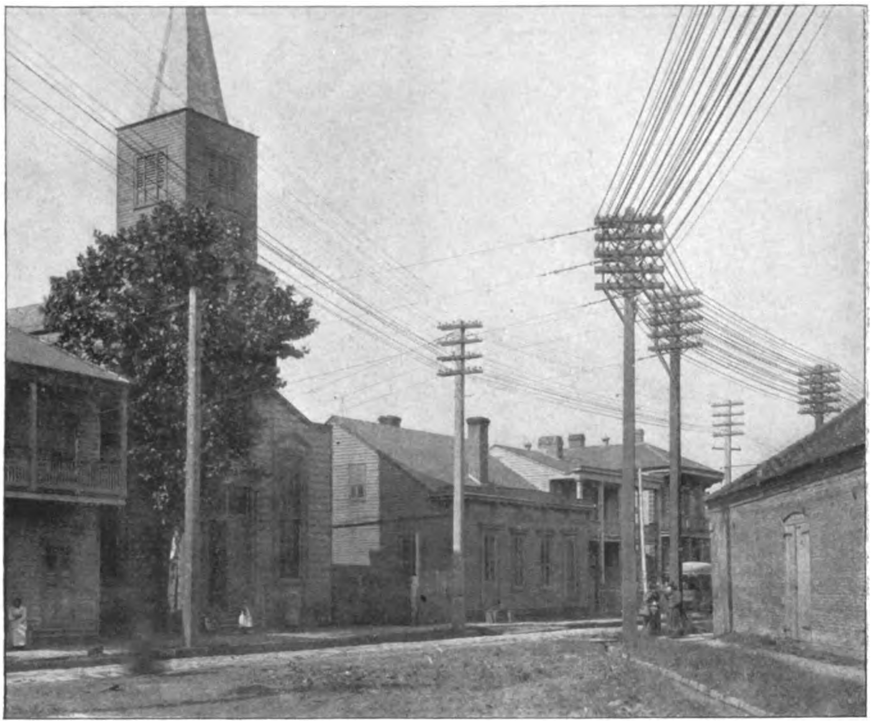


A JUNCTION POLE AND FRAME.

not present an obstructive object for the trolley to catch in. There is no insulation attached to such ears, and this is the only thing in their disfavour, but as there are many insulating devices which can be attached to the hanger to overcomeethis difficulty, this could be consider d a minor point.

A great deal could be said about overhead curve construction, but as there are so many different conditions to meet I will simply conclude my description with a double right angle curve of sixty feet and fifty feet radius. The pull-off ears should be placed 11 feet 8½ inches apart on the outside curve, and those on the inside curve, 9 feet 10 inches apart from centre to centre (commencing at the point of the curve), so that the pull-off wires between the two curves run longitudinally from the axis of the track curves. The three central pull-off wires leading to the centre pole would terminate in an iron ring, three inches in diameter, fixed at a point about twenty feet from the trolley wire and attached to a single cable, fixed to the centre pole by ending in a strain insulator. Each of the other pull-off wires would lead directly to their respective poles, all ending in a strain insulator fastened to the pole top. Each of the suspension ears should be placed directly perpendicular over the track centres and each provided with a strain insulator between the trolley wire and the pole.

There is a wide difference of opinion relative to the arrangement of sections and the methods of feeding such sections of the trolley wire. In many installations a practice is made of leading each individual section feeder to the station and separating the trolley into sections by sectional insulations, making it possible to cut out the various sections at the power house. This is a



A CURVE IN FEED LINE CONSTRUCTION.

convenience in one respect, and that is, it makes every section of the line directly controllable from the power plant, but there are other things equally important to consider, which may convince you that better results are obtainable through another method, and that method would be to have every feeder on the whole line doing a share of work at all times, whether the cars be assembled on one section or distributed over the entire line. This, of course, can be done only by means of connections representing the whole line as being in one general section, making short sections controllable by external switches.

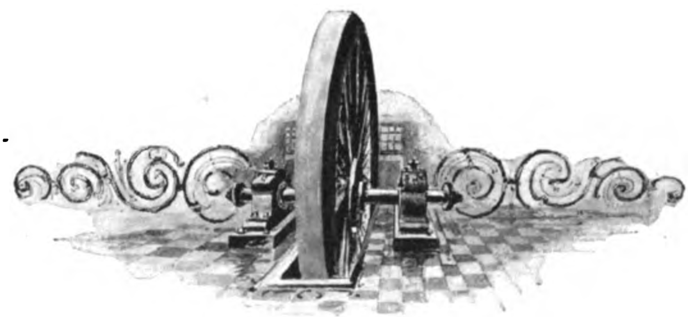
In the first method mentioned, an accumulation of cars may be assembled on one section not estimated for carrying an abnormal load; consequently, the feeder would be overtaxed on this particular section, whereas the feeders on other sections would be doing little or no work, and there would be an unevenness of potential between the adjoining sections. If there is a bridge around each section insulator connecting each section together and connected by a feed wire, so that the current will equalise itself between two sections and distribute itself from all feeders, then we have a small amount of variation of potential from section to section.

I have observed in almost all instances that when an accident occurs to a trolley wire, the whole line is for a time disturbed in its service until the proper attention has been given to the external circuit where the trouble occurs, and those on the ground are the ones who are depended upon for relief before the forces at the power house are aware of the extent of the trouble, and the switchboard tenders are always under instructions or advice from the emergency crew.

Consequently, I maintain that efficient external line appliances, that are controllable by emergency forces, meet the most important requirement, and the most efficient line can be built with a general feeder system leading from the switchboard and controllable, as a whole, for each individual line, and not separated into sections requiring separate feeders for each section leading from the station.

To accomplish this method of uniting the trolley sections, the line is divided into sections by means of sectional insulators, each section so proportioned as to meet the estimated feeding point where the feeder is to be attached. A switch box is placed on the pole at a convenient height, in which are contained two switches and fuses, one for the section on either side of the sectional insulator; the feeder is then divided by connection through each switch, so that the feed wire delivers current to either section through feeder span wires attached to connections on each side of the sectional insulator. When the entire line is in operation, there is an equalisation of current in all sections, and the trolley remains virtually as a solid conductor, but with all necessary features for disconnecting the sections.

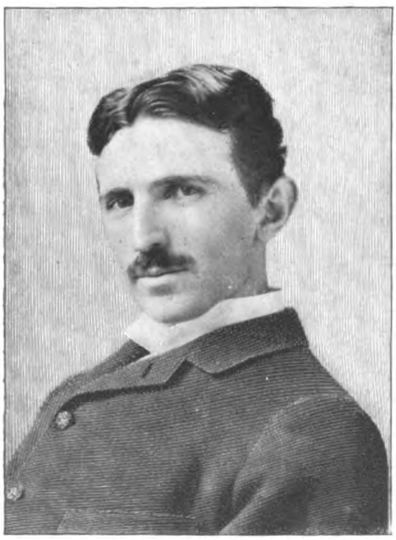
Protection from lightning is now occupying the attention of many railway companies, and there is a wide difference of opinion relative to merits of lightning arresters and their application. I have received correspondence from many different railway companies, and in one instance there are two arresters located for forty-two miles of road, whereas in another instance there were six to the mile. The general idea seems to be that there should be two to the mile, and situated at or near the junction where the feed wire is attached to the trolley wire.



THE AGE OF ELECTRICITY.

By Nikola Tesla.

THE commemoration of the recent introduction into the city of Buffalo of electric power from Niagara Falls was made the occasion of a banquet, held at the Ellicott Club, at Buffalo, on January 12, 1897, the hosts being the Niagara Falls Power and Conduit Company, and the distinguished guests the men, principally, to whose business and engineering talents the world owes the remarkable Niagara undertaking so recently brought to successful completion. Probably none among these has been more honoured than Mr. Nikola Tesla, whose electrical researches and practical accomplishments have been the talk of the world, and whose polyphase alternating current system was the one eventually adopted in the work at Niagara Falls. After the banquet, in responding to the toast, "Electricity," Mr. Tesla spoke at length of the various sciences, with special reference, naturally to electricity, and from his remarks the appended extracts have been made, picturing in a graphic and striking manner the dependence upon power of the development and wealth of cities, the success of nations, the progress of the whole human race, in fact, as he himself put it. —THE EDITOR.



FROM A PHOTO BY SARONY.

For more than half a century the steam engine has served the innumerable wants of man. The work it was called to perform was of such variety, and the conditions in each case were so different that, of necessity, a great many types of engines resulted. In the vast majority of cases the problem put before the engineer was not, as it should have been, the broad one of converting the greatest possible amount of heat energy into mechanical power, but it was rather the specific problem of obtaining the mechanical power in such form as to be best suitable for general use. As the reciprocating motion of the piston was not convenient for practical purposes, except in very few instances, the piston was connected to a crank, and thus rotating motion was obtained, which was more suitable and preferable, though it involved numerous disadvantages incident to the crude and wasteful means employed. But until quite recently there were at the disposal of the engineer, for the transformation and transmission of the motion of the piston, no better means than rigid mechanical connections.

The past few years have brought

forcibly to the attention of the builder the electric motor, with its ideal features. Here was a mode of transmitting mechanical motion, simpler by far, and also much more economical. Had this mode been perfected earlier, there can be no doubt that the majority of the many different types of engines would not exist, for just as soon as an engine was coupled with an electric generator a type was produced capable of almost universal use. From this moment on there was no necessity to endeavour to perfect engines of special designs capable of doing special kinds of work. The engineer's task became now to concentrate all his efforts upon one type, to perfect one kind of engine—the best, the universal, the engine of the immediate future; namely, the one which is best suitable for the generation of electricity.

The first efforts in this direction gave a strong impetus to the development of the reciprocating high-speed engine, and also to the turbine, which latter was a type of engine of very limited practical usefulness, but became, to a certain extent, valuable in connection with the electic generator and motor. Still, even the former engine, though improved in many particulars, is not radically changed, and even now has the same objectionable features and limitations. To do away with these as much as possible, a new type of engine is being perfected in which more favourable conditions for economy are maintained, which expands the working fluid with utmost rapidity and loses little heat on the walls, an engine stripped of all usual regulating mechanism—packings, oilers and other appendages—and forming part of an electric generator; and in this type, I may say, I have implicit faith.

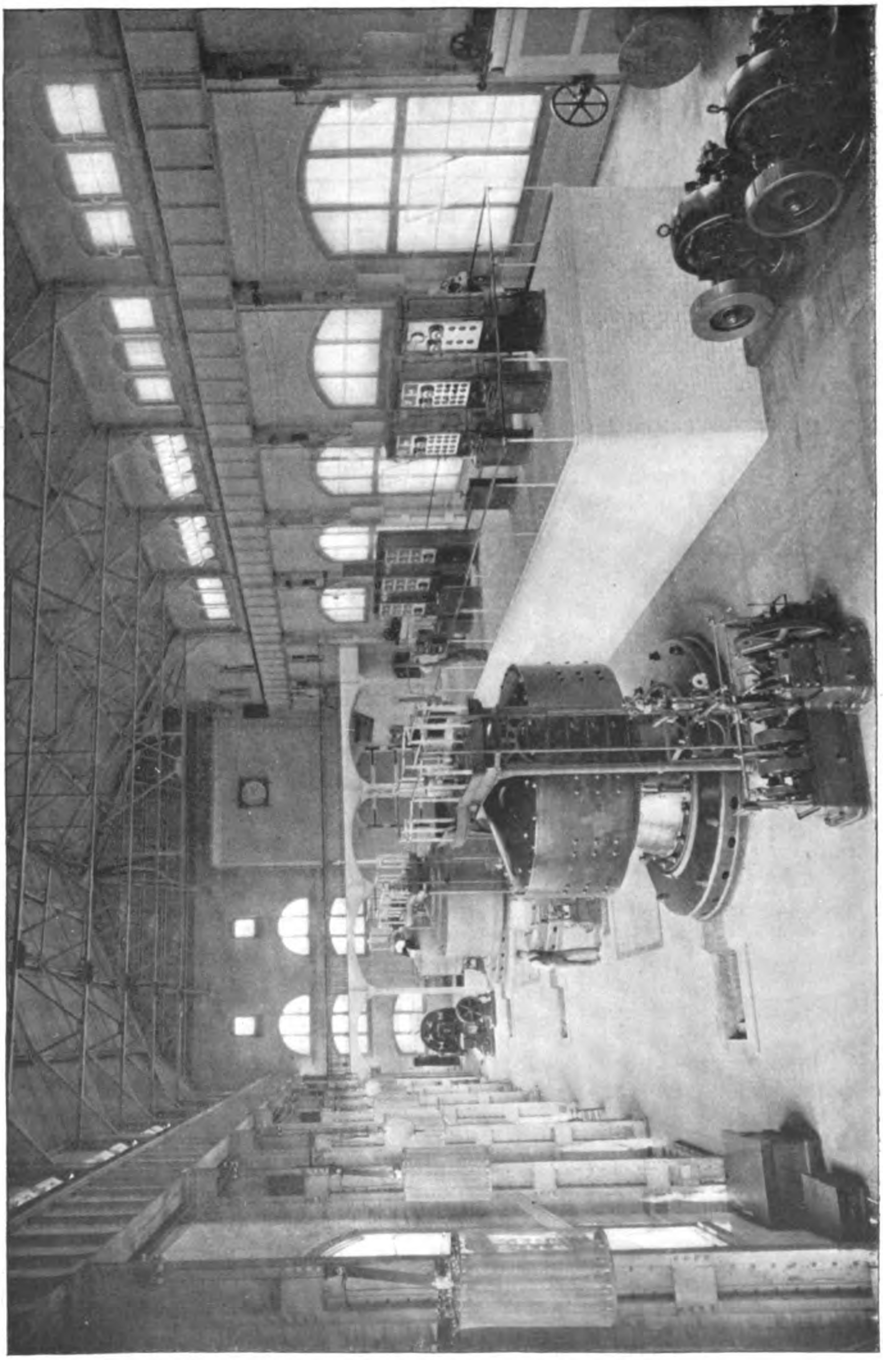
The gas or explosive engine has been likewise profoundly affected by the commercial introduction of electric light and power, particularly in quite recent years. The engineer is turning his energies more and more in this direction, being attracted by the prospect of obtaining a higher thermodynamic efficiency. Much larger engines are now being built, the construction is constantly improved, and a novel type of engine, best suitable for the generation of electricity, is being rapidly evolved.

There are many other lines of manufacture and industry in which the influence of electrical development has been even more powerfully felt,—for instance, the manufacture of a great variety of articles of metal, and especially of chemical products. The welding of metals by electricity, though involving a wasteful process, has, nevertheless, been accepted as a legitimate art, while the manufacture of metal sheet, seamless tubes and the like affords promise of much improvement.

We are coming gradually, but surely, to the fusion of bodies and reduction of all kinds of ores—even of iron ores—by the use of electricity, and in each of these departments great realisations are probable. Again, the economical conversion of ordinary currents of supply into high-frequency currents opens up new possibilities, such as the combination of the atmospheric nitrogen and the production of its compounds; for instance, ammonia and nitric acid, and their salts, by novel processes.

The high-frequency currents also bring us to the realisation of a more economical system of lighting; namely, by means of phosphorescent bulbs or tubes, and enable us to produce with these appliances light of practically any candle power. Following other developments in purely electrical lines, we have all rejoiced in observing the rapid strides made, which, in quite recent years, have been beyond our most sanguine expectations.

To enumerate the many advances recorded is a subject for the reviewer, but I cannot pass without mentioning the beautiful discoveries of Lenard and Roentgen, particularly the latter, which have found such a powerful response throughout the scientific world that they have made us forget, for a time, the great achievement of Linde in Germany, who has effected the liquefaction of air on an industrial scale by a process of continuous cooling; the discovery of argon by Lord Raleigh and Professor



A RECENT VIEW OF THE INTERIOR OF THE NIAGARA FALLS POWER HOUSE.

Ramsay, and the splendid pioneer work of Professor Dewar in the field of low temperature research. The fact that the United States have contributed a very liberal share to this prodigious progress must afford to all of us great satisfaction.

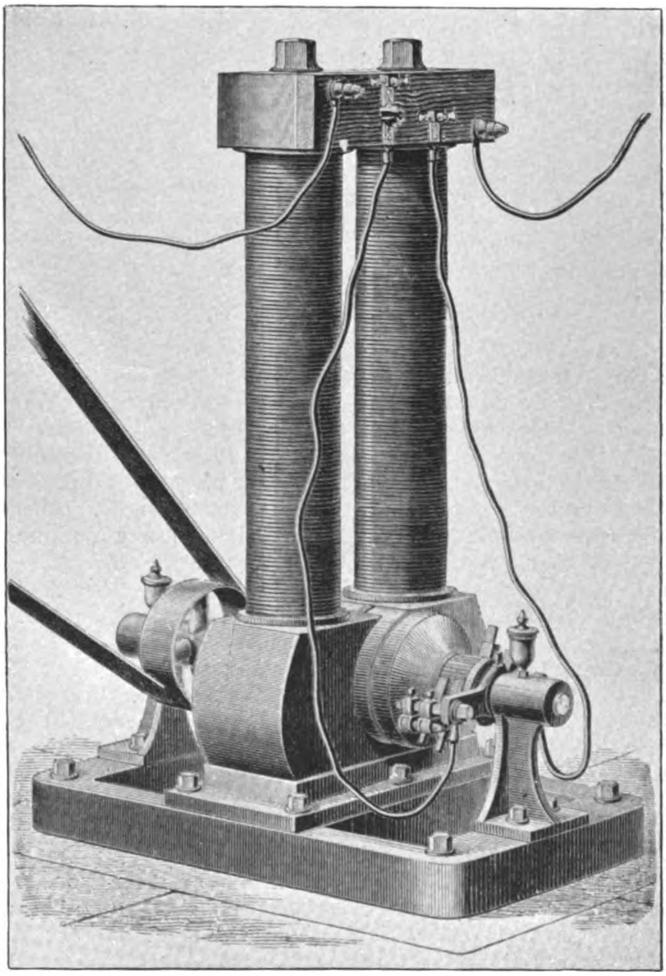
While honouring the workers in other countries and all those who, by profession or inclination, are devoting themselves to strictly scientific pursuits, Americans have particular reasons to mention with gratitude the names of those who have so much contributed to this marvelous development of electrical industry in the United States. Bell, who, by his admirable invention enabling us to transmit speech to great distances, has profoundly affected our commercial and social relations, and even our very mode of life; Edison, who, had he not done anything else beyond his early work in incandescent lighting, would have proved himself one of the greatest benefactors of the age; Westinghouse, the founder of the commercial alternating system; Brush, the great pioneer of arc lighting; Thomson, who gave us the first practical welding machine, and who, with keen sense, contributed very materially to the development of a number of scientific and industrial branches; Weston, who once led the world in dynamo design, and now leads in the construction of electric instruments; Sprague, who, with rare energy, mastered the problem and insured the success of practical electrical railroading; Acheson, Hall, Willson and others, who are creating new and revolutionising industries here under our very eyes at Niagara.

Nor is the work of these gifted men nearly finished at this hour. Much more is still to come, for, fortunately, most of them are still full of enthusiasm and vigour. All of these men and many more are untiringly at work investigating new regions and opening up unsuspected and promising fields. Weekly, if not daily, we learn through the journals of a new advance into some unexplored region, where at every step success beckons friendly, and leads the toiler on to hard and harder tasks.

But among all these many departments of research, these many branches of industry, new and old, which are being rapidly expanded, there is one dominating all others in importance—one which is of the greatest significance for the comfort and welfare, not to say for the existence, of mankind, and that is the electrical transmission of power. And in this most important of all fields long afterwards, when time will have placed the events in their proper perspective, and assigned men to their deserved places, the great event we are commemorating to-day will stand out as designating a new and glorious epoch in the history of humanity—an epoch grander than that marked by the advent of the steam enigne.

We have many a monument of past ages; we have the palaces and pyramids, the temples of the Greek and the cathedrals of Christendom. In them is exemplified the power of men, the greatness of nations, the love of art and religious devotion. But that monument at Niagara has something of its own, more in accord with our present thoughts and tendencies. It is a monument worthy of our scientific age, a true monument of enlightenment and of peace. It signifies the subjugation ot natural forces to the service of man, the discontinuance of barbarous methods, the relieving of millions from want and suffering.

No matter what we attempt to do, no matter to what fields we turn our efforts, we are dependent on power. Our economists may propose more economical systems of administration and utilisation of resources, our legislators may make wiser laws and treaties, it matters little; that kind of help can be only temporary. If we want to reduce poverty and misery, if we want to give to every deserving individual what is needed for a safe existence of an intelligent being, we want to provide more machinery, more power. Power is our mainstay, the primary source ot our many-sided energies. With sufficient power at our disposal we can satisfy most of our wants and offer a guaranty for safe and comfortable existence to



AN EARLY EDISON MOTOR, BUILT IN 1880.

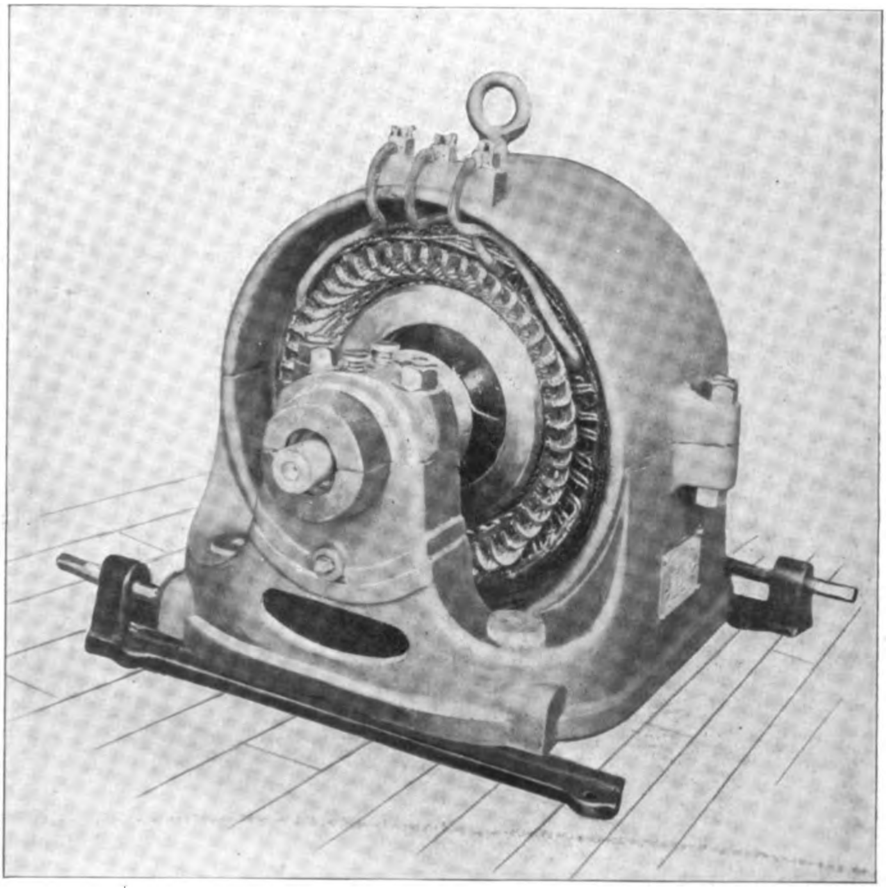
all, except perhaps to those who are the greatest criminals of all—the voluntarily idle.

The development and wealth of a city, the success of a nation, the progress of the whole human race, is regulated by the power available. Think of the victorious march of the British! Apart from the qualities of the race, which have been of great moment, they owe the conquest of the world to—coal. For with coal they produce their iron; coal furnishes them light and heat; coal drives the wheels of their immense manufacturing establishments, and coal propels their conquering fleets. But the stores are being more and more exhausted, the labour is getting dearer and dearer, and the demand is continuously increasing.

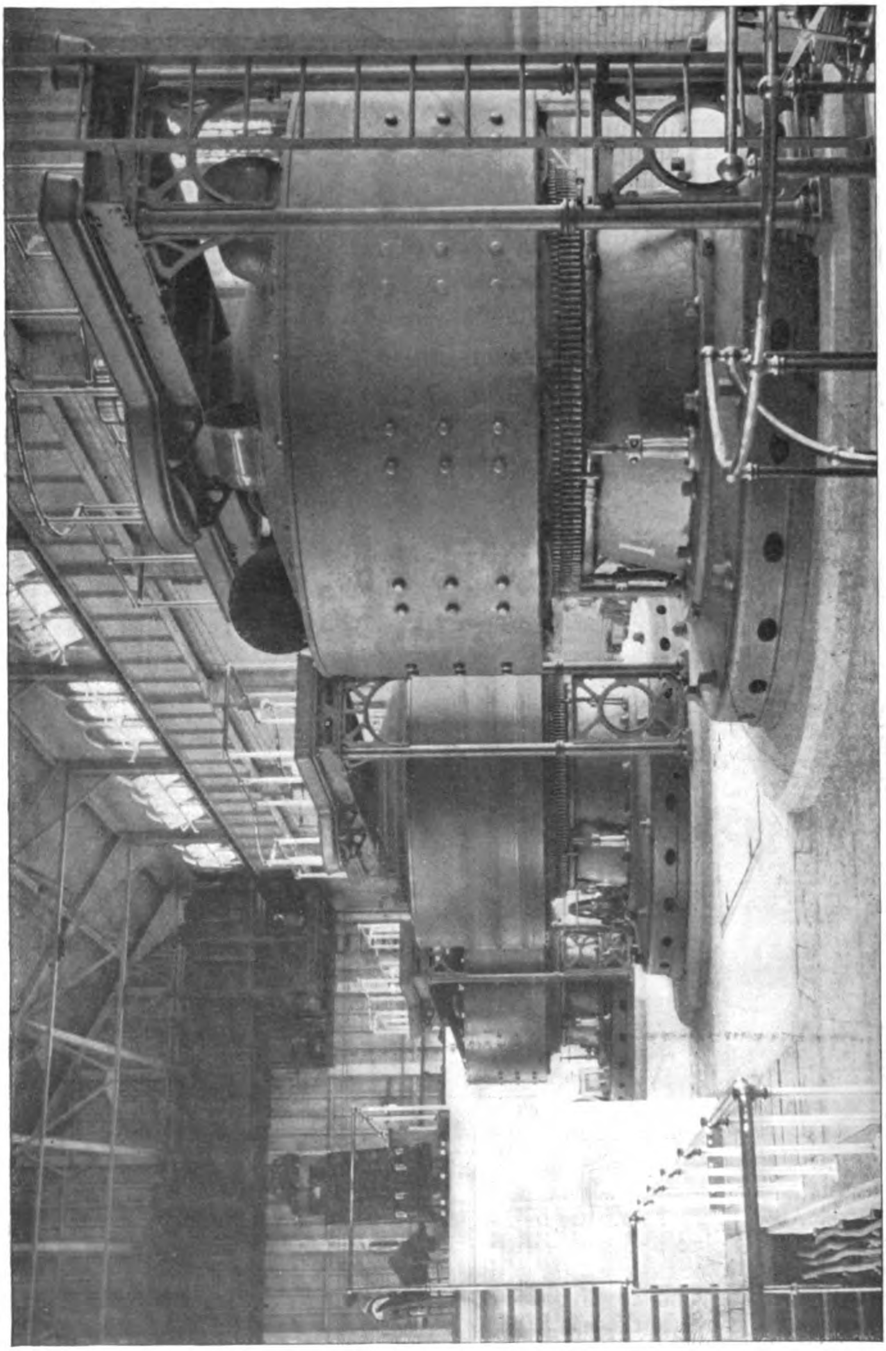
It must be clear to every one that soon some new source of power supply must be opened up, or that at least the present methods must be materially improved. A great deal is expected from a more economical utilisation of the stored energy of the carbon in a battery; but while the attainment of such a result would be hailed as a great achievement, it would not be as much of an advance towards the ultimate and permanent method of obtaining power as some engineers seem to believe. By reason both of economy and convenience we are driven to the general adoption of a system of energy supply from central stations, and for such purposes the beauties of the mechanical generation of electricity cannot be exaggerated. The advantages of this universally accepted method are certainly so great that the probability of replacing the engine dynamos by batteries is, in my opinion, a remote one, the more so as the high-pressure steam engine and gas engine give promise of a considerably more economical thermodynamic conversion.

Even if we had this day such an economical coal battery, its introduction in central stations would by no means be assured, as its use would entail many inconveniences and drawbacks. Very likely the carbon could not be burned in its natural form as in a boiler, but would have to be specially prepared to secure uniformity in the current generation. A great many cells would be needed to make up the electromotive force usually required. The process of cleaning and renewal, the handling of nasty fluids and gases and the great space necessary for so many batteries wouid make it difficult, if not commercially unprofitable, to operate such a plant in a city or densely populated district.

Again, if the station be erected in the outskirts, the conversion by rotating



A MODERN TESLA MOTOR AS MADE BY THE WESTINGHOUSE ELECTRIC AND MFG. CO



ANOTHER VIEW OF THE NIAGARA FALLS POWER HOUSE INTERIOR.

transformers or otherwise would be a serious and unavoidable drawback. Furthermore, the regulating appliances and other accessories which would have to be provided would probably make the plant fully as much, if not more, complicated than the present. We might, of course, place the batteries at or near the coal mine, and from there transmit the energy to distant points in the form of high-tension alternating currents obtained from rotating transformers, but even in this most favourable case the process would be a barbarous one, certainly more so than the present, as it would still involve the consumption of material, while, at the same time, it would restrict the engineer and mechanic in the exercise of their beautiful art. As to the energy supply in small isolated places, as dwellings, I have placed my confidence in the development of a light storage battery, involving the use of chemicals manufactured by cheap water power, such as some carbide of oxygen-hydrogen cell.

But we shall not satisfy ourselves simply with improving steam and explosive engines or inventing new batteries; we have something much better to work for, a greater task to fulfill. We have to evolve means for obtaining energy from stores which are forever inexhaustible, to perfect methods which do not imply consumption and waste of any material whatever. Upon this great possibility, upon this great problem, the practical solution of which means so much for humanity, I have myself concentrated my efforts for a number of years, and a few happy ideas which came to me have inspired me to attempt the most difficult, and given me strength and courage in adversity.

Nearly six years ago my confidence had become strong enough to prompt me to an expression of hope in the ultimate solution of this all-dominating problem. I have made progress since, and have passed the stage of mere conviction such as is derived from a diligent study of known facts, conclusions and calculations. I now feel sure that the realisation of that idea is not far off. But precisely for this reason I feel impelled to point out here an important fact, which I hope will be remembered.

Having examined for a long time the possibilities of the development I refer to, namely, that of the operation of engines on any point of the earth by the energy of the medium, I find that even under the theoretically best conditions such a method of obtaining power cannot equal in economy, simplicity and many other features the present method, involving a conversion of the mechanical energy of running water into electrical energy and the transmission of the latter in the form of currents of very high tension to great distances. Provided, therefore, that we can avail ourselves of currents of sufficiently high tension, a waterfall affords us the most advantageous means of getting power from the sun sufficient for all our wants, and this recognition has impressed me strongly with the future importance of the water power, not so much because of its commercial value, though it may be very great, but chiefly because of its bearing upon our safety and welfare.

I am glad to say that also in this latter direction my efforts have not been unsuccessful, for I have devised means which will allow us the use in power transmission of electro-motive forces much higher than those practicable with ordinary apparatus. In fact, progress in this field has given me fresh hope that I shall see the fulfillment of one of my fondest dreams; namely, the transmission of power from station to station without the employment of any connecting wire. Still, whatever method of transmission be ultimately adopted, nearness to the source of power will remain an important advantage.

Some of the ideas I have expressed may appear to many hardly realisable; nevertheless, they are the result of long continued thought and work. With ideas it is as with dizzy heights. At first they cause you discomfort and you are anxious to get down, distrustful of your own powers; but soon the remoteness of the turmoil of life and the inspiring influence of the altitude calm your blood; your step gets firm and sure and you begin to look—for dizzier heights.

In the great enterprise at Niagara we see not only a bold engineering and commercial feat, but far more, a giant stride in the right direction as indicated both by exact science and philanthropy. Its success is a signal for the utilisation of water powers all over the world, and its influence upon industrial development is incalculable. We must all rejoice in the great achievement and congratulate the intrepid pioneers who have joined their efforts and means to bring it about. It is a pleasure to learn of the friendly attitude of the citizens of Buffalo and of the encouragement given to the enterprise by the Canadian authorities. We shall hope that other cities, like Rochester on this side and Hamilton and Toronto in Canada, will soon follow Buffalo's lead. This fortunate city herself is to be congratulated. With resources now unequaled, with commercial facilities and advantages such as few cities in the world possess, and with the enthusiasm and progressive spirit of its citizens, it is sure to become one of the greatest industrial centres of theglobe.

DOES IT PAY TO EXHIBIT?

By Professor Wm. T. Magruder.

DOES it pay to exhibit? That depends!

The question reminds one of the story of the little boy who, having been punished by his mother for doing something which he considered meritorious, climbed up on his father's knee, and with a long face and suppressed sob, whispered, "Papa, does it pay to be good?"

Exhibiting at expositions is but one of the nineteenth century methods of advertising to the world that you have something which you would like to exchange in trade, and therefore suggests to the other question, "Does advertising pay?"

While answers to these questions are seldom susceptible of rigid mathematical proof, yet most persons will admit that it pays in the long run to do what is right, that careful and systematic advertising increases the number of both customers and sales, and that well-directed exhibiting is one of the surest ways of getting the public to examine what you have to show them, and to see it in operation.

To such an extent is this appreciated that many business houses have one man, frequently with several assistants, whose sole duty it is to superintend the advertising, while other men are constantly employed in the preparation of exhibits, and in devising novel methods of illustrating the uses and qualities, and striking ways of presenting the good features of their exhibit to an eager public, ever thirsting for the novel and the unique and ever willing to stop and see the "very latest."

In the case of expositions, as in the case of advertising, it is extremely difficult to prove just how many orders are the direct result of the exhibit that is made. Men will sometimes tell you of the orders that they took at an exposition, or immediately thereafter, as the result of their having had an exhibit there, and convince you that they think that it paid them.

Recently an engine builder counted up to the writer seven orders for engines which, he was confident, he would not have been at all likely to have received but for his exhibit. Similarly, one meets a man occasionally who claims that advertising does him no good, because his customers tell him that they never see his advertisements, nor yet his exhibits. But then, the same man will tell you that at the Columbian Exposition, for example, he "did not get a single new or suggestive idea, except in the art gallery."

As to whether exhibiting pays or not, it depends:

First.—On whether you have anything worth exhibiting, — anything which is new, useful to, or desired by, others. The idea that "our company has exhibited at every exposition since —," and that therefore they must continue to exhibit the same old line of goods is fallacious. People are asking for new goods and better ones. They know the old by experience. If you have something which is useful, which will save time, labour and material, or something which fills "a long-felt want" which really does exist, you will have little trouble to make your exhibit pay; but, on the other hand, expositions are poor places in which to create demands for goods which no one wants.

Second.—Are the people likely to be sufficiently interested in your goods to think of them a second time when they get home? In this category belong the greater number of exhibits. It is because of a lack of definite individuality. Like the faces in a crowd, it is only the unique ones which impress you. Of three Corliss engines, three duplex pumps, three ice cream freezers, three harvesting machines or three marine paintings, how many visitors can carry away in their minds a distinct idea of the differences or peculiarities?

Third.—Do you know how to arrange an exhibit which will attract the attention of the passer-by, get him to asking questions and to remember your exhibit? Exhibiting, like shop window dressing, is an art in which a large amount of taste and ingenuity can be displayed. The exhibit should be so arranged as to first catch the eye of the visitor, and then to loosen his tongue. When that has been done he will remember you.

Fourth.—Have you attendants at the exhibit who have more patience than the average salesman, and who can show and explain the uses of the exhibit so clearly as to cause the visitor to tell some one else about it? A poor attendant, by his incivility and ignorance, is much worse than none at all, and without an attendant many lines of exhibits had better be left out. The fellow who is off on his vacation, and saunters around for an hour in the morning, and a half hour in the afternoon to see that the exhibit is still there, is a poor apology; while the fellow who does not like to have his flirtation interrupted, or the perusal of his morning paper disturbed, is wasting your money.

Fifth.—Is your contract with the exposition company a one-sided affair—they to do all the squeezing, and you to do all the paying; or are they running the exposition for good and proper business reasons?

If you can answer these questions in the proper way, you will find that exhibiting will pay. Otherwise, do not exhibit, unless for purely patriotic or philanthropic motives.

THE SEA MILLS OF CEPHALONIA.

By F. W. Crosby and W. O. Crosby.

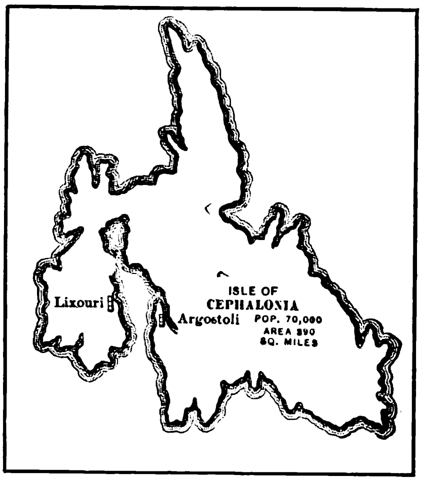
This paper appeared originally in the *Technology Quarterly and Proceedings* of the Society of Arts of the Massachusetts Institute of Technology, Boston, and is here reprinted in part with the permission of the authors and the editors of that periodical. The maps showing the location of the mills have been engraved after sketches made on the spot by Mr. F. W. Crosby, and kindly supplied by him for this reprint.—The Editor.

GREECE is a country replete with geologic interest, but probably it presents no more curious or puzzling structural or dynamical phenomenon than the water power of the so-called Sea Mills near Argostoli on the island of Cephalonia. Our attention was first called to this phenomenon by the following statement in Baedeker's *Greece*. After giving a brief description of Argostoli, the chief town on the island of Cephalonia, Baedeker goes on to say:—"From the Maitland Monument we may proceed along the coast, past the British Consulate and the large wine cellars of Mr. Toole, to the celebrated Sea Mills.

The first of the latter is the mill of Dr. Migliaressi, established in 1859, and one-fourth mile farther on, at the north end of the peninsula, is the old mill, erected by Mr. Stevens in 1835, where we obtain a better view of the phenomenon whence the mills derive their name. The mills are driven by a current of sea water, which flows into the land for about fifty yards through an artificial channel, finally disappearing amid clefts and fissures in the limestone rock. Authorities are not yet unanimous as to the explanation of this unique phenomenon."

The phenomenon appeared not only unprecedented, but contrary to nature. If she "abhors a vacuum," would she, could she, tolerate such a monstrous thing as an inverted river and vast, if not aching, voids, in realms beneath the sea for such an unnatural stream to flow into? Feeling thus somewhat incredulous as to the correctness of this account, despite the general reliability of Baedeker, the senior writer (F. W. Crosby) visited Argostoli and made a personal investigation.

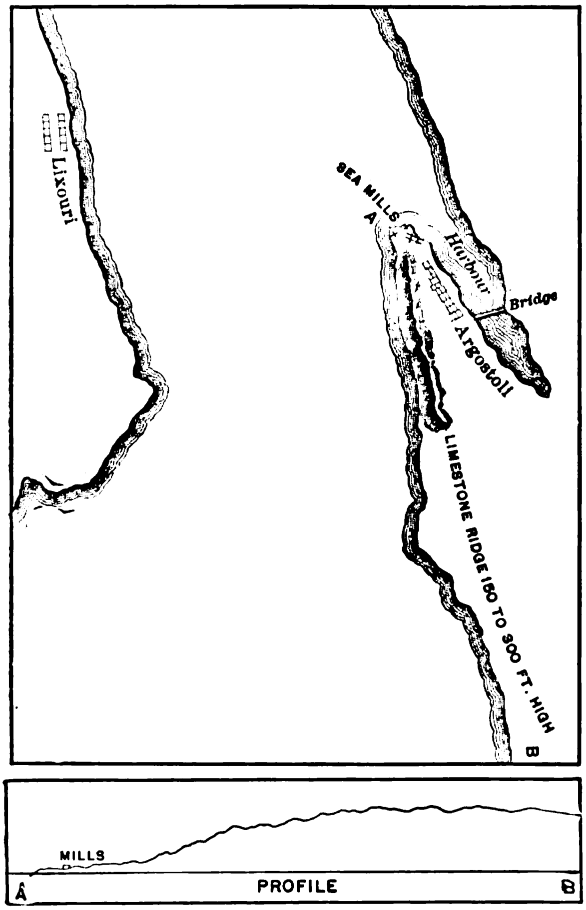
Argostoli is on the southern coast of Cephalonia, on the landward side of a long, narrow ridge of limestone which forms its landlocked harbour. A mile north of the town, at the extremity of the promontory and the mouth of the harbour, are the Sea Mills The entire promontory is composed of the ordinary bluish white secondary limestone. It



THE ISLAND OF CEPHALONIA.

is nearly destitute of soil and vegetation, and the surface is very rough and ragged from unequal weathering. The land is low and flat at the north end in the vicinity of the mills, but it gradually rises as it trends southward, and between the town of Argostoli and St. George's

Castle, five or six miles distant, attains a height of 200 to 300 feet or more. Although Mr. Stevens, in 1835, was the first person to utilise this anomalous water power, the existence of the running water had long been known to the natives without exciting any special interest in their minds.



ENLARGED MAP DETAIL OF CEPHALONIA.

The mills have not been running for years, and are now in a state of dilapidation and decay. The many improvements lately made in the manufacture of flour and the building of large flouring mills at Patras and other places made it unprofitable to continue working these rude water mills, and they, as well as scores of windmills on the island, were abandoned.

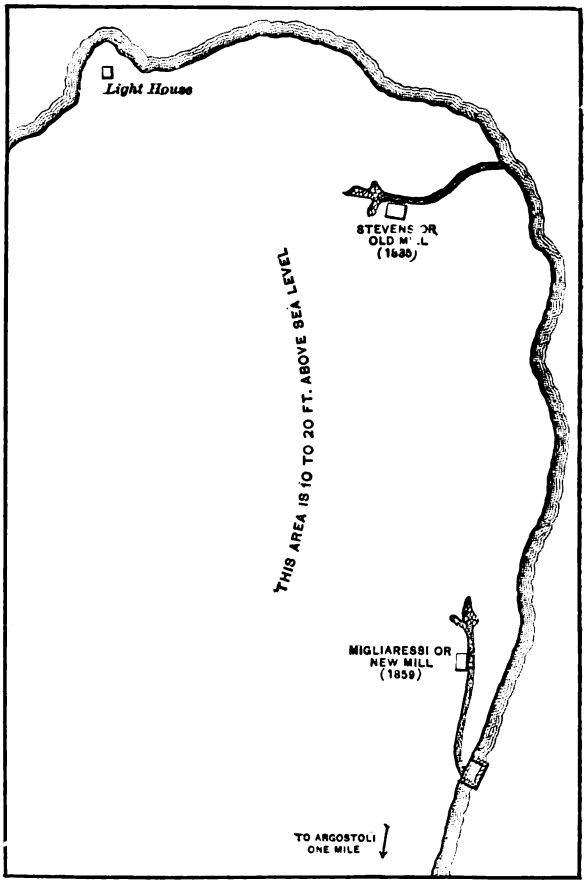
Each race, or flume, is continued for a few yards beyond the mill, and terminates in an irregular pit excavated to a depth of three to five feet below the sea level. From this discharge pond, as it might be termed, the water rapidly disappears through numerous narrow openings, seemingly enlarged joint fissures. The races have a breadth of four to six feet, and the bottoms slope inland sufficiently to insure a strong current at the mills. The wheels in both mills were of the undershot type, of rough country make, and connected by means of equally crude gearing to the millstones within the mill.

The only difficulty experienced in operating the mills was to prevent the ingress of seaweed and other trash which would choke up the discharge vents. At the Stevens mill gratings were used for this purpose, but occasionally the crevices in the rock had to be cleaned out, as more or less weeds would get through the grating.

Dr. Migliaressi, at the new mill, improved upon this by building a walled inclosure about forty feet square in the sea around the mouth of the flume leading to his mill. The wall being laid without cement below the surface of the water, gave access to the water, but kept out the obstructing seaweed. In all other respects the mills were practically alike. The undershot water wheels were placed directly in the race, or flume, which at that point was incased with plank at sides and bottom. After passing the wheels, the water is greedily sucked in by the multitude of ever-thirsty mouths in the pit below; and although the wheels of the Sea Mills will never turn again, and are fast crumbling to decay, the water still flows unceasingly from the sea into the land.

The boundaries of this influx have never been definitely determined, but it certainly extends along the coast for nearly half a mile. At all points between the two mills, and for an unknown distance beyond each, the water is everywhere percolating through the cracks and fissures of the limestone and sinking into the earth. The openings in the sea bottom around the point are, no doubt, mainly closed by weeds, gravel, etc., yet no inconsiderable amount of water must find its way to these mysterious depths through such an extent of beach, lying on a rock that is practically as porous as a sieve; and since this condition may prevail for a long distance from the shore, where the pressure would tend to increase the flow, we may reasonably assume the quantity of water absorbed outside of the mills as undoubtedly greater than that needed to run them.

If we assume that each gristmill would require five horse-power to operate it, and that the head of water actually used was about three feet, we must have a flow of at least 1000 cubic feet per minute, or 2000 per minute for the two mills; and we must double this amount to get even an approximate estimate of the magnitude of the inverted river at Argostoli. This assumption makes the daily consumption of water nearly 6,000,000 and the annual consumption over 2,000,000,000 cubic feet. If we imagine a cavern below we must give it generous proportions, as 2,000,000,000 cubic feet of water would fill a chamber about five miles long, 1000 feet wide, and 75 feet deep. Or, if the water runs into a fissure, say 10 feet wide, it must be about 10 miles long and 4000 feet deep to hold one year's influx at this point. When the second mill was built and put in operation, it was soon noticed that the power of the old mill was perceptibly diminished; that is, either mill had a more copious discharge, and therefore more power, when the other was not running. We may conclude from this that the entire inflow is tributary to a single subterranean channel, and that it is not of sufficient capacity to allow a free discharge from both mills at once. Hence it follows that the building of the mills, with their head and tail races, and more especially the discharge pits, has probably added materially to the influx of water.



DETAIL OF MILL LOCATIONS.

So far as we can learn, there is but a single reference to the Sea Mills of

Argostoli in any strictly scientific work. H. E. Strickland, an English geologist, visited Argostoli in 1835, just after the erection of the first mill, and published a brief but very good account of the phenomenon.* In his volume on *The Ocean* Reclus says, page 146:—

"When the waves of the sea cannot enter into the caverns remote from the shore, except by narrow channels, it often happens that a rivulet of salt water regularly flows toward the interior of the land without ever returning to the ocean. This strange fact, which may seem at first sight a reversal of the laws of nature, may be observed at various points on the coast of calcareous countries, and especially on the coasts of Greece and the neighbouring islands. Near Argostoli, a commercial town in the island of Cephalonia, four little torrents of sea water, rolling on an average fifty-five gallons of water per second, penetrate into the fissures of the cliffs, flow rapidly among the blocks that are scattered over the rocky bed, and gradually disappear in the crevices of the soil.

"Two of these water courses are sufficiently powerful to turn throughout the year the wheels of two mills constructed by an enterprising Englishman. Though the subterranean cavities of Argostoli are in constant communication with the sea, and the entrance to the canals is carefully freed from the seaweed that could obstruct the passage, or at least retard the current, the waters are not the same height in the grottoes as in the neighbouring gulf. This is because the calcareous rocks of Cephalonia, dried on the surface by the sea breeze and the heat of the sun, are pierced and cracked throughout by innumerable crevices, which are so many flues aiding the circulation of the air and the evaporisation of the hidden moisture.

"We can compare the entire mass of the hills of Argostoli, with all their caverns, to an immense *alcarraza*, the contents of which are gradually evaporated through the porous clay. In consequence of this constant loss of liquid, the level of the water is always lower in the caverns than in the sea, and to restore the equilibrium the brooklets, which are fed by the waves, descend incessantly by all the fissures toward the subterranean reservoirs. It is probable that the constant evaporation of the salt water has resulted in the accumulation in the cavities of the island of enormous saline masses. Professor Ansted has calculated that the discharge of the two great marine streams of Argostoli would be sufficient to form each year a block of more than 1800 cubic yards of salt."

Searching among books of travel and tourists' handbooks has brought to light several references to the Sea Mills. John Davy, London, 1842, in giving a description of his sojourn among the islands, tells of the Sea Mills at Argostoli, which he did not see himself, obtaining his information from Dr. White. The description is fairly accurate, as the following quotation shows:—

"The next phenomenon I have to mention is very extraordinary, and apparently contrary to the order of nature. It is the flowing of the water of the sea into the land in currents or rivulets, which descend and are lost in the bowels of the earth. They flow with such rapidity that an enterprising Englishman has erected a gristmill, which is a great success." Farther on he observes, "It is only recently that it has been brought to the knowledge of the English, and it is now become a subject of curious inquiry and speculation."

In 1854 "Murray's Handbook for Greece" was written by G. F. Bowen. His account of the Sea Mills is taken *verbatim* from Davy. In 1863 a book on the Ionian Islands was published by Professor D. T. Ansted. On page 322 he refers to the Sea Mills as "a Cephalonian mystery." He says:—"At four points on the coast the sea, at its ordinary level, enters a very narrow creek, or broken rocky channel, and disappears." There are no streams which could be called rivulets, except the artificial channels leading from the mills, but he is quite right in stating that "the water is greedily and rapidly ab-

* Geological Society, London, Proceedings, 2, 221, 811.

sorbed by the whole surface between the two mills."

Professor Ansted has a theory for the disposition of the water. He says it must be evaporated. But in what manner he does not tell us, and he admits that he sees no way to dispose of the residual salts which would accrue from the evaporation of so great a volume of sea water. He gives as a reason for holding to the evaporation idea the fact "that there are no springs on the island that present any large quantity of saline matter."

In 1846 Viscount Kirkwall's book, "Four Years in the Ionian Islands," was published. After describing how the wonderful watercourses were first discovered and by whom the mills were built, we find on page 67 the following curious statement:—"Admirals, generals, bishops, and distinguished civilian visitors seldom failed to examine this very interesting phenomenon."

It is difficult to decide which is the greater marvel, the Sea Mills themselves or the fact that they have remained practically unknown to the scientific world up to the present day, although described by several authors, mentioned in the guidebooks, and visited, as the viscount says, by "admirals, generals, bishops, and distinguished civilian visitors." Must we not conclude that "fair science" had no devotees among the titled crowd who from time to time looked wonderingly upon the "Cephalonian mystery"?

No explanation of this phenomenon heretofore suggested is even measurably satisfactory. It cannot be connected in any way with tidal phenomena, because this part of the Mediterranean is almost tideless, and there is nothing periodic in the flow of the water into the land. That the water is simply filling a system of fissures and caverns in the earth is clearly inadmissible in view of the well-established facts. The flow of water into the land has certainly been uninterrupted since 1833, when first observed by Stevens, and Strickland stated in 1835* that it had been known to the Greeks for many years. Therefore a continuous downward flow, for a full century, appears to be a reasonable assumption, and a period of several or many centuries is, perhaps, not improbable. The supply of water is exhaustless, and the rate of downpour is limited only by the capacity of the fissures. The present rate of flow, or anything approaching it, continued for a century, would give a total volume of water so prodigious as to far exceed the capacity of any known caverns.

The force of this objection is augmented by the consideration that caverns other than fissures must have been formed by solution of the rocks and have thus required for their formation a volume of water many times greater than that required to fill them. Furthermore, it is virtually an axiom in geology that all cavities in the earth below the drainage level of the district, and especially below sea level, except possibly those due to recent, sudden, and extensive rifting, must be permanently and continuously full of water, and certainly it is hardly conceivable that fracture fissures, developed at the surface as mere cracks, could require centuries for their filling with the sea pouring into them.

None of the suggested modifications of the cavern theory seems to be worthy of serious consideration. We cannot suppose that the water flows into caverns and disappears by evaporation or absorption. Both of these processes below a very moderate depth would necessarily be extremely slow, and the former would gradually fill the caverns with salt. Nor can we follow Strickland in the supposition that an earthquake has at some period opened a communication between the sea and the region of volcanic fire, and that the water, being there converted into steam, is afterward condensed in its upward course and forms those hot springs which exist in various parts of Greece.

Equally objectionable is the view that the water is absorbed at great depths by molten *magmas*. Volcanic phenomena are wholly wanting in this part of Greece; that is, there are no active,

* Geological Society, London, Proceedings, 2, 220, 221.

recently active, or extinct volcanoes, nor, so far as we can learn, any geologically recent volcanic rocks. The great crater of Santorin is three hundred miles distant, while Cephalonia and the neighbouring mainland consist of secondary and tertiary strata, overlying ancient crystalline rocks.

The rejection of all these hypotheses forces us to the conclusion that in some way the water must return to the surface. A circulation, due exclusively to hydrostatic pressure, is manifestly impossible, unless, indeed, it should issue in the basin of the Dead Sea, a full thousand miles distant, since the water starts downward from the sea level. Still less can we suppose with Ansted that it would rise in the form of saline springs on the land.

It has occurred to us, however, that in the subterranean heat we have an adequate cause of aqueous circulation. The temperature of the ground increases downward, and it certainly is not a violent hypothesis that the water gains access to a system of fissures traversing a notable range of temperature. In this connection it may be noted that the conditions are favourable to profound fissuring; for Cephalonia, like the rest of Greece, is distinctly a seismic region—earthquakes, often of destructive severity, being of annual and almost monthly occurrence, and the prevailing rock formation is the massive cretaceous limestone, some thousands of feet in thickness.

This rock forms the promontory of Argostoli and almost the entire island of Cephalonia, as well as neighbouring islands, including Zante and many hundreds of square miles of the mainland. Strickland describes it as "a hard, white limestone, abounding in faults and fractures, as well as caverns, subterranean rivers, and thermal and mineral springs, and presenting a close analogy to the carboniferous limestone of Northern Europe." Limestone caverns are numerous in Cephalonia, and at two places there are deep holes, now small lakes, which were evidently formed by the breaking down of cavern roofs. That these caverns extend below sea level is proved by the fact that in boring an artesian well in Argostoli about a mile from the mills, a few years ago, the drill, at a depth of about 225 feet, broke into a cavern over 200 feet in depth, and the well was abandoned.

Water expands a little more than 4.3 per cent. between its temperature of maximum density and the boiling point, or say 1 per cent. for a difference in temperature of 40 degrees Fahr., corresponding, if we may postulate the normal temperature gradient, to a depth of 2120 feet, or two-fifths of a mile. The mean increase in temperature, for this depth, of the entire column of water, may be assumed as one-half the maximum, or 20 degrees, corresponding to an expansion of one-half of 1 per cent., or 10.6 feet in 2120 feet. This head, which is quite as much as the Sea Mills call for, would be increased if the fissures increased in size downward, so as to bring the greater volume of water in the hotter zone, and *vice versa.*

Doubtless, in a single simple fissure extending to a depth of 2000 feet, and ending there, a circulation, or process of convection, would be established, as in the case of a vessel of water over a fire—warm water rising in certain parts of the fissure, determined by trifling accidents of form, and cold water sinking in other parts; but, of course, no head or marked difference of level could arise under these conditions. Therefore, in this simple form the hypothesis of a thermal circulation does not explain the Sea Mills.

But this difficulty is obviated if we conceive two fissures converging downward and communicating at a depth of several thousand feet, like the two limbs of a gigantic letter V or U, the water descending in one fissure and ascending in the other. A contracted inlet would still be required, apparently, to give an efficient water power or a clear fall of several feet, and the velocity of flow throughout the system would, of course, be inversely proportional to the section of the fissure.

Our first conception was that a special or local source of heat, adjacent to the upflow branch of the system of fissures (x, Fig. 1) would be essential to an efficient circulation, but it now appears that even a quite symmetrical arrangement of fissures and with strictly horizontal isogeotherms (Fig. 2) some slight inequality might determine movement of the water in a definite direction, down one fissure and up the other; and that such a movement, once established,

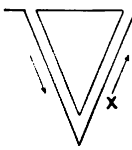


FIG. 1.

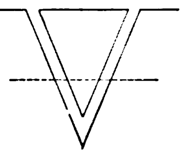


FIG. 2.

would be accelerated by the circumstance that, in consequence of the movement, the downflow fissure is filled almost to the bottom with cold water or water that has experienced only a slight rise of temperature, while the upflow fissure is filled throughout with relatively warm water.

It is very obvious, however, that a much more decided and active circulation would result with an unsymmetrical or one-sided arrangement of the fissures (Fig. 3). Conceive one fissure as highly inclined or vertical, at least in its lowest part, and the other as rising at first in a very oblique or nearly horizontal direction from its lowest part, so as to be relatively long in the zone of highest temperature, and then reaching the surface by a more direct course, so as to be relatively short in the zone of lowest temperature.

This is certainly not an improbable arrangement, and it provides the mechanism for a strong circulation of the water; for below any given isotherm, as that indicated by the dotted line in the figure, a much longer column of water is exposed to the higher temperature on one side of the lowest or turning point than on the other, and each part of this longer column has a longer time in which to absorb the heat of the rocks. It is even conceivable that with such an arrangement of the fissures the outlet may stand at a somewhat higher level than the inlet, and the sea water springs imagined by one writer would thus appear not to be an impossibility. But the location of the Sea Mills of Argostoli on the extremity of a narrow promontory, and the absence in all that region, so far as known, of saline springs, make it extremely probable that the circulation terminates in this case on the sea bottom and thus escapes observation. Although we might think of the silt on the sea bottom as tending to choke up the subterranean fissures and prevent an influx of sea water, it could not prevent the efflux movement.

Professor Moseley mentions* that during a submarine eruption off Hawaii, in 1877, a fissure opened on the coast of that island, from a few inches to three feet broad, and in some places the water was seen pouring down the opening into the abyss below. And Geikie says†:—"The floor of the sea and the beds of rivers and lakes are all leaky. Moreover, during volcanic eruptions and earthquakes fissures no doubt open under the sea, as they do on land, and allow the oceanic water to find access to the interior. Rain water also penetrates along joint cracks and through the pores of rocks."

The existence of fissures or cracks in the earth's crust, extending from the surface to depths where the rocks are highly heated requires no special argu-

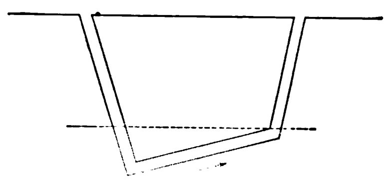


FIG. 3.

ment, for the phenomena of volcanoes and thermal springs and of dikes and veins afford abundant evidence. It is now generally conceded that these earth fractures may maintain themselves as open fissures at depths far below that at which the rocks have the temperature of boiling water (212 degrees Fahr.), and the elevation of the boil-

*Notes by a Naturalist on the Challenger, page 503.

†Text-book of Geology, page 265.

ing point by pressure must permit greater expansion and diminution of density, and therefore increased vigour of circulation.

As an indication of subterranean fissures or cavities of some form in the region of the Sea Mills, we have the fact, already alluded to, that in drilling an artesian well in Argostoli the drill, on reaching a depth of seventy metres, suddenly dropped an equal distance, and the well was abandoned.

The seismic records show not only that severe earthquakes are of almost annual occurrence in Greece, but also that they frequently result in the formation of extensive rifts and fissures; and the extremely hard and rigid secondary limestone, and the crystalline rocks on which it rests, are alike favourable to the persistence in depth of these earthquake fissures, which thus afford more or less permanent channels for a profound circulation of the subterranean waters. For a more detailed view of the earthquake phenomena of this region in their relations to the underground circulation we need refer only to the latest of the more severe Grecian earthquakes.

From August, 1892, till May, 1893, the island of Zante, lying next south of Cephalonia in the Ionian sea, with less than ten miles of water intervening, experienced almost daily tremors and shocks of varying intensity. The seismic disturbance culminated on January 31 and April 17, when almost the entire island was so completely devastated that out of 4500 houses in the capital of the island 2000 were wholly destroyed, 1700 were so badly injured as to necessitate rebuilding, 700 required more or less extensive repairs, and only 100 were not seriously injured. The loss of life was also considerable. The focus of these shocks is placed by Mitzopulos at a great depth under the narrow breadth of sea separating Zante from the mainland.

A little more than a year later, on April 20 and 27, 1894, and in this case without warning tremors, occurred two other disastrous shocks, this time in the province of Lokris, in the northeastern part of Greece, 100 to 150 miles east of Cephalonia. These earthquakes, which caused the death of 255 persons, have been fully and ably described by Dr. Theodor G. Skuphos,* and the district affected was visited within a few days after the second shock by the senior writer.

Skuphos shows that these shocks originated along a line parallel with the channel of Atalanti, which separates the large island of Eubœa from the mainland, and he finds the mean depth of the *centrum* to be 6992 metres for the first shock and 11,000 metres for the second. Rifts and fissures are among the most notable geological results of these shocks. Besides the main fissure, which has a length of fifty-five to sixty kilometres, parallel with the shore, there is an extended network of minor fissures, often of sensible width and, like the main fissure, not uncommonly accompanied by a surface displacement of one to two metres.

The influence of these fissures upon the circulation of the ground water was very marked, and some of the facts have an obvious bearing upon the problem of the Sea Mills. Thus we read that the brackish springs at Pikraki, which furnished sufficient water to drive a mill, completely disappeared after the first shock and returned with greatly increased volume after the second. Also the river-like springs of brackish water which furnished power for a mill at Halmyra were completely swallowed up by the great fissure for sixty hours, and now the flow of water is twice as great as before the earthquake. The water supply of the city of Atalanti has been inceased threefold, while the supplies of other places, as Pasari, have permanently disappeared or the water can only be heard rushing in the fissures at a great depth. The wells of Kasna and Dumpioti have a greatly increased flow, which Skuphos connects with the disappearance of the water at Pasari. Springs near Atalanti which furnished power for several small mills have now greatly increased in flow.

* Zeitschrift Gesellschaft Erdkunde, Berlin, 29 (1894), 409–474.

In like manner, along the entire length of the great fissure, have the wells, springs, and surface streams experienced in general a notable increase or decrease of water in consequence of the earthquakes. Especially remarkable is a spring at the village of Masi, which, before the earthquake, furnished potable water, but is now brackish. A similar change in the character of the water is noted also at Halmyra and other places.

On the island of Eubœa these phenomena are still more marked. Thus, at Ædipsos the number of medicinal springs was doubled and the flow of water increased tenfold. These springs are thermal, and occur in three valleys or ravines. Those in the first valley range in temperature from 41 degrees to 70 degrees C. The most copious springs are in the second valley, with a temperature of 70 degrees C.; while in the neighbouring village of Platanos the water again gushes freely, sometimes to a height of a metre, from fifty old vents which had been dry for many centuries, the temperature of the water ranging from 70 degrees to 82 degrees C., and the other springs of the neighbourhood have risen from 28 degrees to 55 degrees C.

In the third valley the new springs have temperatures of 81 degrees to 82 degrees C. Along the entire course of the stream supplied by these springs (Thermopotamos) many new springs, with a temperature of 81 degrees C., have appeared. The water of the old spring of Hagii Anargyri is diminished, and its temperature has risen from 77 degrees to 80 degrees C. In the old spring basins of the Sylla Baths new springs have appeared, with temperatures of 77 degrees to 78 degrees C., and on the peninsula of Prophet Elias the springs have increased in volume, and the temperature has risen from 31 degrees to 44 degrees C.

These are significant facts, and they appear to prove not only an intimate connection between the earthquake fissures and the underground aqueous circulation, but also that this circulation is sufficiently profound to give rise to numerous thermal springs. Again, no facts are known to us which militate against the view that the brackish springs represent a subterranean circulation which originates in the sea, the sea water becoming diluted during its underground passage. Certainly the enormous volumes of water which these saline springs discharge, and have discharged continuously for decades and centuries, are unfavourable to the view that they have derived their salt from unknown saliferous strata. They are near the sea and, so far as we can learn, near sea level, and in the absence of definite indications to the contrary may, perhaps, fairly be assumed to mark the exits or return currents of some such streams of sea water as we see pouring down into the land in the Sea Mills of Argostoli. Temperature data are, of course, desirable to show whether these saline springs are always warmer than the adjacent sea, and in the absence of such data a positive statement as to the source of the water would not be justified.

An examination of our best general works on geology leaves the impression that the subterranean heat has been somewhat neglected as a cause of the circulation of water through the rocks. With its aid we can explain an active and efficient circulation in the deep region or far below the base level of the district, and a source above the base level appears not to be strictly essential to the theories of thermal springs and artesian wells. In other words, while the underground circulation is conditioned primarily by structure, the motive power is derived from either the subterranean heat or a topographic head—a difference of density or a difference of level. These two dynamic causes may co-operate, they may act more or less independently, or they may antagonise each other; and, as noted, it is at least conceivable that a spring, impelled by the subterranean heat, may rise above its source.

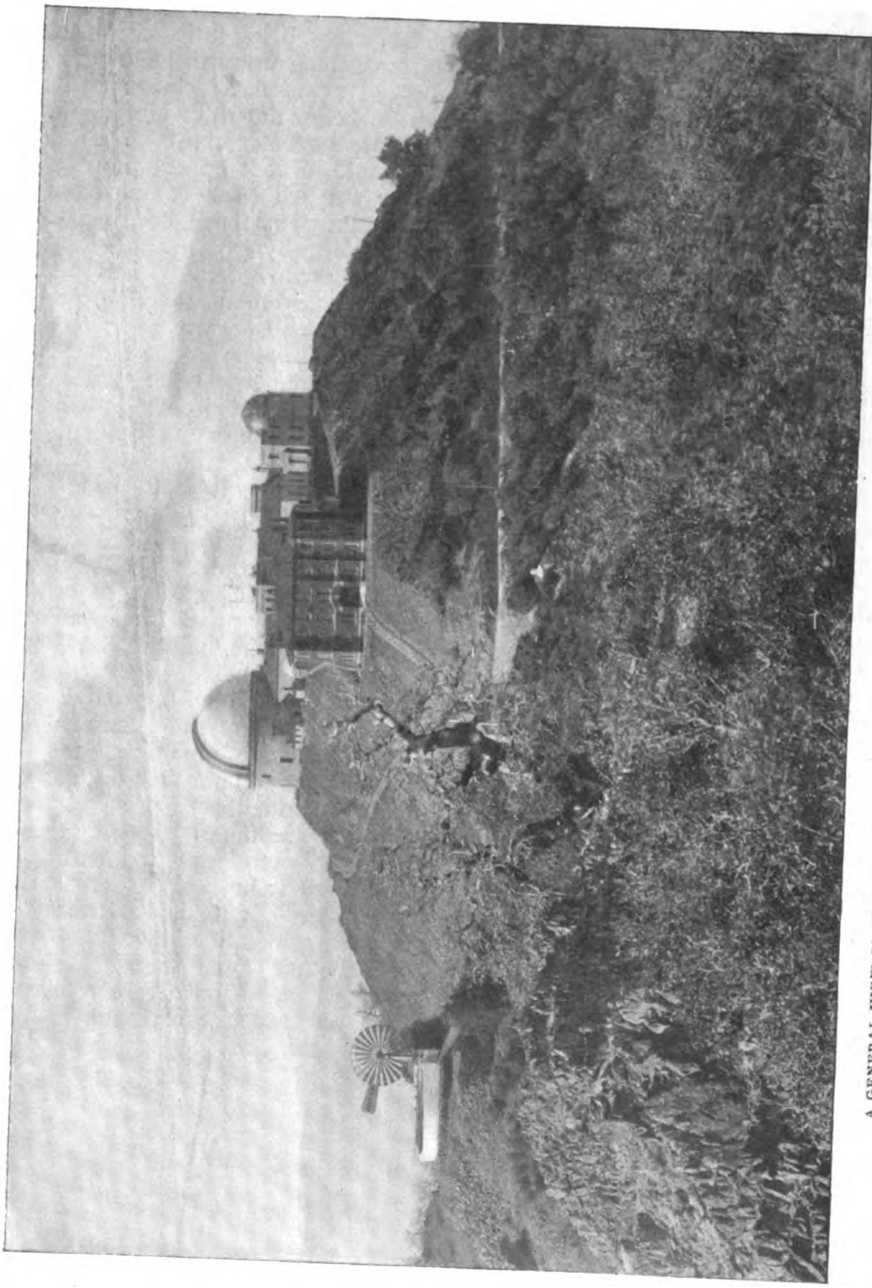
It is generally conceded that, under the influence of the tremendous subterranean pressures, aided by capillary attraction, water pervades all rocks; but it is also recognised that anything like a definite or rapid circulation of the water can only take place in fissures or continuous cavities of some sort or through the more porous strata, such as the coarser fragmental rocks. The phenomena of artesian wells and springs show that porous strata afford very efficient water channels, and no reason is apparent why the subterranean heat should not promote the circulation through these as well as through the open fissures.

Hence, we may conceive that in a deep circulation originating in the subterranean heat a part or the whole of the system of fissures may be replaced by porous strata. Thus the water may, as commonly represented, descend along an inclined porous stratum and rise to the surface through an intercepting fissure (fault line or master joint) or an artesian well. Or it may descend along one limb of a synclinal fold and rise along the other and then the form of the fold, whether symmetrical or unsymmetrical, becomes a matter of import; and, just as in the unsymmetrical system of fissures, the water will, other conditions favouring, descend along the limb of highest dip and ascend along the limb of lowest dip.

As Posepny suggests, the apparent head of an artesian or other deep circulation may be fully neutralised by the great resistance which the water has to overcome in its passage through the strata, the real motive power lying in the thermal contrast and resulting difference of density.* This condition greatly extends the field of the subterranean circulation, especially if it be conceded that a difference of density, due to a local rise of temperature, may take the place of a topographic head as a cause of movement.

Synclines, being little subject to fractures opening upward, have been commonly regarded as closed basins, in which, below the drainage level of the district, the water must be essentially stagnant. But it appears now that, in so far as synclines are composed of porous strata which have been exposed at the surface by erosion, and especially if these are overlain by less pervious beds, so as to confine the water in a definite channel, they will be traversed by currents of water; and the deeper and more unsymmetrical the syncline, the more efficient the circulation will be, at least until the pressure becomes sufficient to close the pores of the rock. Anticlinal folding leads to the formation of cracks gaping upwards, and these may admit water to porous beds which do not actually outcrop. Thus we are led to the conclusion that, other things being equal or apart from the highly impervious rocks, like the clays, shales, and compact limestones, the conditions are least favourable to a general or definite circulation of the ground water in those portions of anticlines lying below impervious and unbroken strata. This, it may be added, is the general position in which are found not only the chief stores of petroleum and natural gas, which might be supposed to seek the under sides of anticlinal arches in obedience to gravitative influences, but also of salt water (fossil sea water); that is, water which we have reason to believe from its composition has been in the strata since their deposition on the sea floor.

* Transactions Amerian Institute of Mining Engineers, 23, 217.



A GENERAL VIEW OF THE LICK OBSERVATORY PEAK AND BUILDINGS ON MOUNT HAMILTON, CALIFORNIA.

AMBROSE SWASEY.

By John A. Brashear.

A RETROSPECT of the mechanic arts, going back no further than the present generation, brings before us a panorama of marvellous advancement, covering every phase of invention, rich in the development of that which contributes to the economy and comforts of life, and the advancement of human knowledge. Indeed, it would seem that there has been more than one magic lamp, to bring forth genii at whose command a Forth or Brooklyn bridge, a ten thousand ton steamer or a mighty railroad is brought forth in a night, like the beautiful palace of Aladdin and his fair bride. America has on its tablets of fame the names of many who have contributed to this wonderful advancement, master minds that have taken hold of the various forms of energy and bidden them contribute to the wants of man.

When a new branch of science presses its claims, there seems to be a law of nature that with the new need comes the new man, ready to take hold of and develop it, at least so far that it may easily be taken up by his successors and carried to completion. The writer well remembers holding in his hands the little induction coil made by Michael Faraday, containing in its few pounds of iron and steel the embryo of the mighty dynamos and motors of the present day. Yet what great minds have arisen to develop and foster this potent form of energy since the time of Faraday!

Compare, if you will, the little telescope of Galileo in the museum of Florence with the magnificent astronomical engines of the Lick or Yerkes observatories in the United States, and you have a typical illustration of the marvellous progress in astronomical mechanics, most of which is the product of the present century. And so it is with every phase of science, particularly in that branch which we have a right to call the science of mechanics.

Of the eminent mechanics and engineers who have contributed much toward the advancement of knowledge in America, by far the larger number claim some one of the New England states as their home. The list is a long one, and "Yankee ingenuity" was a common expression even half a century ago. In fact, not only is New England the centre of many of America's greatest industries, but the impress of her genius has been stamped upon every part of that big country. Many of the master minds that have been developed within her borders have found new opportunities in the Western manufacturing states, and have done honour to their early homes, and it is with pleasure that the writer presents to the readers of this magazine a brief sketch of such a New Englander who sought a field of labour away from the scenes of his birthplace.

Ambrose Swasey was born in Exeter, N. H., his ancestors being among the early settlers of New England, coming to America from England in the year 1638. The fine old farm in Exeter, upon which his grandfather lived to the great age of ninety-four, and where his father spent his long life from 1800 to 1891, is now in Mr. Swasey's possession, and he often goes back to the old homestead where he passed so many of the happy days of childhood.

Mr. Swasey's father was one of the

old New England type of men who are fast passing away, having that force of character, will power and energy sufficient to attack any obstacle. When the Boston and Maine Railroad Company commenced to lay their tracks across his farm, he not only vigorously opposed any attempt to mutilate and, as he thought, desecrate and spoil his property, but he fought them in the courts and then invested the money secured for damages, in the stock of the railroad company.

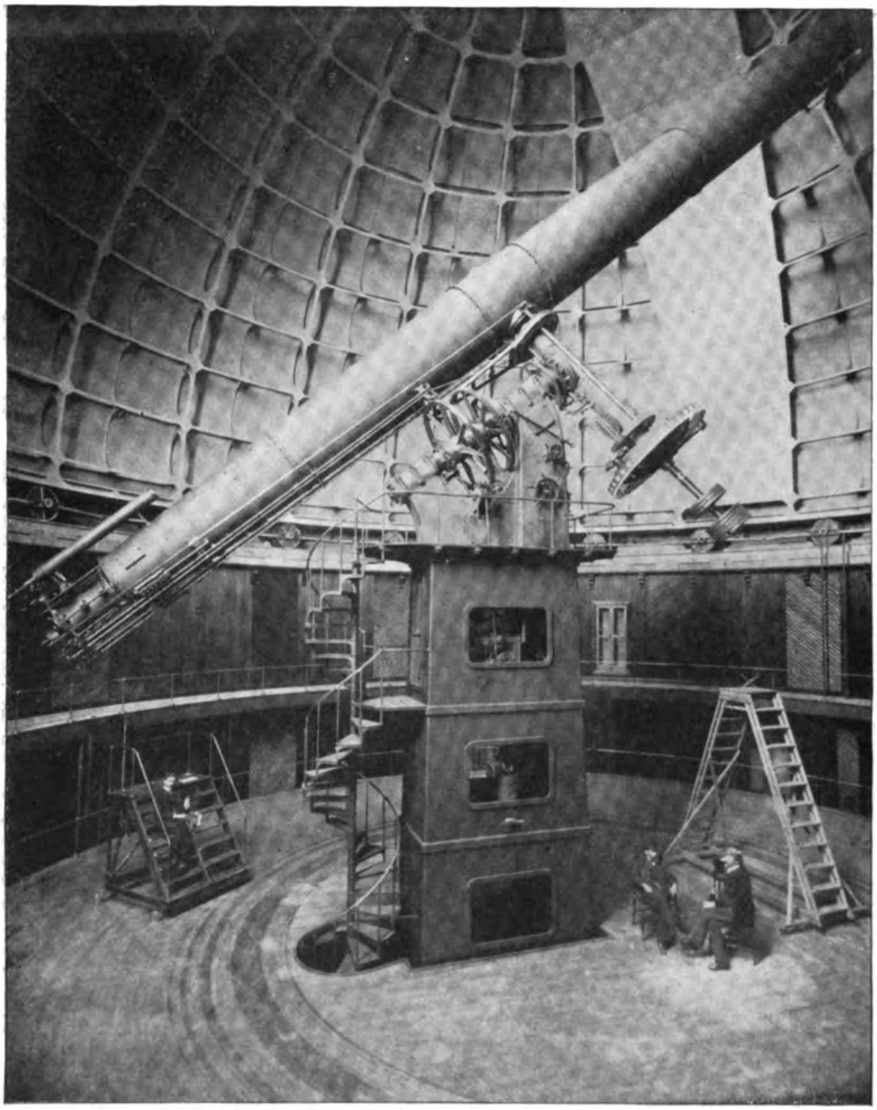
Mr. Swasey received his education in the " Little Red School House " of the district, and his after life has shown that the seed sown by the old schoolmaster fell upon good ground. At the age of eighteen he entered upon the machinist's trade in Exeter, and in 1870, in company with his present partner, Mr. Worcester R. Warner, he left the granite hills of his native State to go into the employ of the Pratt & Whitney Company, at Hartford, Conn. His energy and ability soon became manifest to his new employers, and his aptness in the solution of mechanical problems was so thoroughly appreciated, that the remark, " Send it up to Swasey," was a common one with them.

While in charge of their gearing department, he invented and perfected the epicycloidal milling machine for producing the true theoretical curves of the teeth of gears, and a few years later he made another advance step in the solution of that difficult problem, inventing an entirely new process for generating and cutting spur gears. At one of the recent meetings of the American Society of Mechanical Engineers, Mr. Swasey presented a notable paper, entitled " A New Process for Generating and Cutting the Teeth of Gear Wheels," which at once took a high rank among the valuable contributions to the annals of that society. At the World's Fair he exhibited an automatic gear cutting engine, embodying the principles of this new process, which attracted the attention of many eminent American and foreign engineers on account of its being a practical solution of the very important theory of the interchange system of gearing. In 1880 Mr. Swasey resigned his position with the Pratt & Whitney Company and, together with his present partner, established in Cleveland, O., the business which has since grown to such large proportions. Mr. Swasey's inventive and mechanical genius has emphatically manifested itself in the design and construction of the fine machine tools and astronomical instruments made by his firm.

It seems a most fortunate circumstance that these two men, Ambrose Swasey and Worcester R. Warner, should have associated themselves together as partners, for although the making of astronomical instruments was not in their original scheme when starting the business of machine construction, Mr. Warner's taste for astronomy, and his interest in the appliances used by astronomers, combined with Mr. Swasey's love for artistic design, and his ability as a mechanical engineer, very naturally led them to take hold of the questions pertaining to such instruments.

In recent years observatories and instruments had increased to such dimensions in America that most intricate problems, requiring the highest engineering skill, were demanding solution. The largest refracting telescope constructed previous to 1880 were the 26-inch telescope of the United States Naval Observatory, at Washington, D. C., the 27-inch of the University of Vienna, Austria, and the 30-inch instrument of the Pulkova Observatory, Russia; but the Lick telescope, as projected, was to have nearly half as much more light-gathering power than any refractor that had hitherto been constructed, and the difficulties of mounting such an immense instrument are enormously greater than those attending the construction of a smaller one.

Imagine the great object glass, weighing 500 pounds, poised at the end of a steel tube fifty-six feet long, weighing, with its accessories, more than five tons. The tube must be practically free from flexure, and at the same time be so deli-

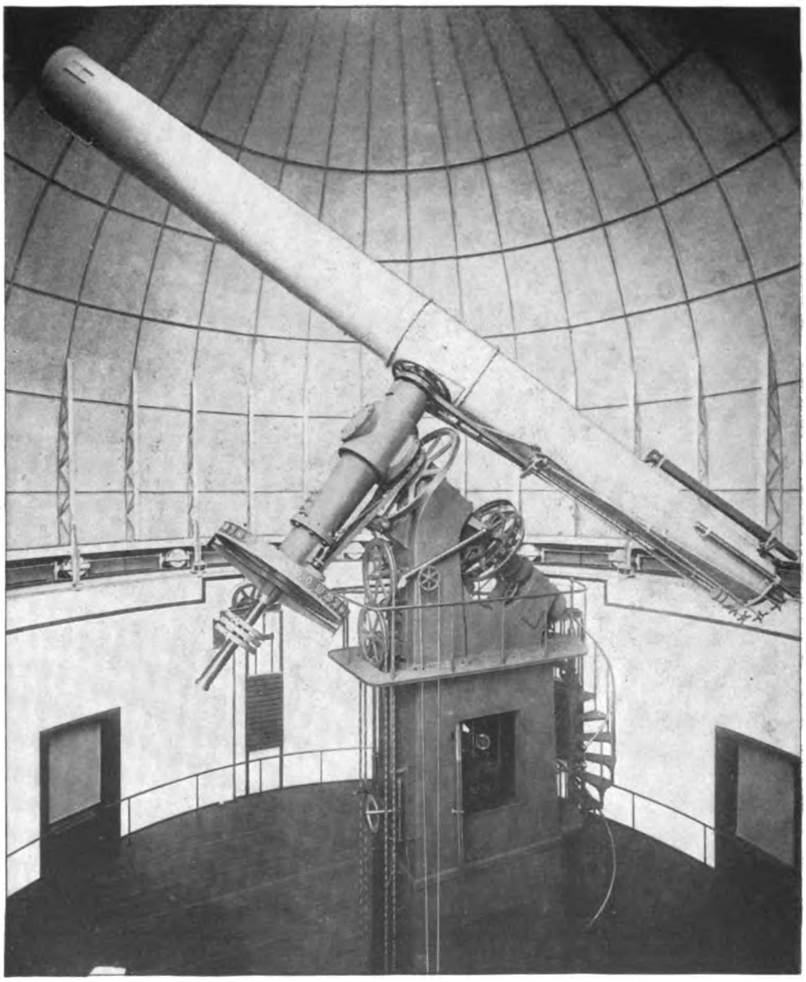


THE 36-INCH EQUATORIAL TELESCOPE OF THE LICK OBSERVATORY, DESIGNED AND CONSTRUCTED BY MESSRS. WARNER & SWASEY, CLEVELAND, OHIO.

cately mounted on its bearings that when it is pointed to a star, and the image of the star is bisected by the spider lines of the micrometer, it shall move as steadily as the heavens.

The instrument must be as firm as a rock, its bearing must move as frictionless as it is possible for mechanism to make them, there must be no lag in the great optic tube, which receives its impulse from the driving clock, and its motions must respond readily to the touch of the astronomer as he sweeps from star to star, from planet to planet, for at each new setting he must move many tons of material.

It is sometimes required to use a magnifying power of a thousand diameters upon the stellar image in order to measure the distance of its components, if, perchance, it be a double star. Let us see what this means! Suppose the telescope tube with its massive counterparts vibrates one-thousandth of an inch, and we place in the micrometer our eyepiece magnifying a thousand times. This means that we also magnify our vibration in the same ratio, giving the star an apparent motion of one inch. It needs no further illustration to show the delicacy of such measurements and the problems that enter into the construction of one of these immense astronomical engines.



THE 26-INCH EQUATORIAL TELESCOPE OF THE U. S NAVAL OBSERVATORY AT WASHINGTON, D. C.

In 1886 the Lick trustees invited four firms to submit designs for the 36-inch telescope, which was to be the largest and most powerful ever constructed. Two of the competing firms were from abroad and two from the United States. The fact that this was the first instrument to be devoted to the triple purpose of visual, photographic and spectroscopic work, brought out many new problems in addition to those required on account of the instrument's great size and completeness, and the astronomer having the work in charge frankly admitted that he feared the requirements were beyond the possibility of accomplishment by the engineer.

The competing designs for this great telescope were sent to the Lick trustees in San Francisco, and after careful consideration the plans submitted by Messrs. Warner & Swasey were accepted, and they were awarded the contract, although their price was the highest. The design of this important instrument was carefully studied in every detail, and the highest standard of excellence was maintained throughout. It was finally erected on Mount Hamilton, in California, during the winter of 1887 and 1888 under Mr. Swasey's personal supervision.

The observatory was built upon a mountain peak 4200 feet high, on the top of which there was scarcely room for the 6-inch telescope previously carried to the summit by Professor Burnham to test the purity of the mountain air; indeed, it required the blasting and removal of 42,000 tons of rock before a space large enough for the observatory could be obtained. The erection of the Lick telescope was so far away from the "base of supplies" that it was a herculean task to transport all the parts of this huge instrument, weighing over forty tons, to the top of the mountain, over a newly-made road, sometimes in a driving snow storm, with the wind blowing from sixty to eighty miles an hour.

During his stay on Mount Hamilton Mr. Swasey made many delightful acquaintances, and when these lovers of astronomy and mechanics happen to get together they bring up many pleasant memories and experiences. Some of those who were thus associated with Mr. Swasey, and whom he held in high esteem for their sterling qualities of hand and heart have gone to their rest, —among the number, Captain Richard Floyd and his estimable wife. Captain Floyd was president of the board of trustees and did all in his power for the successful issue of the great enterprise, made possible by the will of James Lick.

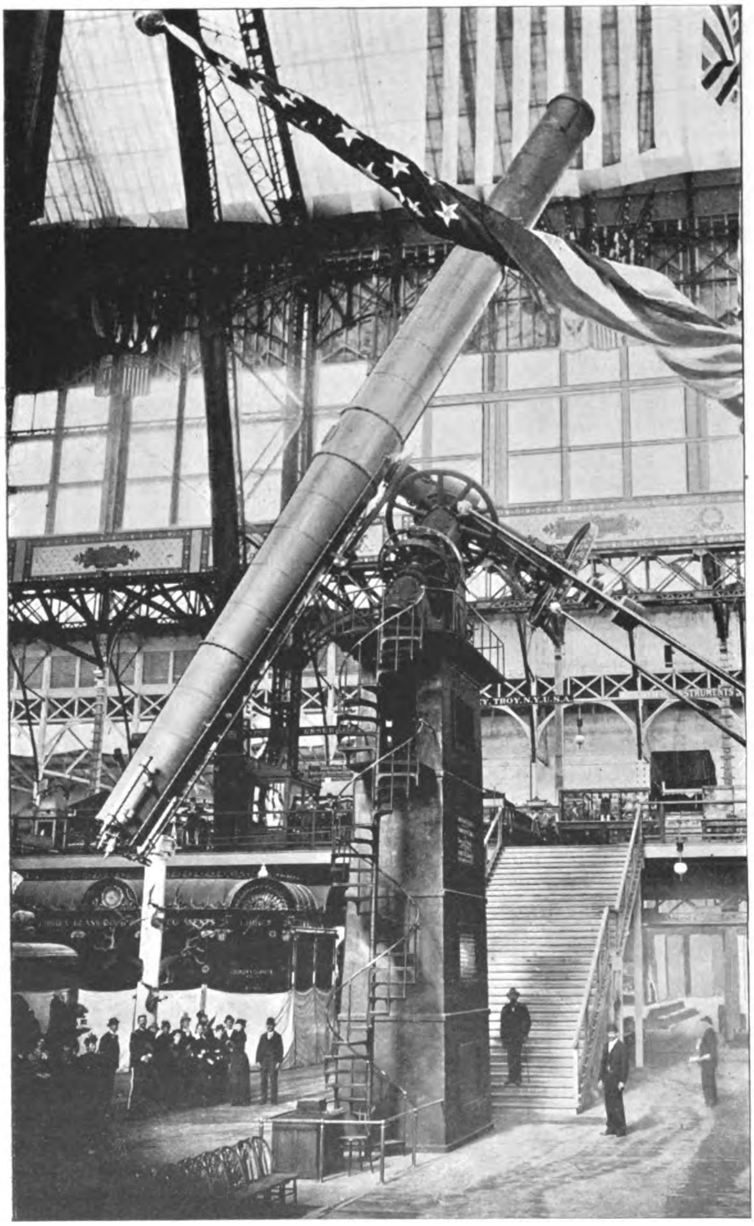
At last the work was finished. Mr. Swasey started the great driving clock, the mighty engine of astronomy obeyed its commands, and the optic tube, pointing to the skies, was ready to unravel the mysteries that had hitherto baffled the searching eye of the astronomer. What this great telescope has given to science through the labours of Holden, Burnham, Barnard, Keeler, Campbell and other astronomers has already become historic, and the end is not yet.

"Priest ministrant, within this mighty fane
Whereon thou standest now is holy ground,
Divinest gift is thine to gaze the first
On glories yet unseen by mortal eyes."

The instrument was such a departure from the usual construction that it was severely criticised. It stood, however, as all such work must, on its own merits, with the result that in 1890 the United States Government decided that the Naval Observatory at Washington must be rebuilt and equipped with new and modern instruments, and the contract for the great telescope and meridian circle was awarded to Messrs. Warner & Swasey. This equatorial is one of the most beautiful and symmetrical mountings ever constructed, and while there is not a single superfluous part, every possible accessory is provided for the convenience of the astronomer.

When the 40-inch Yerkes telescope was to be constructed there was no longer a question as to the style of mounting, and the work was given to the makers of the Lick instrument without competition. This telescope will long be remembered as it stood in the main aisle of the Liberal Arts Building at the World's Fair in 1893, with its great tube reaching far above the galleries of that immense building. It has just been erected at the Yerkes Observatory, at Lake Geneva, Wis. Its great dome, 90 feet in diameter, with elevating floor, 75 feet in diameter, having a rise and fall of 25 feet, was also constructed by Warner & Swasey. The whole equipment of this modern achievement in optical and mechanical engineering will, in its turn, reveal to us new worlds now hidden in the depths of the heavens.

It is apparent from the success of these famous telescopes, which are to be dignified as feats of astronomical en-



THE 40-INCH YERKES TELESCOPE AS EXHIBITED AT THE WORLD'S COLUMBIAN EXPOSITION, CONSTRUCTED FOR THE YERKES OBSERVATORY AT GENEVA LAKE, WIS.

gineering, that great need indeed develops great capacity. In the construction of instruments of such beautiful design, combining strength, rigidity, precision and delicacy of motion, Mr. Swasey has accomplished a notable work for the cause of science, while placing himself high in the ranks of American engineers.

About two years ago Mr. Swasey's firm commenced the task of constructing a dividing engine for automatically dividing circles, to be used more especially with meridian instruments where precision is of supreme importance, and where the most perfect engine that has been, or ever can be, devised and constructed will be none too good for the work.

It would require many magazine pages to give a history of all that has been done on this difficult problem since the days of Tycho Brahe; yet to-day the number of dividing engines that are sufficiently accurate for the demands of modern astronomical measurements may be counted on the fingers of one hand. The best engines have errors, and the question is, how much can these errors be reduced.

As one-third of an inch subtends an angle of one-second of arc at a distance of one mile, it may readily be seen how minute the measurements will be on the periphery of a circle, say of three feet diameter. As there are 1,296,000 seconds of arc in a circle and all seconds must theoretically have the same value, it is easy to conceive the difficulties of dividing a circle in which the errors shall be less than a second of arc. Homogeneity of material, proportionate parts that will equally respond to small changes of temperature, and many other factors enter into this difficult problem, aside from the final corrections of the dividing mechanism.

Every approach to perfection, be it never attained, brings greater assurance to the astronomer that his results will be commensurate with the faithful and conscientious work he puts into his measurements.

It has cost an immense amount of study and application, as well as a large sum of money, but from the present indications Mr. Swasey has the promise of a full reward for his labour, as already a practical test of the engine shows that it is more accurate than any heretofore constructed. Mr. Swasey is especially interested in construction as applied to engineering and architecture, and his travels at home and abroad have enabled him to study and become familiar with much that is ancient and modern in that line.

In his address, delivered as president of the Civil Engineers' Club of Cleveland, on "The Specialist in Engineering," there are many paragraphs that fairly glow with expressions of his love for the beautiful in architectural design. Surely he would have been a master in this profession had he adopted it as his life work. Mr. Swasey was married before he left the soil of New England, and Mrs. Swasey has made the home life contribute in a large measure to his happiness and almost enviable success.

Mr. Swasey is past president of the Civil Engineers' Club of Cleveland, and a charter member of the American Society of Mechanical Engineers. He is often consulted in regard to important engineering matters and is called upon to assume various trusts in the commercial and business interests of the city of his adoption.

His genial good nature is apparent at home or abroad, and all who have the pleasure of his acquaintance will assent to the verdict, that he is a man among men.

ELECTRICALLY ANNEALING HARVEYISED ARMOUR PLATES ON A BATTLESHIP.

By Chas. J. Dougherty.

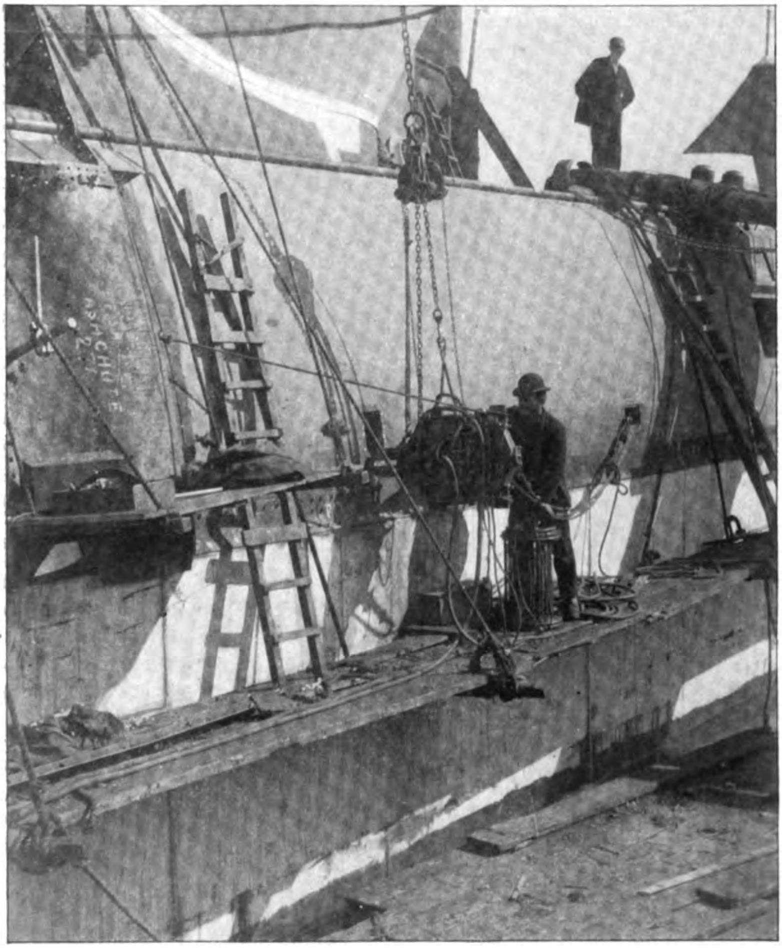
CONSIDERING the rapid development, and the many applications of electricity in the past few years to the various needs and requirements of engineering work, perhaps few people indeed realise the important part which it plays in the construction of the latest type of cruisers and battleships armoured with Harveyised steel plates.

As many times before, in other work of different character and equal importance, the subtle fluid was the only agent that solved almost hopeless problems, so also in the case of taking the temper out of certain spots to permit the drilling of holes in the Harveyised plates of some of the recent battleships of the United States, electricity has come to aid on the eve of despair and failure.

The *Iowa* is one of these ships still under construction at the works of the William Cramp & Sons Ship and Engine Building Company, at Philadelphia. She is 360 feet long, with 72 feet 2½ inches beam, and 24 feet draught, having a total normal displacement of 11,296 tons. The main battery consists of four 12-inch and eight 8-inch breech loading rifles in turrets. Her principal vital points are well protected by heavy armour. For a considerable portion of her length, a belt of armour extends from three feet above to four and one-half feet below the water line. The upper portion of this armour is fourteen inches thick and decreases in thickness from a point a foot below the water line to seven inches at the bottom. The armour, which consists of Harveyised nickel-steel plate, is imbedded in the ship's side so that its outer surface is flush with the outside plating of the vessel, while its inner surface is bolted against an elaborate system of framing, forming a portion of the hull.

For those not conversant with the Harvey process it should be briefly stated that it is the introduction of carbon, by cementation, into the face of an ordinary low-carbon steel plate, and subsequently it is water-hardened similarly to an ordinary tool. After this treatment it presents a hard-faced surface to the depth of about one inch, designed to stop and break up projectiles before serious penetration takes place.

The Harveyised plate must necessarily be secured to the structure of the ship by means of large steel bolts, and must be drilled and tapped to accommodate these. At first it was found feasible to drill and tap holes in the face of the plate at any stage of the process prior to hardening, and without detracting from the plate's resistance; but as it was impossible to locate these holes with precision without first fitting the armour into place on the ship, this method was abandoned in favour of one by which the carbon was prevented from penetrating over certain areas in the wake of the fastenings. This method also had its disadvantages in that the carbon gases frequently seeped through the protective material and carbonised the surface beneath. The experiments which were made for preventing this carburation could not be relied upon, and the great difficulty was to drill and tap such a face-hardened plate. The



ANNEALING SCUPPER HOLES IN THE SIDE ARMOUR ON THE U. S. BATTLESHIP "IOWA" AT THE CRAMP SHIPYARD.

oxy-hydrogen flame and the electric arc were applied, but the plate resisted most effectually all attempts to anneal the spots which were required to be drilled. Drills of every design and method of tempering were tried, with no success.

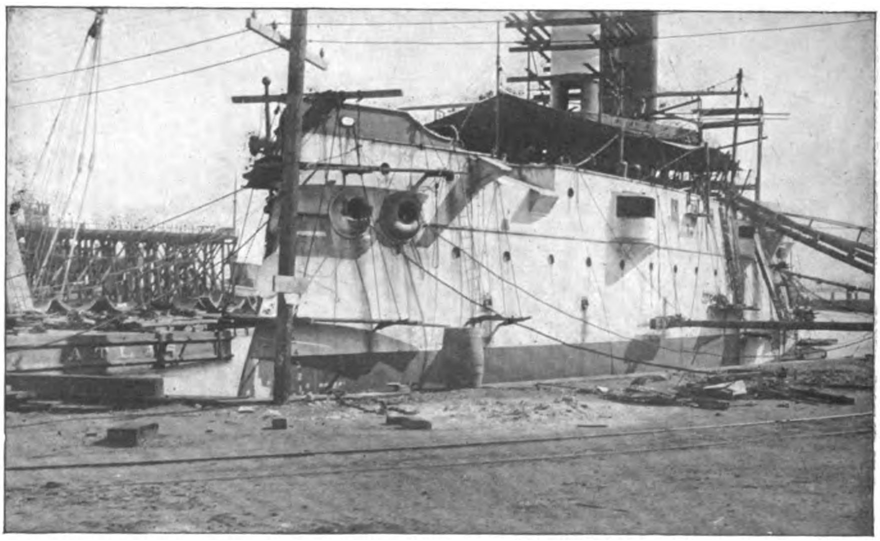
At last the Thomson Electric Welding Company, of Lynn, Mass., after a series of experiments, demonstrated their ability to anneal any surface, however hardened, by sending a current of large volume through any spot thus to be treated and raising the temperature of that spot to about 1000 degrees Fahrenheit, and at that temperature there can be no doubt that the temper has been withdrawn. One feature, however, presented itself in the fact that on taking off the heating current, the heat was so rapidly conducted away by the surrounding mass of metal, that it caused the heated spot to become chilled just as if it had been plunged into cold water. No manner of outside protection of the heated spot would prevent this chilling, and it was found that only a gradual and slow withdrawal of the current produced the necessary gradual cooling of the spot.

The apparatus which is necessary to perform the work of annealing these Harveyised plates consists of a separately excited alternating current generator of variable potential, giving a maximum of 300 volts, and a current of 100 ampères, the frequency of the generator being fifty cycles per second. The fields of the generator are separately excited by a small direct current exciter of 110 volts, belted direct to the generator from a pulley on the commutator end of the shaft, delivering to the fields a maximum current of fifteen ampères at full load. A rheostat, placed close by the transformer—the annealing machine proper—regulates the primary current in the transformer as required by the process.

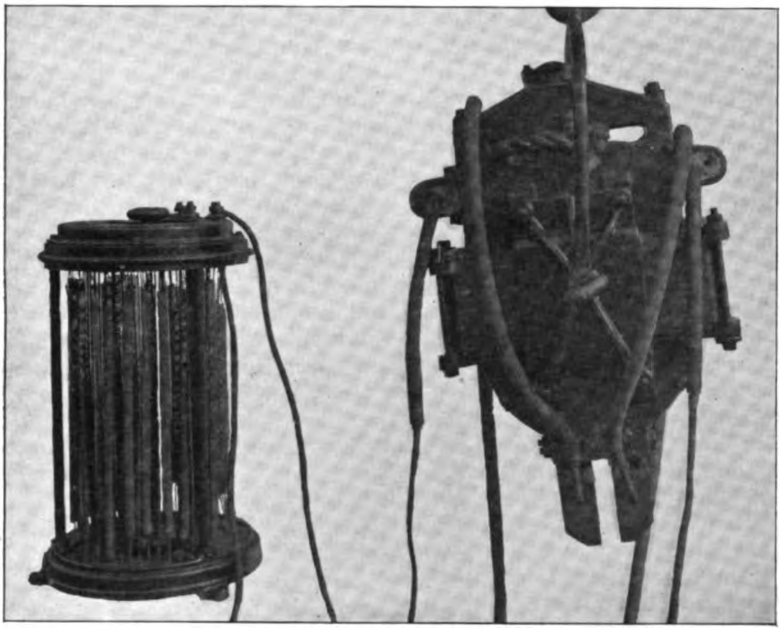
Two No. 6 B. & S. gauge wires carry the current from the brushes of the generator into the primary coil of the transformer, and two No. 8 B. & S. wires perform the same duty between the rheostat and fields. On the ship, double-pole knife switches, fuse blocks, current and potential indicators, are the necessary adjuncts to the working of the plant.

The annealing machine is a transformer similar to the well known welding transformers used in welding steel rails. It is the copper-clad type of transformer, one in which the secondary is composed of two copper castings, each having a rectangular groove, which two halves, when bolted together, form a closed rectangular frame in which the primary is held enclosed. The hollow space intervening between the primary and secondary is filled with a heavy oil called "Transil Oil," which acts both as an insulator and conductor of heat from primary to secondary. The secondary, by completely surrounding the primary, affords an excellent mechanical protection, and prevents electric as well as magnetic leakage. The latter features are quite important, since it is necessary to operate the annealer on board vessels during construction and in exposed positions; yet it may be handled with immunity from electric shocks, even when operated in rain or snow.

The primary coil consists of a copper ribbon, insulated between coils with thin asbestos. The ratio of conversion is 100 to 1. The transformer has two trunnions fastened to its sides in a line a little above the centre of gravity. These trunnions swing in bearings,—part of a yoke which straddles the whole. The yoke, in its turn, has a hook which may be secured at any place of the arch, thus allowing the trans-



THE "IOWA" APPROACHING COMPLETION.



THE ANNEALING TRANSFORMER AND RHEOSTAT.

former to be suspended, like a compass in gimbals, in any position desired.

The copper castings which compose the secondary are cut through at one place in the circuit. On either side of the cut, two short platforms form the base for the copper contacts of various shapes and sizes, by means of which the currents are made to enter and leave the plate to be annealed. These contacts are made of forged copper, hollowed out to receive water circulation for cooling purposes, and terminate in a narrow tip, rounded out at the end.

The total weight of the annealer is about 1000 pounds, and this is sufficient to give proper contact pressure for all work on a horizontal plate. When inclined surfaces are to be worked upon, the machine is suspended so that its weight shall not interfere with the contact pressure which is then obtained by bracing the contacts directly, with wooden wedges, against any object near by.

The most remarkable thing in the operation of annealing a spot is the great amount of current that is carried by the copper contacts into the plate. The contact surface itself is seldom more than about half an inch square; yet 10,000 ampères are made to flow through it continually. This is equivalent to 40,000 ampères per square inch,—a current capacity which is possible only on account of the thorough cooling of the copper contacts by continuous water circulation through them.

The operation of annealing a plate is performed in the following manner:—The transformer is placed in position, the contacts touching the plate on either side of the spot marked to be annealed. Then the primary current is brought up by means of the rheostat to from seventy-five to ninety ampères for a period of from four to five minutes. The metal attains a dull red heat, and this temperature is experimentally found by holding a small pine stick in contact with the plate at the spot till it takes fire. This, then, is the maximum temperature desired. The current is then diminished by turning the rheostat one point each minute till all the resistance is placed in circuit, and by this method the spot is gradually cooled, and the chilling of the plate prevented. The operation of running a heat after the machine has been set takes about fifteen minutes.

Right under the contacts the metal comes to a bright cherry heat, while the portion surrounding the contacts is just a visible red, and on examining the spot after the annealing process is finished, it is found to be of a dull chocolate colour; and the place where the contacts have been resting is scaled and hard and cannot be touched by a tool to a depth of about a quarter of an inch.

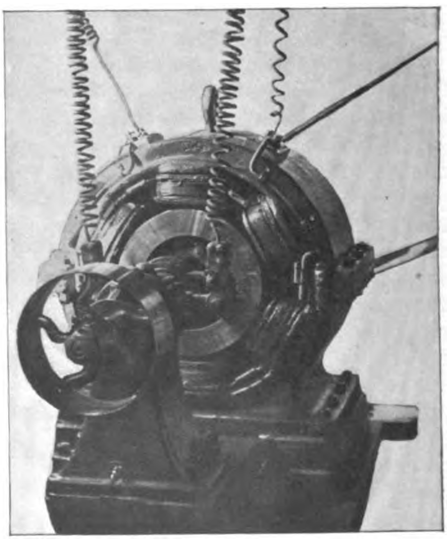
In the construction of a modern man-of-war there are many armour plates which act as shields to the guns. Some of these are circular, others oval. The only possible way to perforate these shields was after carburation and before being water-hardened, until the discovery of the electric annealing process above described. But to-day these plates are cut in various shapes to suit the work, by simply annealing a series of spots forming the shape of the hole to be cut and finally running a cutting tool over the surface thus annealed.

It sometimes happens that the Harveyised plate must have a certain length cut off to suit certain work after delivery at the ship yard, and this occurred in several instances on the *Iowa*. In place of annealing a line of holes down the plate in the same straight line, side by side,—a slow process, indeed, since the machine must be set for each individual hole,—a more expeditious method was followed. It will be remembered that earlier in this article special attention was called to the fact that it was absolutely necessary that the temperature of any individual spot should be gradually and slowly reduced to prevent any chilling. The effect of gradually withdrawing the heat from one spot to another was accomplished by moving the annealer, itself, relatively to the plate to be treated, the ratio of this movement, of course, depending upon the ratio at which the temperature was to fall in any particular spot to prevent chilling.

The annealer was so arranged as to be moved along a line to be annealed, the motion being obtained by an ordinary screw and nut, held in a bracket, the nut being turned at a predetermined rate controlled by a watch, and it was found that the correct speed was about a quarter of an inch per minute to ensure positive and thorough annealing. Thus the work was performed in a short space of time compared to the usual method of setting the machine for individual heats.

The copper contacts were of the simplest kind, as described before, bedding themselves into the surface of the plate, and when dragged along by the screw, raised in front of themselves a chip similar to that produced by a planing tool, and even after a day's continuous running the copper contacts were found to be intact. A number of steel chips were found lying around, thus developing the peculiar phenomenon of a hard steel chip cut by a copper tool.

Besides annealing holes in armour



THE ALTERNATING GENERATOR FOR THE ANNEALING.

plate, the annealer may be used for the reversal of the annealing process, namely for creating isolated hard spots in soft tool steel by sending a current through the spot to be hardened until it reaches a bright cherry heat and then suddenly removing the current from the machine.

On the *Iowa* two complete annealing

plants have been at work constantly, night and day, Sundays inclusive, for a period of three months. Six hundred holes have been annealed in the side armour, 800 holes in each of the 12-inch barbettes, and about 500 holes in the diagonal armour, besides many others for scuppers, mooring shackles, eye pads and other fittings, in the belt armour.

Current Topics.

THE protection against rust of bright parts of machinery, when put out of service for any appreciable length of time, becomes an important matter indeed in those countries of the South where there is a "rainy season." In the sugar factories of Cuba, for example, it became a practice long ago to bury the parts to be protected in air-slaked lime, and long lime troughs are, therefore, characteristic adjuncts to the equipment of every one of those establishments. At the end of the cane grinding season the machinery is dismantled, and everything about it that would become ready prey to the all-pervading atmospheric moisture is stripped off, packed away in the lime box, and left there in all security until again needed. The conventional coating of white lead and tallow would accomplish the desired protection nearly as well, perhaps, but putting it on and afterwards again taking it off are quite as troublesome, if not more so, than the disconnection of the machinery and its partial burial. The lime box has for many years demonstrated its efficiency and will for many more, no doubt, continue in service.

APROPOS of the constantly increasing voltages in electric transmission lines, Mr. C. P. Steinmetz, the well-known American electrical engineer, recently remarked before one of the electrical societies that while only a few years ago 3000 volts were hardly considered commercially safe, 11,000 and 12,000 volts are now use extensively, and 15,000 to 20,000 volts are under discussion. The danger limit is reached in the high-potential lines, not in the step-up and step-down transformers. Transformers can be built and operated safely at voltages far beyond anything ever thought of for power transmission. Only a few months ago Mr. Steinmetz was able to reach, by stationary transformers, a potential of 160,000 volts effective, or nearly a quarter of a million volts maximum—by the way, probably the highest alternating voltage ever experimented upon by man, if we leave out electrostatic charges and oscillatory discharges as limited power phenomena, while in his case he had practically unlimited power—a 100 kilowatt motor—behind the 160,000 volts. In line insulators considerable progress has been made, and insulators can now be secured which will not be pierced below 50,000 or 60,000 volts effective alternating potential in dry weather. When damp, in fog or rain, a considerably lower voltage will leak or creep over the insulator surface and thus short-circuit the line, and this brings us to the real limitation of transmission voltage which exists at present, the climate. In a perfectly dry climate Mr. Steinmetz would not hesitate to consider 20,000, or even 30,000 volts quite safe, while in a very damp and foggy climate, in rain and sleet, half this voltage may be decidedly unsafe.

A WATER-TUBE jail is one of the latest achievements of Yankee ingenuity. It is no longer necessary to make the prison bars so heavy and so hard that cutting through them becomes very difficult; but, instead, they are made simply of pipes, forming part of a high-pressure water system. Should any of these pipes be severed, the water would escape and quickly give warning of the break.

PISTONS and plungers, taken from engines after long periods of use, have, on several occasions, been known to explode with more or less violence under rough shop handling, showing that the dangers of violently banging them about under certain conditions are apt enough to be forgotten. It is not long ago that in a well known shop a brass plunger, which had been removed from a steamer's pump, was ordered to be broken up for scrap. Preparatory to doing this, the two men who were assigned to the job, heated the plunger to a high temperature,—near the melting point,—and then one of them brought a sledge hammer down upon it with all his power. The plunger went to pieces with a report like that of a cannon, and the fragments frightfully wounded the two men, eventually causing their death as the facts are now recalled. In this instance there was, in all probability, a cavity somewhere in the brass casting which had filled with water during the long service of the plunger, and heating the piece transformed the water into steam at an enormous pressure.

THE proper quantity of coal to burn under stationary boilers in order to secure the best possible economic results has more recently again been under investigation. The results have been given in a paper presented at the annual meeting of the American Society of Mechanical Engineers a short time ago by Mr. Wm. Wallace Christie, and are based upon the data of 108 different boiler tests, obtained from various sources, and reasonably authentic, so that the averages may be taken to fairly represent present practice. The substance of Mr. Christie's work was given in the shape of a set of curves, plotted from the figures gathered, and which showed that 13 pounds of anthracite coal burned per square foot of grate per hour gave the greatest economy in evaporation. The greatest amount of anthracite coal found to have been burned per square foot of grate per hour was 33.70 pounds; the least, 4.70 pounds. The greatest amount of bituminous coal found to have been burned per square foot of grate per hour was 57 pounds; the least, 6.70 pounds. Land stationary boilers were the only ones considered. Less than 4 pounds of coal, it was found, in the greater number of cases, had to be burned per square foot of grate per hour to produce a horse-power, and as 13 pounds of coal were found the most economical rate of combustion, 13 divided 4, or 3.25 horse-power per square foot of grate per hour are economically attainable. In the case of bituminous coal 23.8 pounds burned per square foot of grate proved an economical rate of combustion, and 23.8 divided by 4, or 5.95 horse-power per square foot of grate per hour, are, therefore, economically attainable. The averages of the whole number of tests were,—3.64 pounds of coal per horse-power developed per hour; 3.04 pounds of combustible per horse-power per hour; and 18.16 pounds of coal per square foot of grate per hour. These figures are for both anthracite and bituminous coal.

THE most expensive product in the world has latterly been the subject of some inquiry with the result that the metal gallium has been put at the head of the list with the approximate value of about $100,000 or £20,000 per pound. Following this have been placed the metals beryllium and lanthanum, a pound of which is held at $10,000, or about £2000; rhodium and thorium, which is said to be worth $6000, or £1200 per pound; didynium and rubidium, worth $4000, or £800; indium and tantalum, $3500, or £700; erbium, niobium and yttrium, $3000, or £600; and ruthenium and vanadium, worth $2000, or about £400. Ambergris, a secretion of the whale, has, similarly, been said to be the most expensive organic substance known, with a price of $600, or £120 per pound weight.

THE comparatively recent demolition of the well-known Soho Foundry at Birmingham, England, has prompted Professor John E. Sweet to kindly contribute to these pages the accompanying sketch of the original Soho Works of Boulton & Watt, together with some interesting historical data. Professor Sweet writes:—"While living at Smethwick, one of the suburbs of Birmingham, in the winter of 1862-3, I was told that they were tearing down the old Soho works of Boulton & Watt at Handsworth, about a mile and a half away. I naturally had an interest to see it and reached there when they had the left half down nearly to the central tower. I made a sketch of what remained and have had this drawing built up, showing fairly well how the building must have appeared. If I remember correctly, Mr. Boulton was in business before the partnership between the two great men was established, and no doubt at this place. I think it must also have been used by the firm before the new works at Soho

THE OLD SOHO WORKS OF MESSRS. BOULTON & WATT, AT BIRMINGHAM, ENG.

were built. The sketch shows that industrial works in those days possessed some architectural pretensions and might well be copied by those who are building three-story shops. These old Soho works were about half way between the more modern Soho Foundry and Handsworth Old Church, where James Watt is buried. At Smethwick there was, at the time I mention, one of the Boulton & Watt pumping engines at work, pumping from a low to a high level canal, and it had been so working for ninety-eight years when I saw it in 1863."

"AT Spon Lane, or Oldbury, a few miles further west, there was still working a Newcomen engine, drawing coal from a mine. This engine had no protection from the weather, except a pointed board covering over the cylinder and tell-tale that indicated the position of the skip. Boiler, walking beam and fly-wheel or winding drum were all out in the open air and condensation took place in the cylinder itself. How many years old the engine was could not be ascertained, but the lad who was engineer said that his father and grandfather before him had always run the engine. This is a digression from the subject, but admissible likely as a few of the many historical items grouped around this intensely interesting historical locality."

APROPOS of the projected celebration in 1901 of the jubilee of submarine telegraphy, it seems fitting to make mention of the conspicuous services rendered by Sir Charles Tilston Bright to the cause of Atlantic telegraphy. In his earlier days, he became famous as the engineer who carried out a large proportion of the telegraph lines constructed in the United Kingdom, as well as the first cable to Ireland in 1853. At the age of 18 he became engineer to the Magnetic Telegraph Company, and in that capacity, a year later, laid a system of telegraph lines under the streets of Manchester in the course of a single night without disturbing the traffic, thus completing telegraphic communication between London, Manchester and Liverpool for the first time. Subsequently, as detailed in "Men of the Time," he joined with the late Cyrus Field, in projecting the first Atlantic cable and after demonstrating the feasibility of the submersion and working of such a great length of submarine conductor, the possibility of which was, at that time, doubted by many scientific men, he with his friends, raised the bulk of the capital for the enterprise. Finally, in 1858, as engineer-in-chief, he took charge of the expedition and successfully laid the first cable between Europe and America. For this service to his country he was rewarded by the honour of knighthood, at the unprecedently early age of twenty-six.

SIR CHARLES T. BRIGHT.

AFTER laying various other cables in the Mediterranean and elsewhere, he was engaged by the British and Indian Governments to carry out the communication between Europe and India. This was accomplished in 1864 by the laying of a cable at the head of the Persian Gulf to Kurrachee under his personal superintendence. In 1868, Sir Charles laid a cable from the United States to Cuba, and followed this up in subsequent years by establishing the first telegraphic communication with Central and South America, connecting the British and other colonies of the West Indies. Later on he was appointed a commissioner by the Foreign Office of Great Britain, to represent his country at the French International Exhibition of 1881. In the jubilee year of the Queen's reign he was elected president of the Institution of Electrical Engineers. Sir Charles was a fellow of various learned societies and an officer of the Legion of Honour. On the occasion of his death the London *Times* very aptly said that "if a man's life is to be measured by the work he accomplishes, Sir Charles Bright has lived long, though dying at the early age of 55. Few men have ever crowded more, and more useful, work into 27 years."

IT has become quite the regular thing to give the steam boilers in any town or district all, or nearly all, the credit for whatever smoke pollution of the atmosphere there may be, and yet they are by no means the worst offenders. Steel and iron furnaces have always added conspicuously to the general discomfort arising from the evil, and where they exist in great numbers their producing capacity in this respect completely overshadows that of any other form of coal fire. This point was emphasised recently in *The Engineer*, of London. In the old days of puddling, as there stated, it was simply impossible to prevent smoke from the furnaces, because, during certain stages of the process, a deoxidising flame had to be maintained over the metal under treatment, and the admission of air was purposely checked. At such times a furnace would evolve volumes of smoke. The puddling furnace is almost a thing of the past, but no mill manager likes to see so much air admitted to his heating furnaces that oxidation may readily take place. Apart from this, it is a very difficult matter to work a large heating furnace with raw coal in such a way that it will not liberate volumes of smoke. The only way out of the difficulty lies in gas firing. But it must be admitted that for certain purposes gas firing does not answer as well as raw coal. It is possible that the objections to its use may be overcome; but there they are, and the attempt to render some places smokeless ought to take the form of a propaganda in favour of the producer and the regenerator. For the Siemens-Martin process, it is true, they are indispensable, but for metalliferous work generally their use appears almost to begin and end with the open hearth. Producer plant is enormously expensive, but it pays well in the long run, and in many localities a great work could be done if only firms would put down and use gas firing plant instead of raw coal. In this many manufacturing towns will find salvation. But even then one can, perhaps, hope only to see smoke abatement effected, not smoke prevention.

COMMENTING further on this, *The Engineer* aptly remarks that nothing is easier than to sit at a desk and pen denunciations of smoke. Probably no individual living has a good word to say for smoke in the air. Any utterance indeed, however extravagant, concerning it, if only in the way of denunciation, is sure to be popular. But the very fact that this is the case ought to induce writers to stop to think whether, after all, there is not some method in the madness of great towns. If hundreds of thousands of people complain bitterly, and invoke the aid of the law to abate a nuisance, and yet the nuisance is suffered to continue, it seems to be evident that something can be said for the nuisance. Some purpose is served by it. The intelligent, able men who manage mills and forges would not suffer the evil to prevail if they saw their way to dispense with it. So long as this fact is overlooked, or its importance undervalued, so long will the smoke nuisance continue. Furnaces smoke because smokeless combustion will not effect the intended purpose; and those who want to effect a change for the better, and to obtain purer air in their cities, must give up the old parrot cries. It is quite easy to so burn coal that it will not make smoke. But a considerable section of mankind has to be shown how to make smokeless fires always answer any and every purpose.

MIXING compressed air with the steam in an engine cylinder with the view of securing greater economy, owing to reduced cylinder condensation, has been a favorite engineering topic for many years, and experimental investigations have been made on several occasions to determine just what economic benefits might be hoped for from the practice. The latest of these trials, which were carried out not long ago at Stevens Institute and seem to have been very carefully conducted, ought, for a time at least, to put a damper on further agitation in this line, having demonstrated pretty clearly that when all the circumstances are duly considered there is no saving to be obtained from the admixture of the air. Four series of tests were made with air at different temperatures and in various proportions, and in these the best results showed a saving of about 7 per cent., but this was almost exactly offset by the power required to compress the air.

OIL-FED twist drills are now put on the market by the Morse Twist Drill & Machine Co., of New Bedford, Mass., and appear to be fashioned on about the same principle as the lubricated milling cutter mentioned in the January number of this magazine. The drills are provided with small tubes passing down the body of the tool from shank to point. Oil is forced into these at the shank end, and by its escape at the bottom of the hole being drilled, it lubricates the cutting edges of the drill far more effectively than is possible by the older method of squirting oil into the hole from a can. A minor advantage claimed for the tool is that the oil, as it flows outward through the hole, assists in the removal of the chips. Drills of this kind, like the lubricated milling cutters, should give good accounts of themselves. The principle is an excellent one.

CONTINUOUS rails, made up of ordinary rail lengths, welded together electrically, are in use on many miles of electric street railways in the United States, and with excellent results too, having shown themselves to constitute an ideal track. Whatever misgivings may have arisen at one time as to the serious pranks which expansion and contraction might play with such continuous tracks, have been effectively allayed, as experience has shown that the difficulties likely to grow from these causes are not extraordinary. It is interesting, however, to note that of the troubles from temperature variations in the track, that due to a temperature lower than the one at which the rails were welded is the only one requiring serious consideration. It is found in the tendency of the rail to shrink in a longitudinal direction and this must be counteracted by a pull on the ends of the rail sufficient to produce a corresponding amount of stretch. Temperatures above that at which the rails were welded, cause compression, and this has never been found to make trouble where the track was at all secured by the roadbed.

IN a discussion of the continuous-rail problem in a recent number of the *Street Railway Journal*, Mr. Ward Raymond points out that in view of the circumstances just cited, one aim, clearly, should be to have the rails, when being welded, at as low a temperature as possible. Most of the track welding has heretofore been done during the summer season when the ground and rails were warm; but where track has been welded in fall, a remarkable decrease has been noted in the number of track breaks. Experience, therefore, Mr. Raymond says, would seem to point to the winter season as the time for welding continuous track as then the rails are materially contracted, and though exceptionally cold snaps may be productive of a slight state of tension in the rails, yet the maximum stress would be nothing like that in rails welded in the summer, and probably far below the strength of the welds. The idea that unsettled and inclement weather should be looked for in winter to interfere with the work is more an imaginative than a real evil. To be sure, there will be bad days, but taking them through a month they are not so many as, on first thought, appear. In some places objection may be made to opening the streets at this time of the year, but this question will not often arise and the advantages to be gained by welding at this season are so great that they should weigh heavily against this objection where it can be overcome.

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STEAM · ELECTRICITY · POWER

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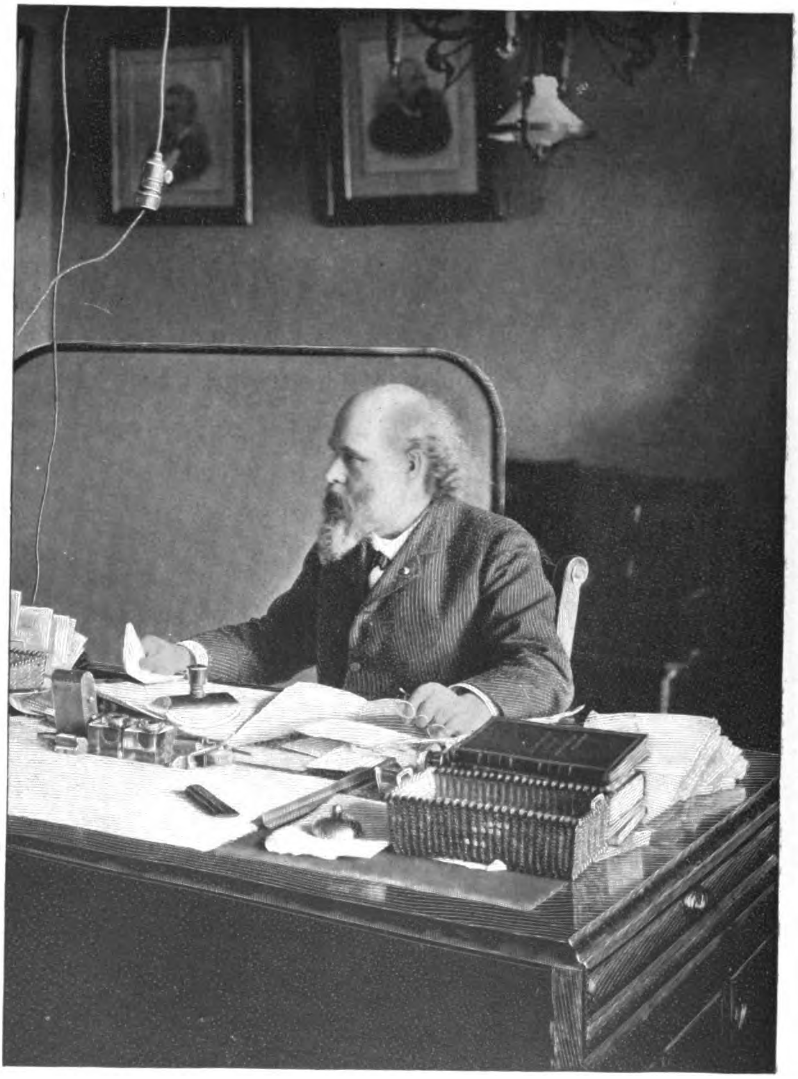
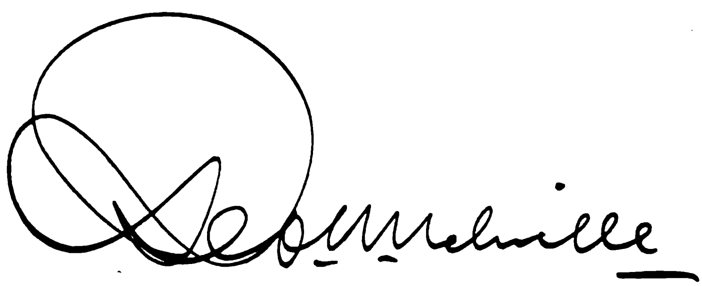


FROM A PHOTOGRAPH BY HART, BROOKLYN, N. Y.



ENGINEER-IN-CHIEF OF THE UNITED STATES NAVY.

CASSIER'S MAGAZINE.

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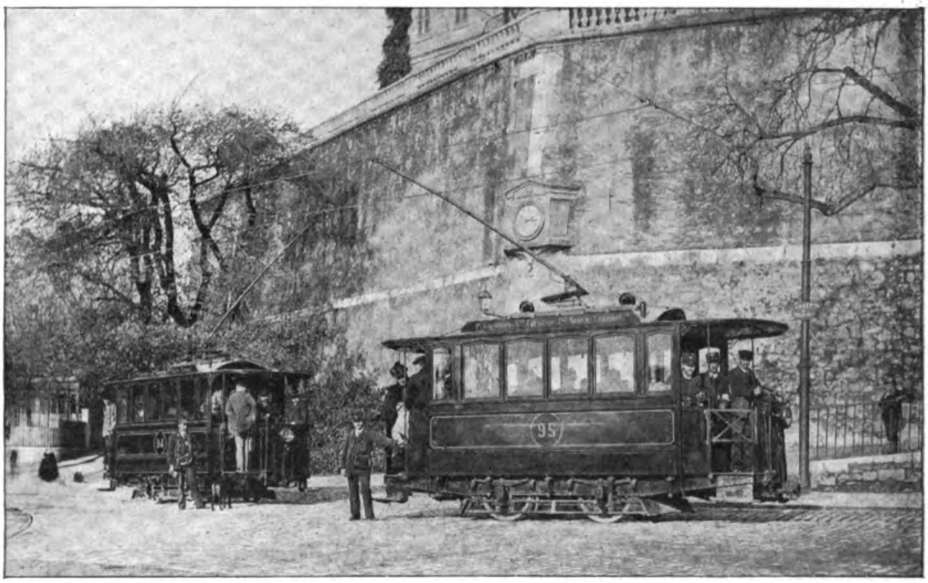
ELECTRIC TRACTION IN CITY STREETS.

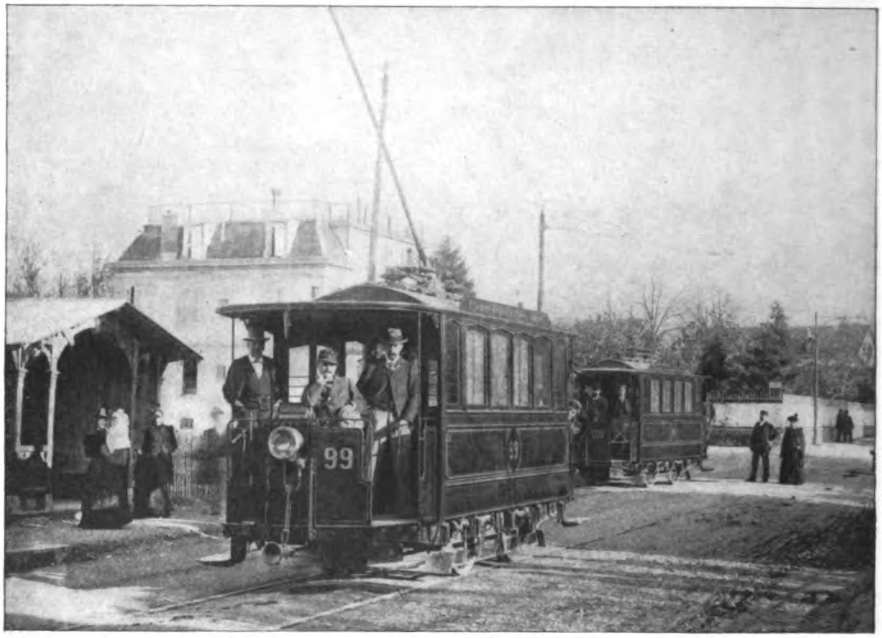
By Nelson W. Perry, E. M.



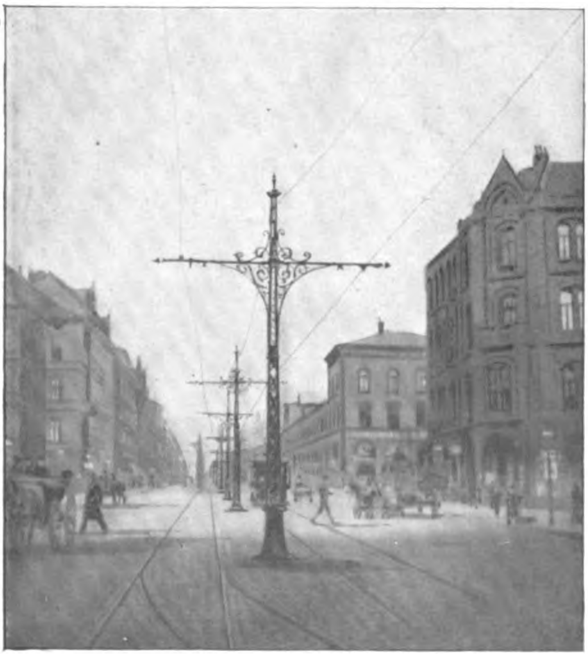
OVERHEAD TROLLEY CARS AT GENEVA, SWITZERLAND.

WITH the official announcement, recently made, that electric traction is to be substituted for horses on the several street car lines in New York City, interest in the means now available for such purposes is revived, and it may not prove amiss at this time to present the status of each of these methods in purely disinterested professional circles. The relative merits of the overhead and underground trolley and the storage battery systems have been very fully discussed and the opinions of leading electrical engineers are fully on record.

The chief causes for differences of opinion which still remain are the many local conditions which, in a general discussion of a subject, cannot be given their proper weight, but which in local cases



ANOTHER GENEVA STREET VIEW.



A TROLLEY LINE AT HANNOVER, GERMANY

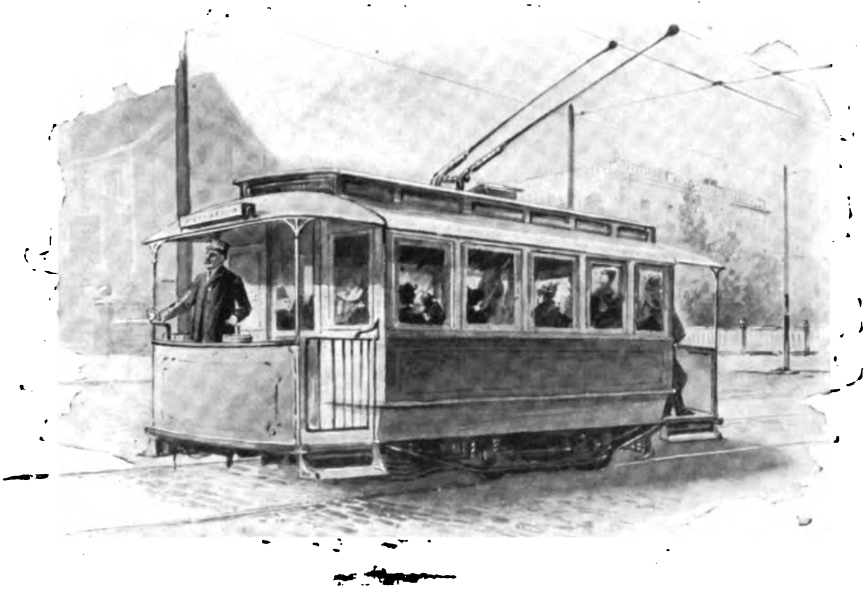
might be, and often are, controlling. For instance, in an electric lighting project, reliability of service is of far more importance than simple economy and the best engineering talent hesitates not to sacrifice economy of installation and operation for reliability of service. But just where to draw the line to the best advantage is not always quite clear, and in such cases there is room for legitimate differences of opinion.

In street railway work, reliability of service, though still important, is of far less importance than economy, and local conditions may be far more controlling than they usually are in other directions. The question, therefore, as to what system is best in a given case, may, in its practical aspect, become a complex and much-mooted one, whereas in its purely theoretical aspect it may be almost ideally simple.

Taking up the various methods of electric traction, first from the purely theoretical point of view, the overhead trolley, both by reason of its cheapness in first cost and simplicity, and by reason of priority of introduction, stands first. The overhead trolley, now so generally employed, did not, however, spring into existence full fledged.

The best electrical engineering talent was at one time divided as to how the current should be rendered available to the moving car, and some of the (now historical) most successful experiments involved the double-trolley system, with over-running trolleys. Under-running trolleys succeeded the over-running, but the difficulty and expense of insulating the positive from the negative wires, because of their necessarily close proximity, and some other causes, led to the abandonment of the double-trolley system. The latter has its advantages, however, and these are appreciated in Cincinnati, the only place in the world where the double-trolley overhead system is exclusively used.

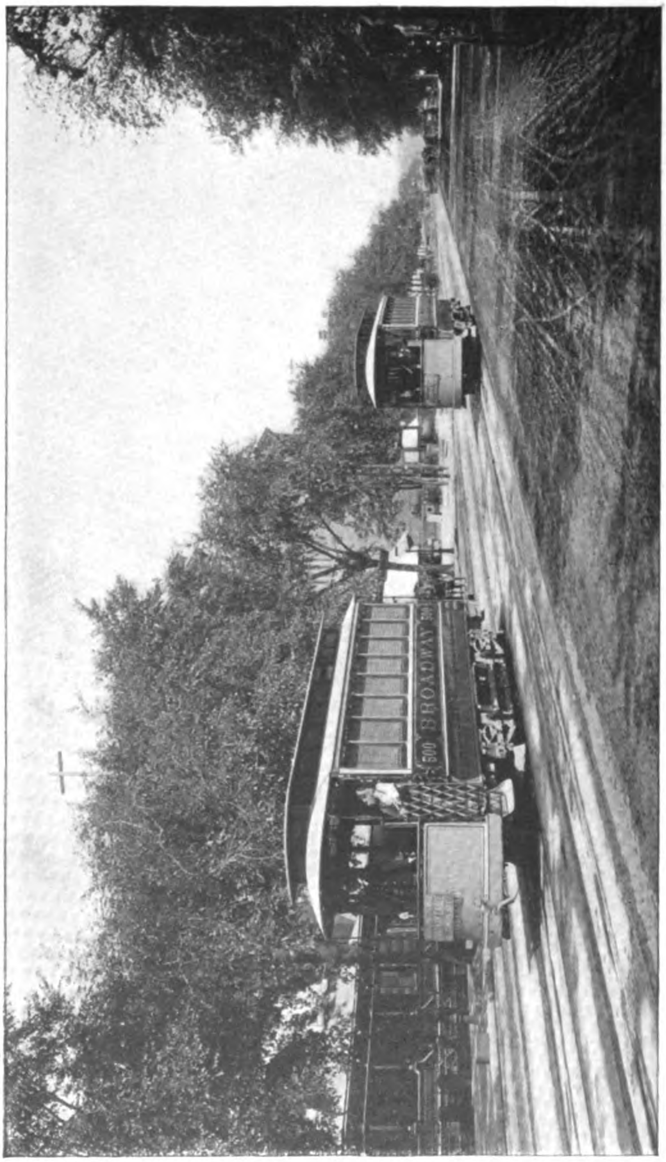
The main advantage claimed for the double-trolley system is that it renders the car independent of the track for its motive power. One of the chief disadvantages is that the two sides of the circuit, being necessarily near together, render leakage a factor of greater importance to be dealt with. Mechanically, the system is undesirable, especially in localities where trolley lines cross or intersect each other, or branch.



A DOUBLE-TROLLEY CAR AT CINCINNATI, OHIO.

It is clear that when two single wires cross each other, there is but one intersection, but when two pairs of wires cross each other there are four intersections. The difficulty is really less a mechanical one than an electrical one in this case, but, however perfectly the problem may be solved in the future, the relative merits of the systems must ever be the same.

After electricty became a commercial product, the trouble was to find some means of conveying the current to the



THE LENOX AVENUE UNDERGROUND CONDUIT ROAD IN NEW YORK CITY.

moving devices. Up to a certain time the over-running trolley seemed to be the favourite with experimenters, but it is now not thought of, except in special cases.

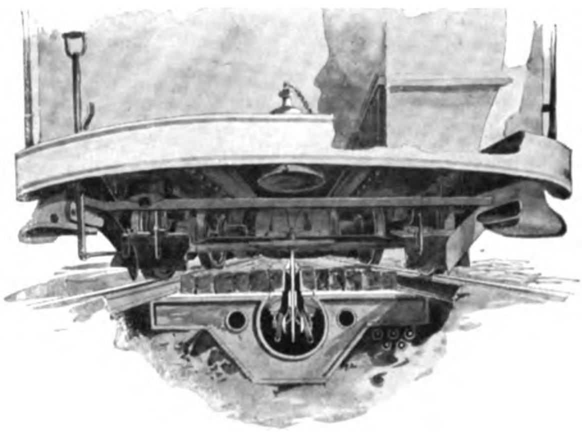
In the early days of electric railway development it was assumed that the earth was a sufficient conductor for the return current. This was one of the most potent arguments in favour of the single-trolley system. It was thought by the best experts, who at that time were telegraph men, that the rail and the earth combined made a good return for the current after it had passed through the motors and done its work.

If this were true, the single-trolley system was preferable because of greater mechanical simplicity, greater ease of insulation and greater cheapness of construction, there being required but about half the wire necessary in the double trolley system. Experience taught, however, that the track and earth unaided are entirely inadequate for the return current, and the rails are now carefully bonded, and return copper feeders are provided, so that in the latest and most approved construction the return circuit of the single trolley costs as much, if not more, than does the outgoing circuit. This being the case, the double overhead trolley construction is actually cheaper than the single trolley.

In comparatively recent years a new argument has come up against the single trolley which is not applicable to the double trolley, namely, that in any system which employs the earth as part of its circuit, a portion of the current will find its way to the gas and water pipes and other metallic underground structures in the streets, and this, when leaving these conductors by reason of finding an easier path back to the power house, causes corrosion and final destruction of those conduits by electrolytic action.

This has caused general alarm among gas and water companies, electric light and telephone companies and others owning or interested in underground conduits or cables, and the demand has been made, and in a few cases upheld by the lower courts, that the electric street railway companies whose current was responsible for this electrolytic destruction, be compelled to abate the nuisance. How to prevent it has been the subject of much scientific and expert investigation and of extended discussions at the meetings not only of engineering societies supported by electricians and the electric railway interests, but by those devoted to the gas and water and other interests.

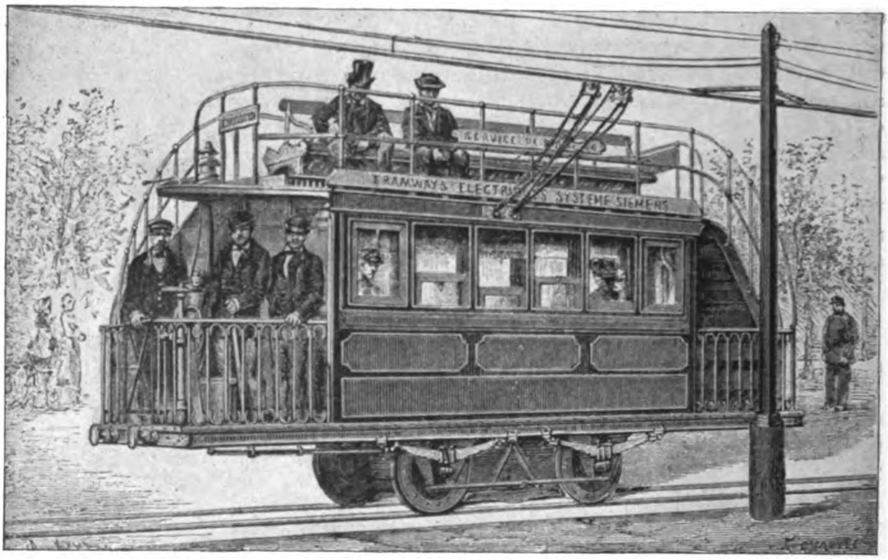
The outcome of all this has been that



A SECTIONAL VIEW OF THE LENOX AVENUE CONDUIT.

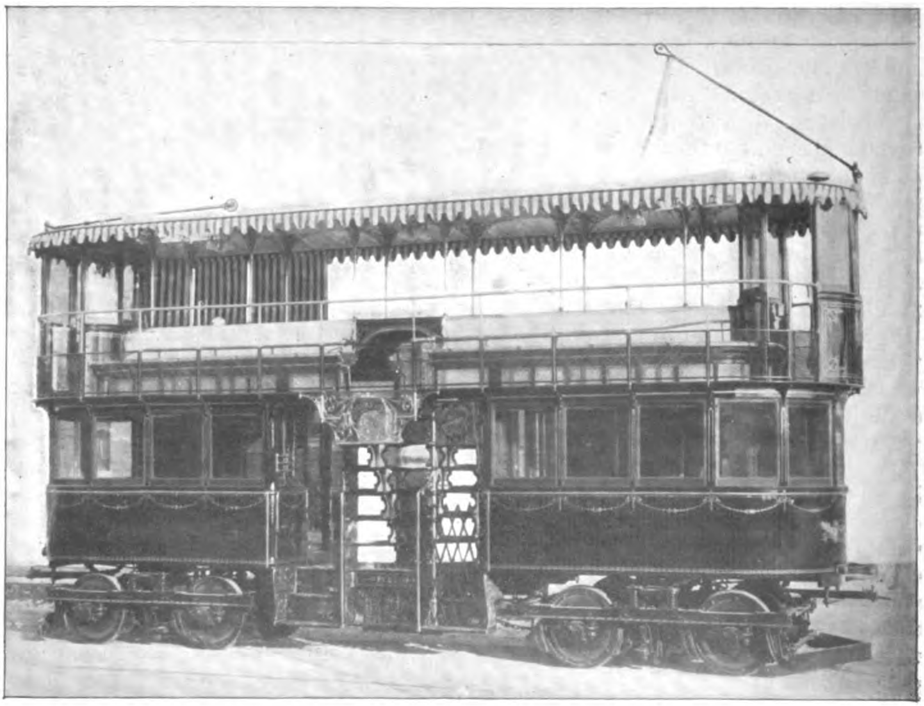
it is now all but universally admitted that so long as the earth is used as a part of the circuit, the best that can be done is to mitigate the evil and that no radical means are either practically or theoretically possible. But even with the best means now known, this evil, so insidious as perhaps not to be suspected, will continue, and it is only a question of time when its influence will become apparent. These palliative measures are merely postponing the day of reckoning.

The double-trolley system, by keeping the current entirely away from the rails and therefore away from the earth, *is* a radical cure; so also is the storage battery car for the same reason, and if



A TROLLEY CAR IN PARIS IN 1881.

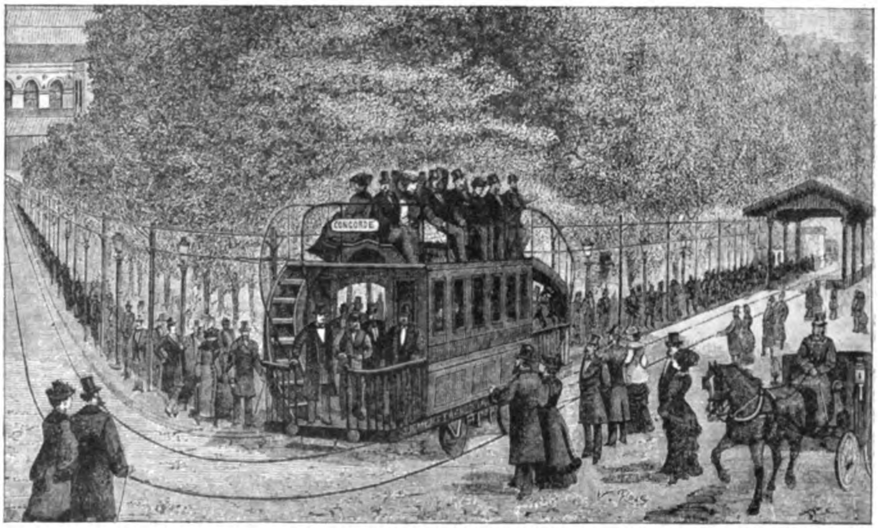
electrolysis is ever to be entirely avoided, electric traction must be effected either by recourse to the storage battery, or by a return to the now practically abandoned double trolley system. Of the two, the double trolley



A CENTRE VESTIBULE TROLLEY CAR, BUILT BY C L. PULLMAN'S CENTRE VESTIBULE CAR COMPANY, CHICAGO, ILL.

system, in the present state of the art, is altogether the most available.

We see, therefore, that the inducements to return to the double trolley are, among others, that the latter is really cheaper to construct, that it renders the operation of the car practically independent of the condition of the track and that it averts entirely that alarming, but growing and insidious evil, electrolysis. The objections to this return are the mechanical and electrical difficulties at intersections and switches, and the greater difficulty of preventing the leakage of current.



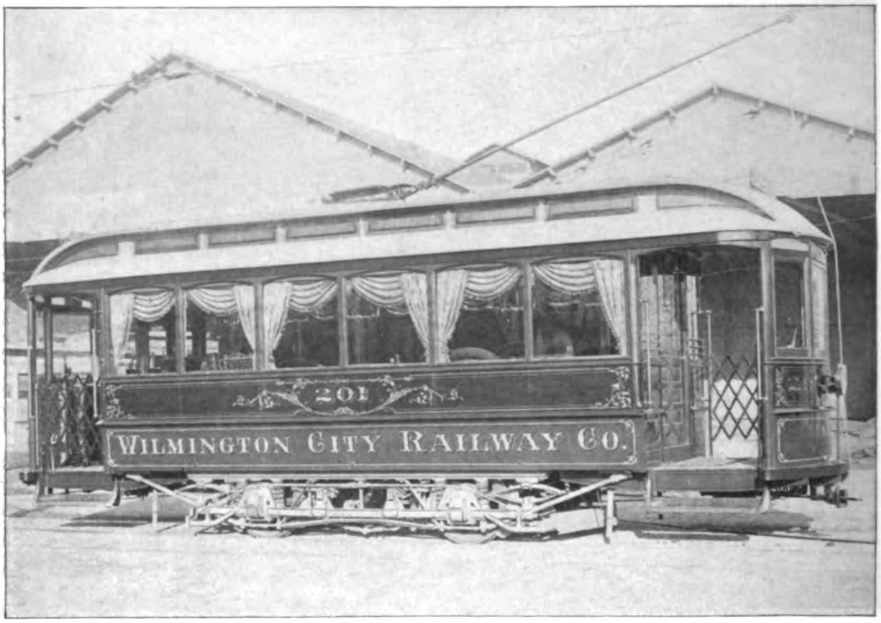
ANOTHER VIEW OF THE CAR AT THE TOP OF THE OPPOSITE PAGE.

Great as are the advantages of the double-trolley system over the single (and it possesses some not mentioned here), its disadvantages outweigh them to such an extent that the electric railway fraternity will not make the change, nor the electrical engineering fraternity recommend it unless this change is made compulsory by law.

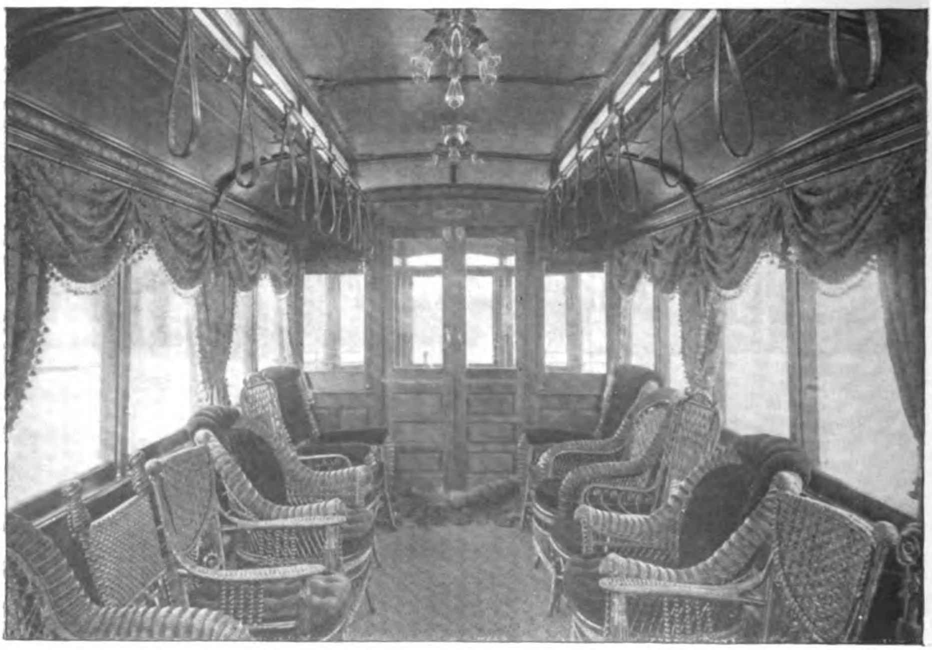
Storage battery traction, with an ideal storage battery, would be an ideal method. No overhead construction would be required, the electrical losses inseparable from all transmission methods by wire would be avoided, the mechanical and electrical difficulties of intersections and switches in conductors and the difficulties of insulation would disappear, and, equally with the double trolley system, would electrolysis disappear. And what is more important from the commercial side, the boilers, engines, dynamos and attendants at the power station might all be kept continuously employed at their best efficiency.

In street railway practice the traffic, —and therefore the power demand,— varies between very wide limits. During the rush hours in the morning and evening it is often four or five, or even ten times as great as during the slack hours of the day, and usually not less than two or three times the average of the twenty-four hours. Two or three times as much machinery must, therefore, be installed and kept in order as would be required to operate the road were the load a continuous one, evenly divided throughout the twenty-four hours, and much of this is necessarily lying idle or working inefficiently for a large portion of the time.

The storage battery would obviate all this, because, by storing the excess of power during the slack hours, this could be used during the rush hours, and thus, with a proper equipment of storage bat-



A WILMINGTON, DEL., TROLLEY CAR BUILT BY THE JACKSON & SHARP CO., OF WILMINGTON.



THE INTERIOR.

teries, only sufficient machinery to supply the average demand need be installed, and this could be kept constantly employed at its rate of maximum efficiency.

But there is now no ideal storage battery for street car equipment and there probably never will be anything approaching it, even theoretically, until a most wide and radical departure is made from the present types. The best that can be done is to use lead plates, of one form or another, as the material in which to store the energy, and dilute sulphuric acid as the liquid to be electrolysed. Both of these are exceedingly heavy and bulky. Extreme weight and bulkiness,—two qualities especially objectionable for street car purposes,—are inherent objections. They are also expensive.

To illustrate by figures:—If a street car is equipped with storage battery capacity sufficient to operate it for three hours and requires an average of twenty horse-power to propel it, the storage battery to do this service would weigh not less than three tons, or as much as forty passengers. Thus the storage battery car, when empty, must carry a load in addition to that of its motors, nearly, or quite, equal to the total passenger load of which it is capable. This storage battery would occupy a space equal to nearly, or quite, 400 cubic feet.

Two sets of batteries are required for each car in order that one set may be charged while the other is in use. The storage battery equipment for each car would cost, in the United States, not less than $3000 (£600), which is twice as much as the motor equipment would cost to-day.

ALONG THE LINE OF THE BUDA-PEST CONDUIT ROAD, BUILT BY MESSRS. SIEMENS & HALSKE, OF BERLIN AND CHICAGO.

As an offset to the saving in transmission losses by the storage battery are cited, first, the inefficiency of the battery. Under most favourable circumstances in electric lighting stations the average efficiency throughout the year rarely, if ever, reaches 80 per cent. Street car service is very far from being as favourable to the efficiency of batteries as lighting service, and it is doubt-

THE BUDA-PEST CONDUIT ROAD DURING CONSTRUCTION.

ful if it ever reaches 70 per cent.,—a loss of 30 per cent. as against about 10 or 12 per cent. in transmission by wire.

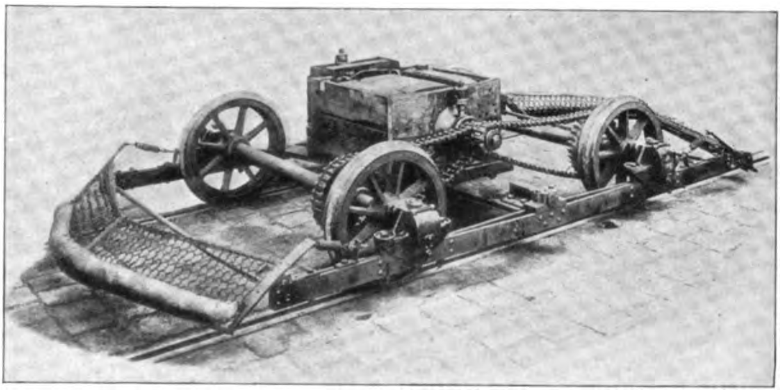
Second, and more important, is the more rapid deterioration. The jolting and swashing of the liquid, and the frequent excessive demands upon the battery lead to its very rapid destruction, so that, while for lighting purposes the life of a battery may be ten years, the life of the same make of battery, used on a street car, would be measured in months instead of years. This means, of course, a maintenance expense very far in excess of that incurred on the overhead structure, and to add to this are the increased wear and tear to the track, due to the excessive weight of the batteries.

Storage battery manufacturers seem not to be deterred by the frequent costly failures to make storage battery traction a success, but among engineers generally the opinion is all but, if not quite, universal that the inherent defects of the lead storage battery are such as to preclude the possibility of its ever being successfully applied to street car traction.

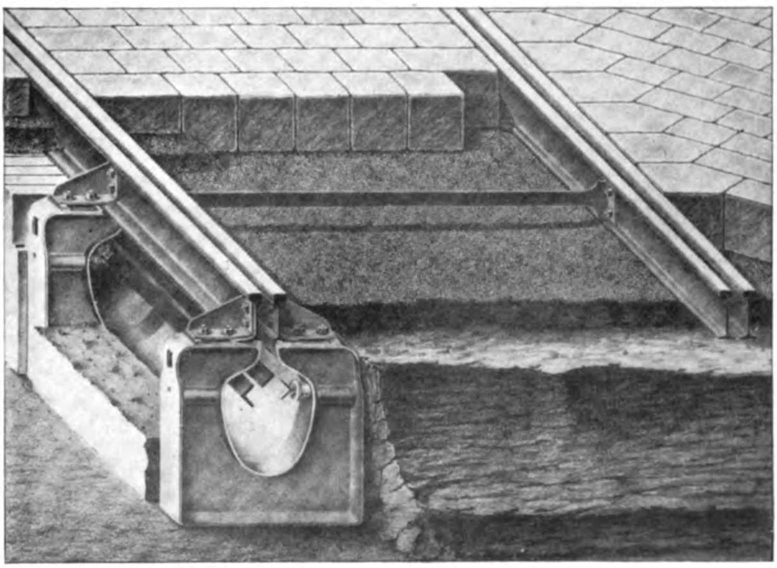
The underground trolley system may be divided into two generic classes,—the conduit system and the sectional system. These two are sometimes combined in a single plant, and in each may be found many subdivisions; but for present purposes the above classification will be sufficiently definite.

In the conduit system the trolley wires, instead of being suspended above the roadway, as in the overhead system, are carried in a conduit beneath its surface. The most approved conduit differs little from that employed in cable roads. The method of distributing the current to the cars is exactly the same as in the overhead system, so that it possesses no advantages that the overhead system does not possess, except from the æsthetic point of view.

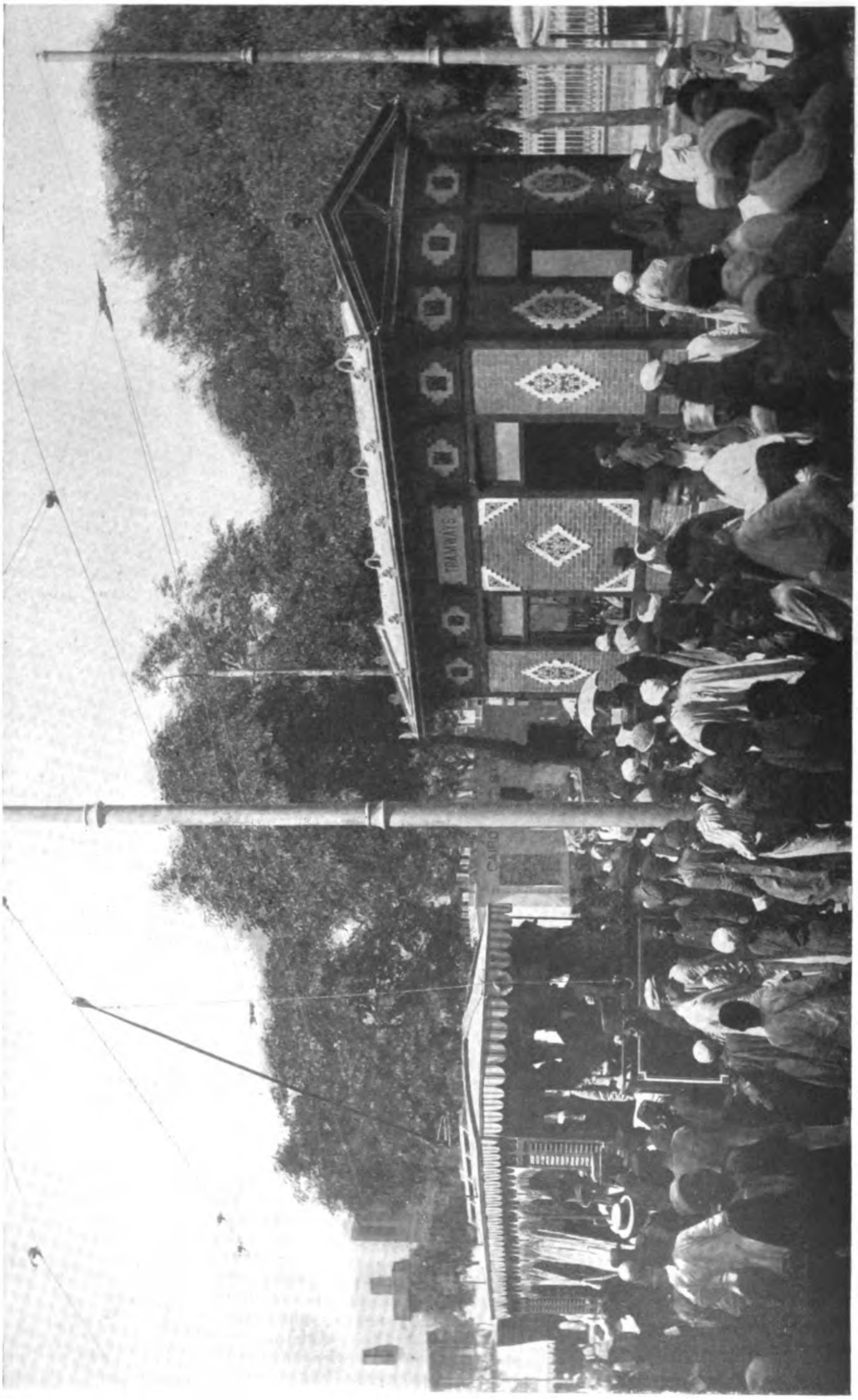
For various reasons, chiefly those of insulation, it is desirable to have the conduit as roomy as possible. Since the trolley wires or conductors must be bare and their supports are within the



THE TRUCK OF ONE OF THE BUDA-PEST CARS, SHOWING THE CHAIN GEARING.



A VIEW OF THE CONDUIT.



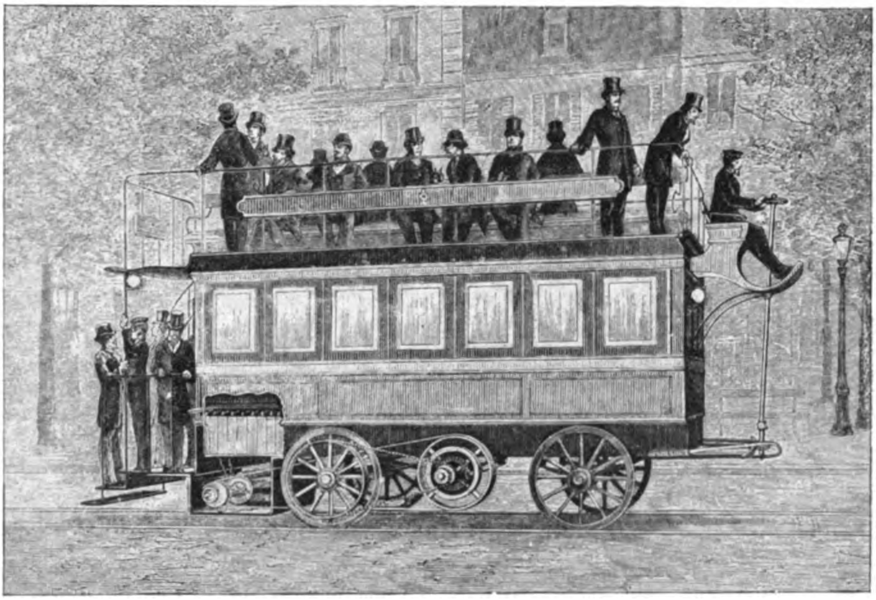
AN OVERHEAD TROLLEY LINE AT CAPE TOWN, SOUTH AFRICA.

conduit, it is far more important that the latter be well drained than that a cable road conduit should be drained. In fact, a cable conduit to which all due attention in this direction had been paid, would be totally and absolutely unsuited for electrical purposes in many cases.

It must also, owing to the greater weight of an electric car, be quite as strongly built as a cable conduit, and for this reason the expense of building it, independent of the cost of conductors and their proper insulation from the earth, will be greater under the same conditions than that of a cable conduit, and far greater than that of the overhead trolley.

But simple expense in construction is a minor matter if adequate advantages are gained. But, are they gained? By reason of the position of the wires, within a confined space beneath the ground, it is far more difficult to insulate the conductors from the ground, or to insulate the positive wire from the negative than in the case of overhead construction, and for this reason the metallic circuit or double-trolley system is rendered absolutely necessary to successful operation. It is, even then, impossible to effect the same insulation as in overhead construction, for in the damper air the best insulators partially break down, permitting the current to creep over their damp surfaces.

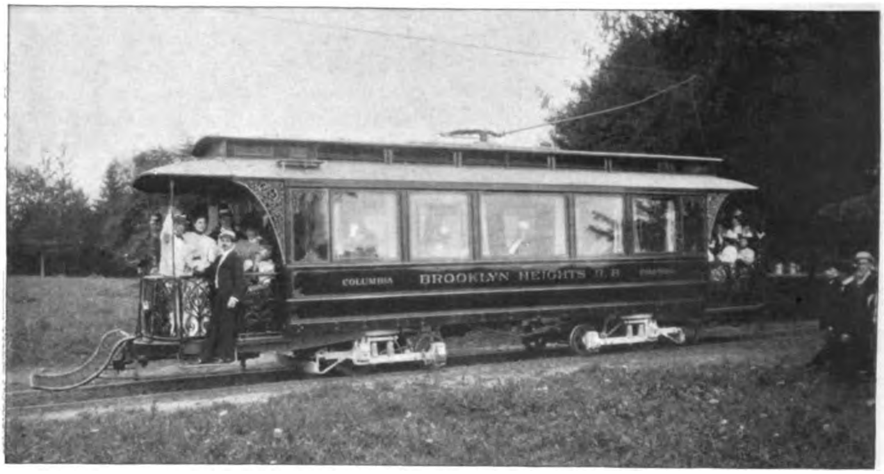
For this reason it has been found impossible to employ the usual voltage of the overhead systems, namely 500 volts, 300 volts being as high as any one seems to dare to go. In the Lenox avenue conduit system in New York City the voltage at the generators is 350 and at the further end of the line—two and three-eighths miles away,—the drop, or loss, when twelve cars are running, is 35 per cent.



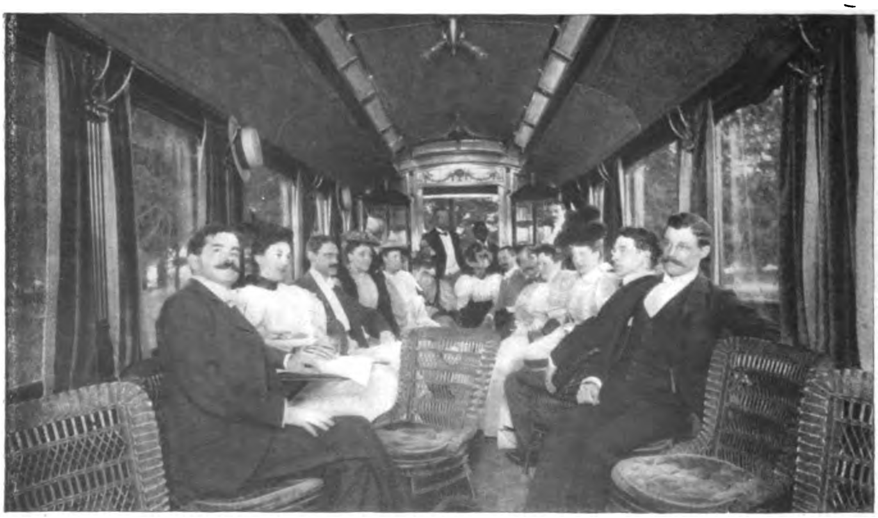
AN EARLY STORAGE BATTERY CAR IN PARIS

In the overhead construction, under similar conditions, except as to voltage, the drop would not be over 10 per cent., according to accepted engineering practice. The New York road is, therefore, throwing away 25 per cent. more energy than would be necessary or allowable in the overhead system. This means, not 25 per cent. of its coal alone, but 25 per cent. of its manufactured product, which is a far more serious matter. It means also that 25 per cent. more of boilers, engines and dynamos must be installed, and furthermore it is difficult to see how satisfactory, or even tolerable, service can be gotten out of motors subjected to a variation of 35 per cent. in voltage.

This excessive loss could be avoided by putting in sufficient copper, but to maintain the same loss on the two systems, the one operated at 300 volts and the other at 500 volts (disregarding leakage entirely in both cases), the relative weights of copper required would be as 25 is to 9. This means that two and seven-ninths times as much copper would be required on the 300-volt system as on the 500-volt system to give the same results. But the same results would not even then be attained in damp or snowy weather if the 300-volt system were in a conduit and the 500-volt system in the air.

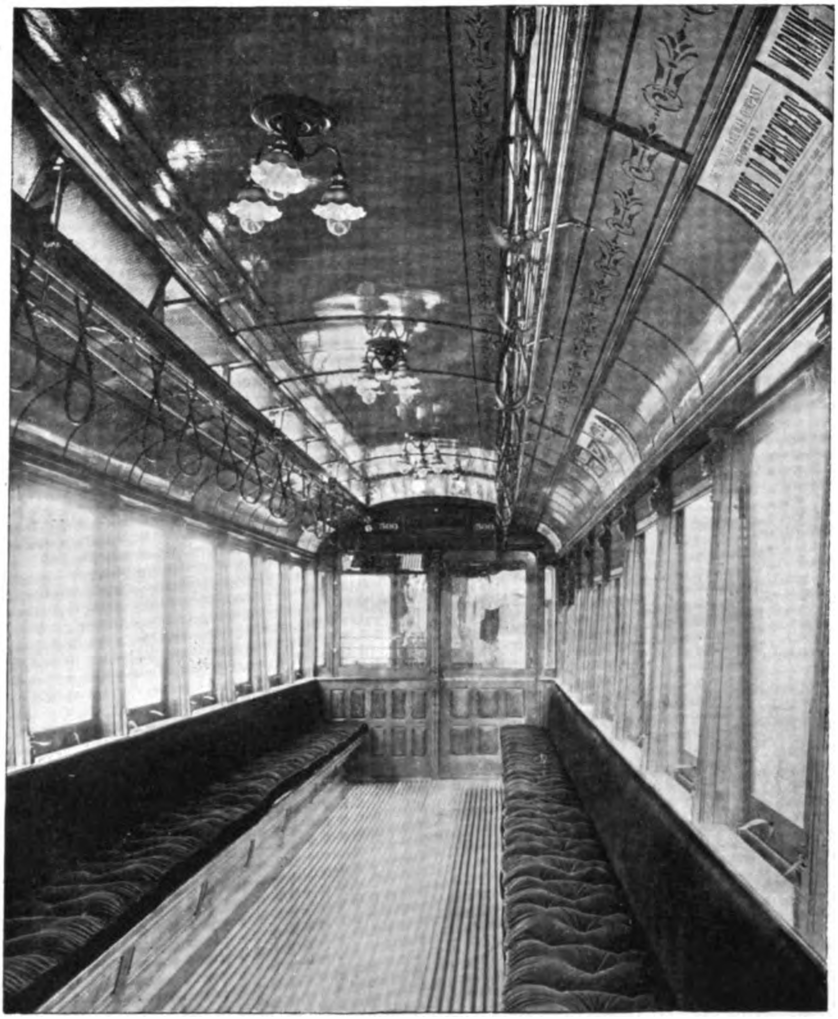


A PARLOUR CAR ON THE BROOKLYN HEIGHTS, N. Y., TROLLEY ROAD.



AN INTERIOR VIEW.

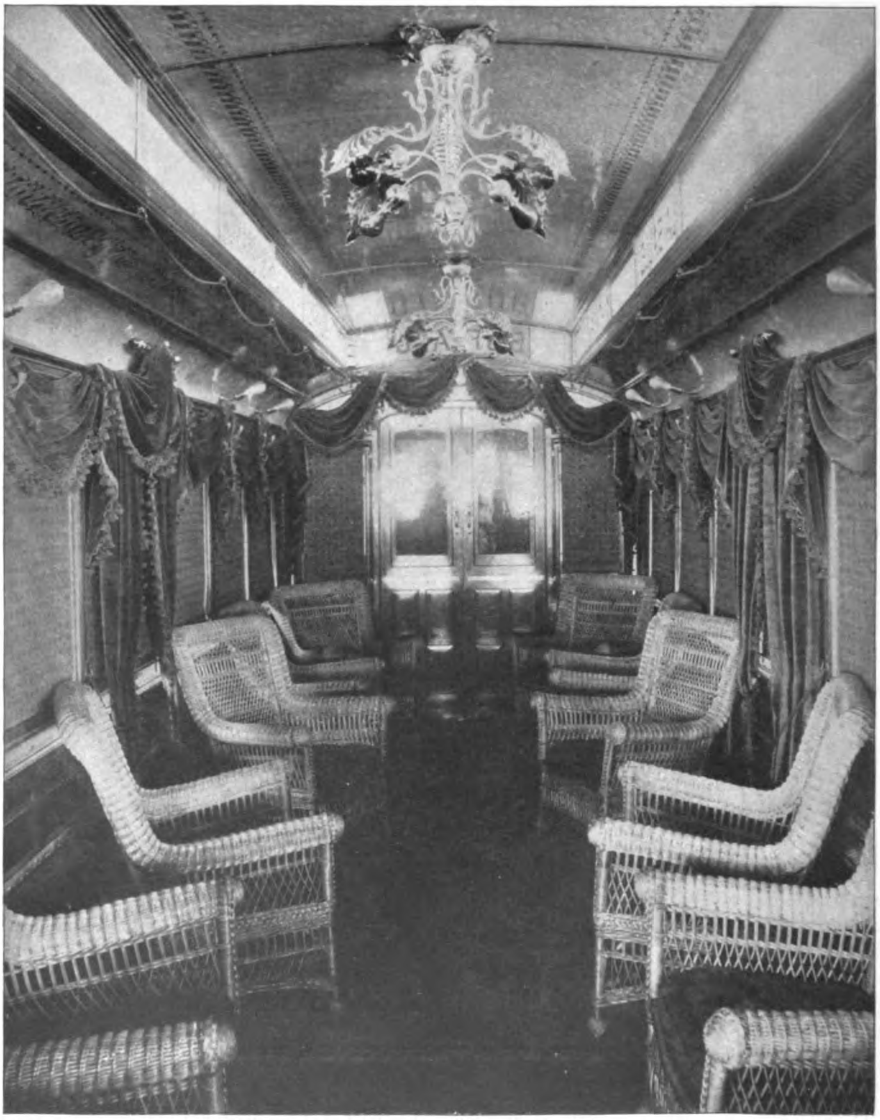
The truth of this was well illustrated



THE INTERIOR OF A CAR OF THE TORONTO, CANADA, STREET RAILWAY CO.

during recent falls of snow in New York City when the conduit lines were completely stalled, whereas the overhead trolley lines were embarrased only in keeping their tracks clear of snow. The daily papers stated the blockade to be due to the excessive leakage from the conductors, due to the presence of snow in the conduits. The authorities ol those roads, however, were quoted as claiming that it was not due to leakage at all, but to the conductors becoming covered with ice, which prevented electrical contact between the shoes and the trolley wires. Be this as it may, the fact remains that the conduit service was interrupted while the overhead trolley service was not.

It is of little interest to the public how large an investment the operating company has made, or whether it is paying dividends or not, but it may not be uninteresting at this point to compare the cost of the Lenox avenue conduit system in New York with that of the most approved overhead construction. The figures for the Lenox avenue installation are taken from an estimate in *Electricity*,



THE INTERIOR OF A CAR ON THE BUFFALO AND NIAGARA FALLS ELECTRIC RAILWAY.

based on data, most of which were from official sources, and the remainder known to be approximately correct. The figures for the overhead construction are taken from Abbott's "Electrical Transmission of Energy," 1895, and are supposed to be the outside figures for the most approved construction.

In the Lenox avenue computation it was assumed that provision was made for the full complement of cars originally intended, viz., 50, and that the best economy in copper attainable by a judicious use of feeder wires was practiced. The results as given, and they have not yet been disputed, were:—

Underground System.

Copper per mile of track	$34,214	(£6,842 16 sh.)
Conduit " "	29,832	(5,966 8 sh.)
Total	$64,046	(£12,809 4 sh.)

This figure does not include cost of laying the feeder wires, drainage or special work of any kind.

Overhead System.

Best iron pole, span wire construction	$3,300	(£ 660)
Track	5,000	(1,000)
Total	$8,300	(£1,660)

The above figures appeal more forcibly to the mind, however, when both totals are carried out to 2⅜ miles of double track. Doing this we find:—

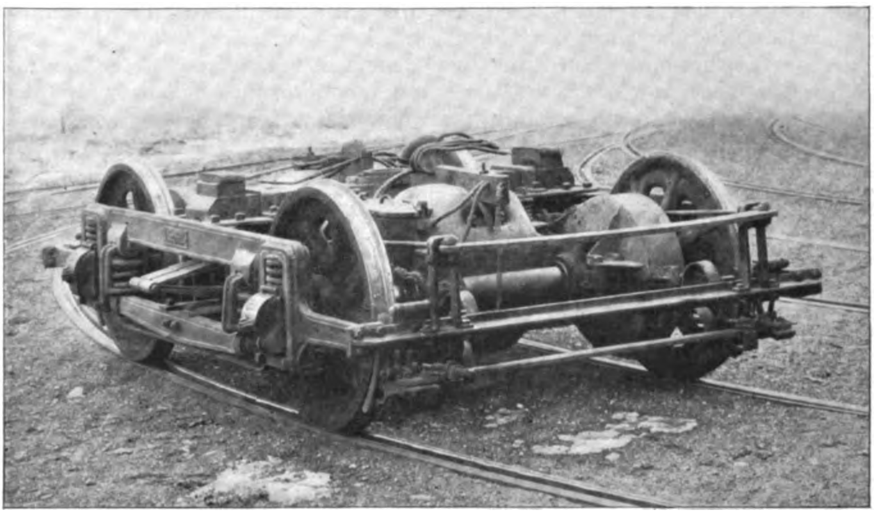
Cost of conduit	$304,220	(£60,844)
Cost same length single trolley	39,508	(7,901 12 sh.)

In both the above cases the cost of laying one mile of track is assumed to be $5000 (£1000), including paving. In New York it will cost more, $15,000 to $20,000, according to paving, being more nearly what it costs with a seventy-five pound rail.

It has been stated that the public does not care what the investment is. It does object, however, to the tearing up of the streets, for this is a very serious matter, involving, as it does, in the case of the conduit, a blockade for several months and the disturbance of water, gas and already established electrical lines. Even these might be borne, but the public is concerned as to the reliability of the service after it has been subjected to all these annoyances, and of this reliability no satisfactory guarantee can be given at the present time. It would seem that the best that can be hoped for from the underground trolley is that it may equal in service that afforded by the overhead.

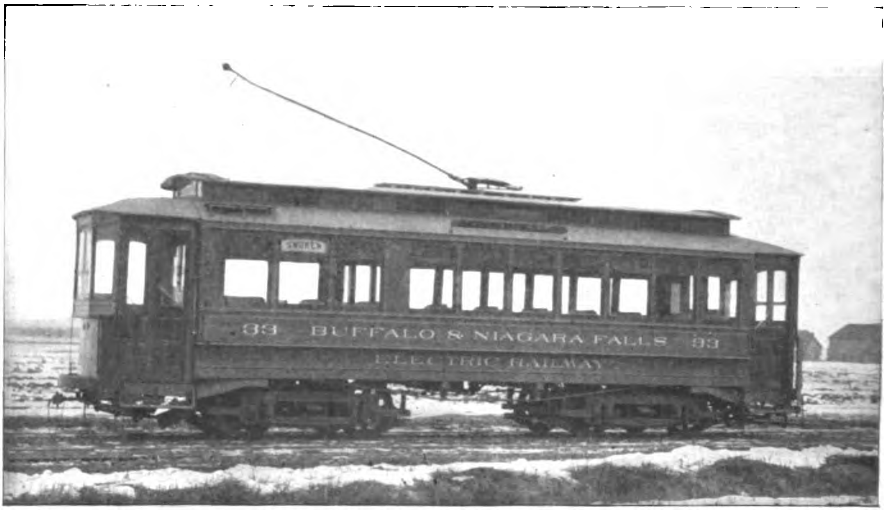
The sectional system is designed to avoid the heavy leakage losses liable to be incurred in the conduit system by dividing the working conductors up into numerous comparatively short lengths which are normally dead and therefore cannot leak, but are successively thrown into circuit as the car passes on to them, and thrown out of circuit as it passes off.

This switching in and out of circuit is accomplished either mechanically or electrically, according to the whim or choice of the inventor. Usually the length of such sections is not greater than the length of a car body. If we should assume that the length might be thirty feet, this would mean 176 mechanical or electrical switching devices per mile of single track, or double that number per mile of double track.



ONE OF THE NIAGARA FALLS MOTOR TRUCKS.

The inventors of these systems are all optimists, but the conservative engineer feels and knows that any moving device such as this, depending, as it must, for



A BUFFALO AND NIAGARA FALLS ELECTRIC RAILWAY CAR WITH SMOKING COMPARTMENT.

its reliability upon automatic action may get out of order. However reliable any such system may be, every one will readily admit that that system would be better if the switching device could be omitted. It, therefore, constitutes a weak point in that system, and in a line where these devices are as far as thirty feet apart, there are 176 weak points for every mile of track.

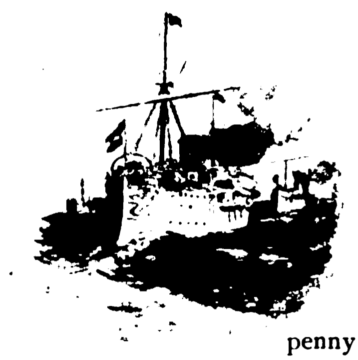
The usual duty of an electric car oftener exceeds than falls short of 100 miles a day. It therefore passes over 17,600 of these weak points every day, and should any one of them fail, it will stall that car and perhaps stall others before the difficulty can be remedied. Conservative engineers, therefore, do not look with favour upon this style of construction.

There is this to be said in its favour, however, that in the variety known as the "surface contact" system, the cost of construction is far less than for the conduit system and that if the switches and contacts do not fail to work, the leakage would be reduced, under favourable circumstances, to a figure comparable with that unavoidable on the overhead system. There are, in fact, two genera of surface contact systems. In one of these, metallic plates, separated by the length of a car body, are exposed above the street surface, and in the other, sections of rail, not longer than the car body, are exposed. In both cases the switch by which the main current is diverted to the car motor is actuated by a local current from the car passing through the plate or rail. In the first case, where the plate is small, the leakage would not be large even in wet weather, but in the latter case it would be prohibitory if high voltages were used.

The view presented in this article may seem pessimistic. It is not the picture that has been held up to the public, but it is the picture that the engineer, who knows the facts, sees.

SHIPBUILDING IN GREAT BRITAIN.

By Robert MacIntyre.



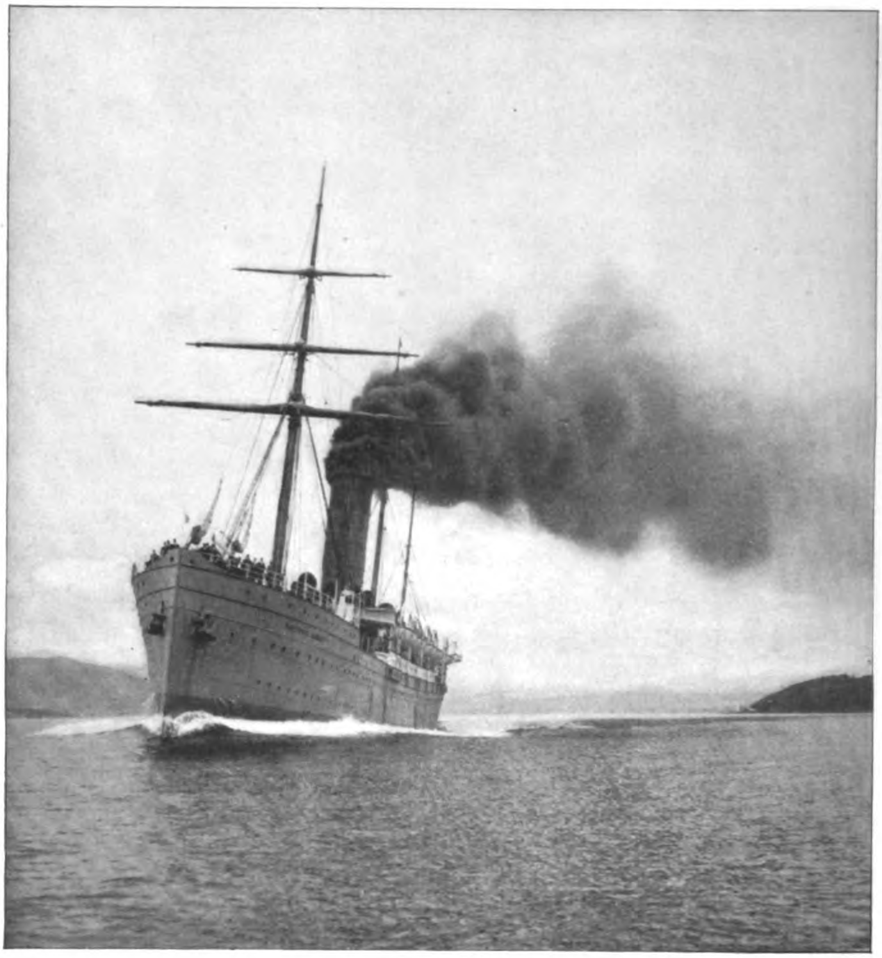
WHEN you talk in Great Britain of the ships which are built on the American lakes, and indicate in tons gross what their dimensions are, people smile and question your veracity. Lakes, to their insular view, are twopenny - halfpenny affairs, and they cannot conceive inland waters which are navigable to vessels nearly as big as the middle class Atlantic liner. From the purely American point of view this may be an amusing error, but there is compensation to Britons in the fact that those who dwell in the shadow of the star-spangled banner know practically very little about the diminutive islands which produce the biggest and the best of the "greyhounds" connecting the older world with the newer. To the average American everything that flies either ensign is British and no more; yet any Englishman, or Irishman, or Scotchman who knows anything about the sea can tell almost at a glance, not only the type or trade of a vessel he meets, but, almost to a mile, her birthplace, and, almost to a month, her age.

The shipbuilding industry is one of the biggest in the Kingdom. In it are employed thousands of men, and the effects of its fluctuations are so far-reaching that hardly a man of means or influence can afford to be ignorant of its rises and its falls. A coal strike in any important district paralyses it; trouble with the ironworkers brings it to a standstill, and with all three branches of the industrial army with "the keys of the street" in their pockets the United Kingdom of Great Britain and Ireland may safely be said to be on an involuntary holiday. Shipping and shipbuilding returns are always a fair measure of the state of trade in the country, and everybody consequently anxiously waits for them, and eagerly analyses them.

If you were to tell a native that in 1896 the shipbuilding yards of the United Kingdom built 1084 vessels of 1,391,249 tons, as against 1,154,018 tons in the preceding year, he would very likely say that that represented good business; but after his momentary exultation he would as likely ask what the types of the vessels were, and which predominated. His satisfaction at the increase in production would be speedily tempered by a fear of the effect on the freight market, and, as we say in Scotland, he "would want to know" where the million and a quarter tons had gone. To tell him outright would absorb time which the average man is unwilling to give, but if you put the table which follows before him, an hour's perusal would satisfy him. The figures in it have been compiled from returns supplied in every case by the shipbuilders themselves, and as a measure of the year's work in the Kingdom they are, beyond question, accurate.

	Vessels.	Tons.	Vessels.	Gross Tons.	Total 1896.	Total 1895.
Clyde	97	46,814	280	374,027	420,841	360,152
Forth	..	....	22	8,650	8,650	16,757
Tay	..	....	8	4,364	4,364	8,918
Dee	..	....	19	5,069	5,069	4,738
Dockyards..	..	....	9	71,070	71,970	70,350
Tyne	10	9,363	121	237,519	246,882	174,319
Wear	..	....	84	218,350	218,350	138,641
Tees	6	3,978	57	109,429	113,407	116,480
Hartlepools.	2	100	31	83,100	83,200	90,869
Humber	21	3,478	65	24,256	27,734	17,953
Mersey	1	40	14	19,266	19,306	6,972
Thames	64	1,330	35	15,271	16,601	6,110
Barrow	..	....	7	14,654	14,654	25,644
Minor ports.	62	7,073	45	13,393	20,466	14,019
Belfast	4	3,329	20	116,327	119,656	102,086
	267	75,505	817	1,315,744	1,391,249	1,154,018

Minor ports, the Forth, the Tay, the



THE ROYAL BRITISH MAIL STEAMER "DUNVEGAN CASTLE" ON TRIAL IN THE CLYDE. BUILT FOR THE CASTLE MAIL PACKETS CO., LTD. (CAPE LINE), BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD., GOVAN, GLASGOW.

Dee, the Dockyards, the Humber, the Mersey, and the Thames would be struck out at once because their productions included little or nothing that could possibly affect the money earning qualities of sea-going boats. The three Scotch East coast rivers mentioned do not by any means build leviathans, and, as shipbuilding centres, count for very little. Earle's Company, Hull, which, under Mr. Seaton's able direction has, in its day, built several fast cross-channel steamers and a warship or two, has always had to contend against a poor geographical situation, and despite the fact that it could, other things being equal, produce specimens of naval architecture equal to the best, it has failed to set the shipbuilding world ablaze. Steam trawlers, of which the Clyde and English East coast between them build hundreds every year, represent the bulk of the Humber total.

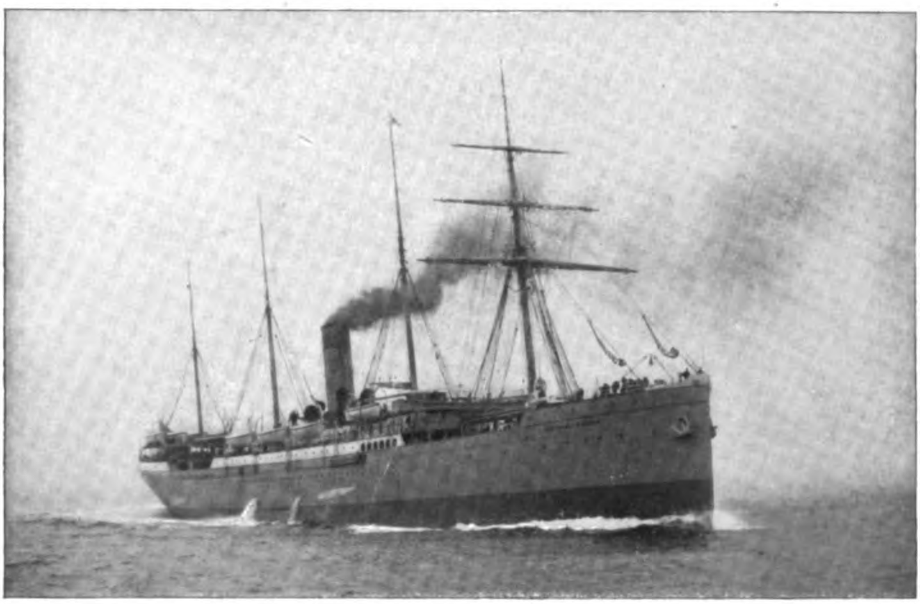
From the Mersey and the Thames shipbuilding seems to have departed. Of the Thames it is said that labour troubles brought it down from its high estate, but considering the question in cold figures, as I shall do presently, I am afraid it will be found that the cause is elsewhere. Living is dearer in London, and the metropolitan who pays the price he does for his fuel, will not have far to seek for a more satisfactory explanation.

The decline on the Mersey is more difficult to account for, and all the more because of the success which Messrs. Laird, of Birkenhead, who were in the beginning of iron shipbuilding and are likely to be in the end, have achieved. There are bigger yards in the country and more perfectly equipped ones, but from none comes better work, nor is there in any a greater desire to further the twin sciences of shipbuilding and engineering. Their torpedo boat destroyers for Britain and Chili, and their twin-screw steamers for the Irish mail service supply sufficient proof of this.

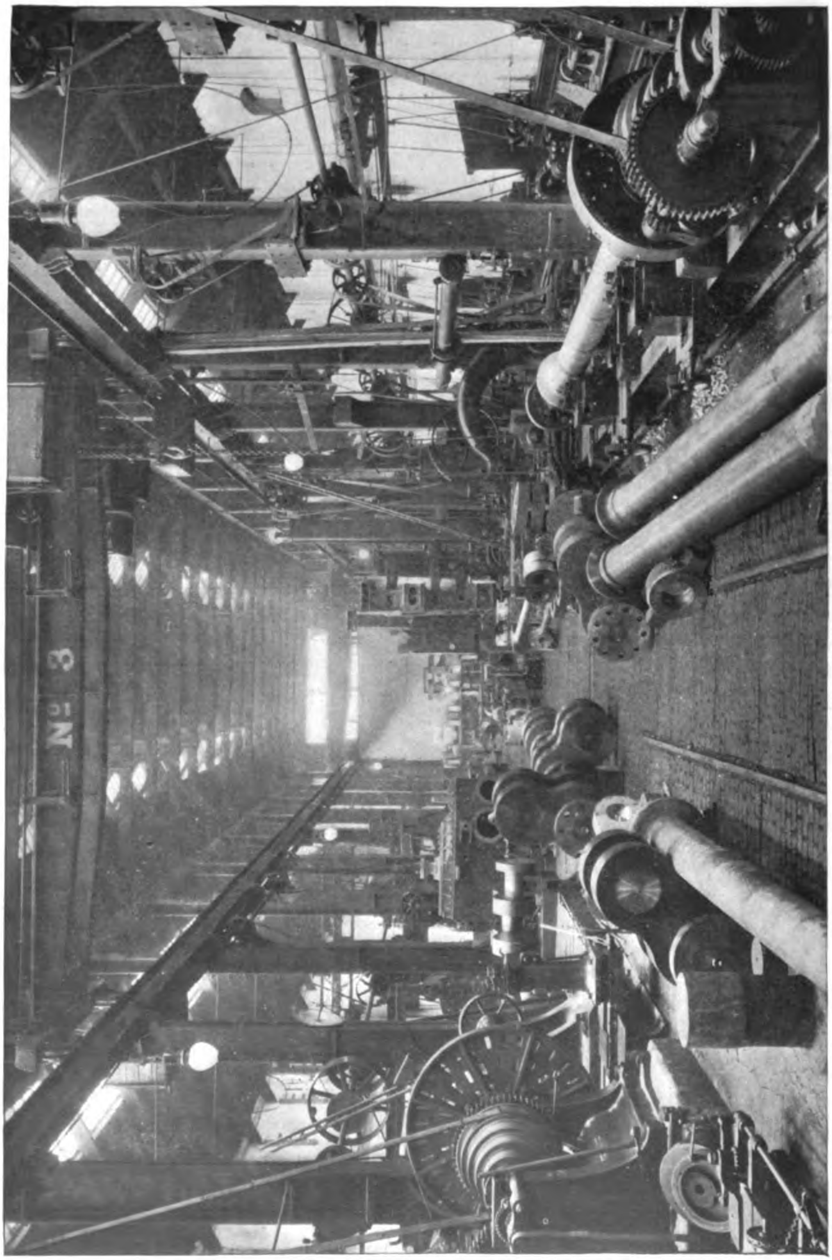
And yet Liverpool, practically in the heart of the Kingdom, is not a shipbuilding centre. But it is one of the greatest ports in the world, and that, very likely, is the reason of its decadence in the other respect. Shipping purely pays it, and with keen competition in other districts for the building of its investments there is little likelihood, unless the Manchester canal booms, of any considerable diversion of capital.

Of the others, the premier river is the Clyde, the production of whose shipyards approaches every year the combined totals of the Northeast Coast of England. On the murky stream, which has made Glasgow, the most notable vessels built have been floated, and its shipbuilders and engineers have well kept the fame that their fathers earned. Hardly a yard in the world has not its Clyde-trained experts, and hardly a man on earth—outside Scotland, of course—would believe me if I said that a hundred years ago the famous waterway was little better than a puddle.

In 1811, it was the boast of citizens that "vessels of forty-five tons" could safely reach the Broomielaw; in 1821 vessels with a draught of 13 feet 6 inches could risk it; and only the other day, so to speak, the *Campania*, the *Lucania*, H. M. S. *Ramillies*, and the *City of Rome* were all afloat on it at one and the same moment. On its banks are, roughly speaking, fifty shipyards, and depending on them are hundreds of establishments, big and little, all actively



THE R. M. S. "TONTAGEL CASTLE" OF MESSRS. DONALD CURRIE & CO.'S CAPE LINE. BUILT BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD.



THE FITTING SHOP OF THE WALLSEND SLIPWAY AND ENGINEERING CO., LTD., NEWCASTLE-ON-TYNE.

employed in one way or another, completing the work they are continually turning out.

And the speed of production is remarkable. The Hamburg-American liner *Normannia* was turned out by the Fairfield Company in nine months. Messrs. Russell & Co., of Port Glasgow, if I remember rightly, built a sailing vessel of about 1800 gross tons in less than thirteen weeks; and Messrs. James and George Thomson, Limited, Clydebank, delivered six gun boats to the Spanish Government in something like ten weeks from the date of the placing of the order.

Messrs. James and George Thomson, Limited, and the Fairfield Company are among the most famous builders on the river, but the Dennys, of Dumbarton—a race of shipbuilders known all over the world—the Cairds, of Greenock, and the Scotts of the same proverbially moist latitude, are quite as active elements.

With every possible apology to the Tyne, I must admit that the Clyde's most serious rival in shipbuilding is Belfast. Its production in 1896 is magnificent testimony to the skill and business capacity of its citizens, and the White Star steamers which Messrs. Harland & Wolff have built constitute a record of which any district might be proud.

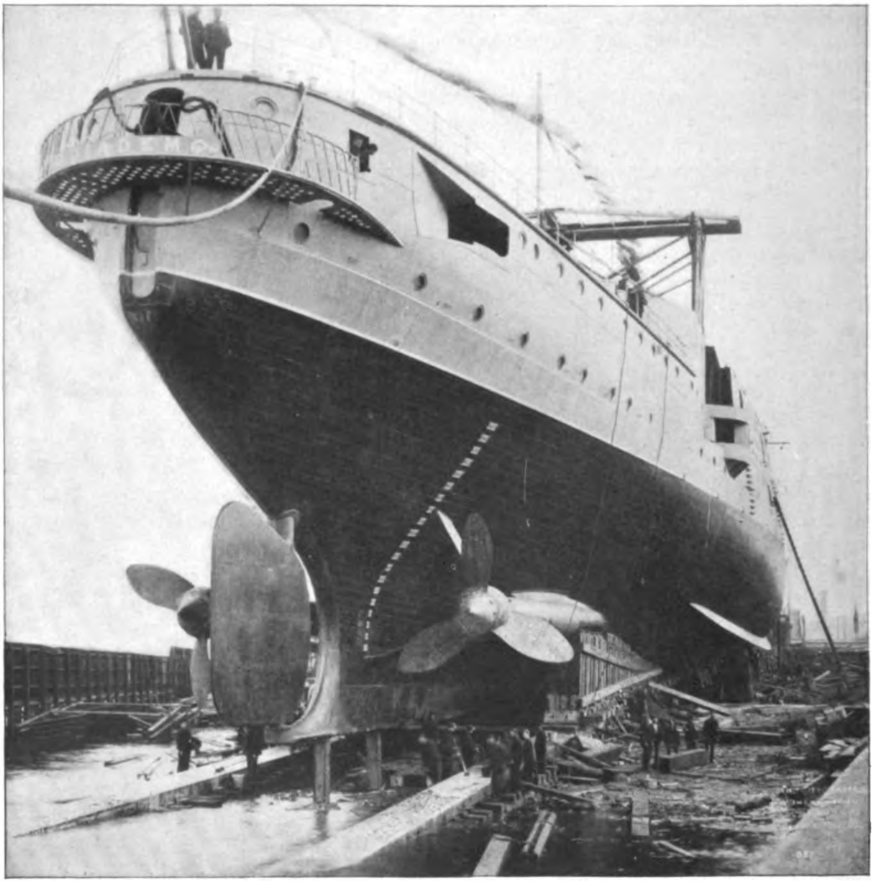
Over breakfast once—at Barrow, it was, when the cruiser *Powerful* was launched—I discussed ships and shipbuilding with an unassuming gentleman who, to the eye, seemed scarcely able to distinguish a liner from an omnibus. But before the sun set I had other views; my acquaintance was the late Sir Edward Harland, and of Belfast's chances as a shipbuilding centre my views became decidedly optimistic.

Barrow is another important rival of the Clyde, but it has drawn its best brain from the old river. Mr. Byce Douglas, who first directed it, was one of the late Sir William Pearce's henchmen in the palmy days of Fairfield, and Sir Adamson, who succeeded him, is another of the sons of Clutha; in fact, there is hardly a man of any note on the staff who does not boast of Clyde training.

On the English Northeast Coast the Tyne is supreme, and in many respects it is a serious rival of the Clyde. When I remember the waterway first, the Palmer Company at Jarrow, and Sir W. G. Armstrong & Co., Limited, were far and away out of the competition which vexed their inferiors. Invariably the guns for British warships built by contract are supplied by the Admiralty, which largely accounts for the paucity of government orders to the Armstrong firm, but the vessels for foreign governments, built, engined, and armed by the Armstrongs, indirectly enable the careful student of armaments to gauge exactly what, in the matter of the navy, the private shipbuilding yards of this country could do in time of war. Excluding high-speed twin-screw and paddle steamers, and first-class liners, the Tyne can build anything at least equal to the Clyde, but with Mr. Saxton White and Mr. Andrew Laing,—who, between them, turned out the *Campania* and the *Lucania*,—now employed on the river, the district hopes to, at least, get even with their powerful northern rivals.

At Hartlepool, and on the Wear and the Tees only what may be described generally as "tramps" are turned out. But the business is great and fairly profitable. "They've got to do their business, and make the most they can," which, though Kipling, is true. Old-time types are still built, but lately there has been an effort to embody the features of the American whaleback in vessels designed originally for the trades in which British "carriers" are engaged. Messrs. Doxford's turret boats are an old story, but the trunk type, about the origin of which both of the rivers under consideration seem to be disagreed, may displace it. About the chances of either most folks are doubtful, for the object of shipowning is money making, and under the circumstances experiments are dangerous.

A run through the table which follows will show, — if tonnaged and horsepower are both taken into account, —the standing of each of the leading British firms in 1896:—



H. M. S. "DIADEM" IN THE YARD OF THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD.

	Tons Gross.	I. H. P.
Harland & Wolff, Belfast....	81,316	61,326
Sir W. G. Armstrong & Co., Newcastle..................	54,157	67,770
Sir W. Gray & Co., Hartlepool..........................	43,545	24,950
C. Connell & Co., Glasgow...	40,864	----*
Ropner & Son, Stockton.....	40,260	15,200
Doxford & Sons, Sunderland	39,553	3,550†
Workman Clark & Co., Belfast..........................	38,340	19,850
J. L. Thomson & Sons, Sunderland.....................	37,323	3,534†
Sir Raylton Dixon & Co., Stockton....................	36,111	16,000
Stephen & Sons, Glasgow....	35,185	25,380
Denny Bros., Dumbarton....	32,677	44,000
Short Bros., Sunderland.....	32,321	2,921†

* Are not engineers.
† Nominal horse-power.

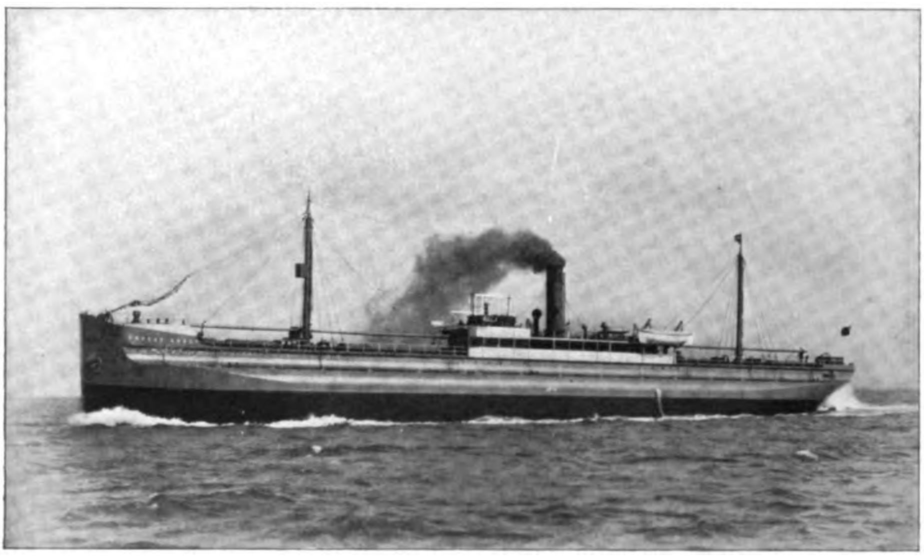
A comparison of this table with those of former years leaves the Belfast firm with the premier position over a number of years, and the English concern with second place. None of the shipbuilding yards on the Continent or in America approach these totals, though Messrs. Wheeler, of West Bay City, Mich., come very close with 29,666 tons and 15,100 I. H. P. Messrs. Cramp, of Philadelphia, produced 24,048 tons and 32,894 I. H. P.; the Flensburger Schiffsbau Gesellschaft, 21,604 tons; and the Vulcan Company, at Stettin, 21,000 tons. This firm has had, by the way, about 40,000 tons of work for the German and the Chinese Governments. The Forges et Chantiers de la Mediterranée, in France, produced 13,397 tons.

The conclusion of a careful scrutiny of the figures—all of which are supplied by the builders themselves—is that

Great Britain is still the centre of the shipbuilding world. In France, because of the bounties, there is no market for the products of perfidious Albion or perfidious anybody else. We have lost a lot, and of the work we can best do, by the boom in shipbuilding in Germany; and the success of the *St. Louis* and the *St. Paul* shows how much the American gain is. But although these markets,—and they were good markets,—are closed to us, there is some consolation in the fact that all the other outlets for the fruits of our industry are safe. America may build warships and ocean-going vessels for itself, and German shipbuilders meet all purely local demands for tonnage; but the pinch will surely come when, in the nature of things, both nationalities are compelled to seek fresh fields and pastures green for an industry, the immediate object of whose promotion was protection pure and simple. But the field is undoubtedly a wide one, and there is evidently no end to its development; taking everything, from the humble barge to the leviathan warship, into account, I should say that the vessels produced in the world in 1896 easily represent over two million tons gross.

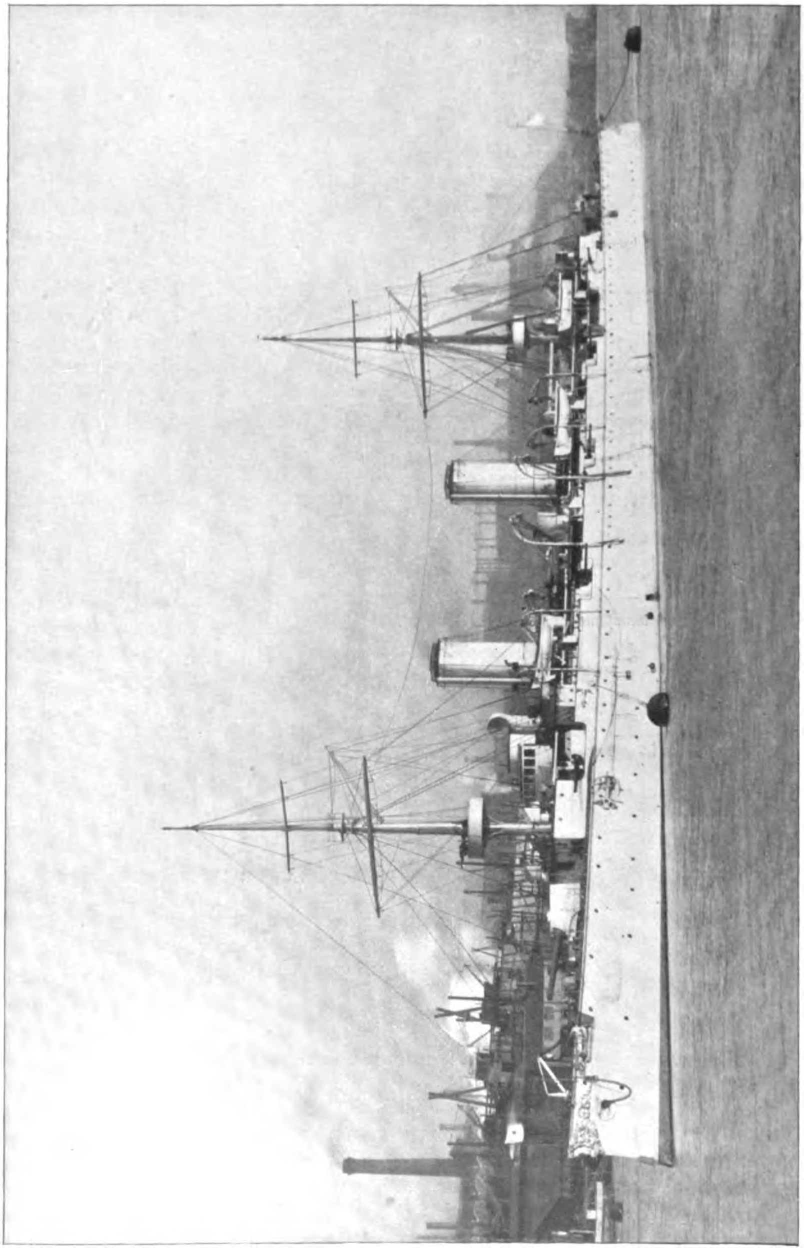
The reader has been assured of the immense importance of the industry to Great Britain, and from the first table may gauge its economic influence; but, like Oliver Twist—all readers seem to me to be Oliver Twists—he may want more. The capital sunk I should not like to estimate in black and white, but if I said that it took a million and a quarter pounds a year to pay the wages of the shipbuilding and marine engineering operations in the upper reach—one-half, that is—of the Clyde, will anybody believe me? And yet anybody can satisfy himself on the point.

Of marine engineers alone there are over 9000 employed on the Clyde, and in the boiler shops, slightly over 3000 more men; in the shipyards a full muster of fitters, platers, riveters, caulkers, carpenters, joiners and labourers would add more than 30,000; and over and above would have to be included an army of draughtsmen, clerks, timekeepers and counters in proportion. These are official figures.



A TURRET STEAMER, BUILT BY MESSRS. WILLIAM DOXFORD & SON.

Belfast, where no official figures are



THE ARGENTINE CRUISER "BUENOS AYRES," LENGTH, 424 FEET. BUILT BY SIR W. G. ARMSTRONG & CO., LTD., NEWCASTLE-ON-TYNE.

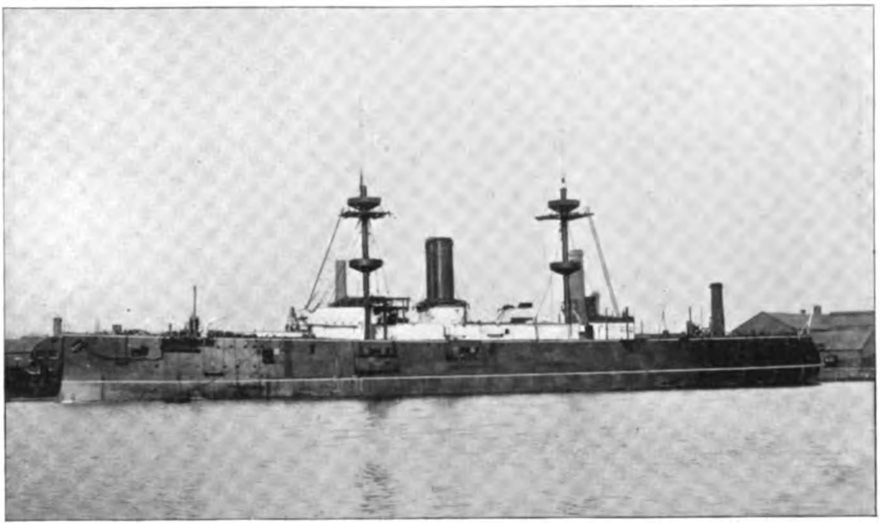
available, may safely be set down as employing 6000 men, and about half that total is the measure of the industrial activity in one commercial capital of Ireland. Taking the extensive repair work into consideration, 5000 men represent about the total on the Mersey; in the Royal dockyards at Pembroke, Devenport, Portsmouth, Chatham and Sheerness, 23,049 men are employed, of whom about a third are in the engine shops; and on the Thames, which is, despite its decadence in shipbuilding, an engineering centre, the total number of men employed in the industry is approximately 8000,—3000 shipworkers and 5000 engineers. Of the Northeast Coast of England I am unable to speak with authority, because the official figures of the men employed are not at hand as I write; but I should say that the total, including the Humber, is not far short of 70,000, of whom about two-thirds are shipyard hands.

It may interest readers abroad to know that the Royal dockyards are now almost perfect establishments of their type. The figures I have given refer purely to the shipbuilding and engineering departments, and the table which follows may be accepted as a corollary:—

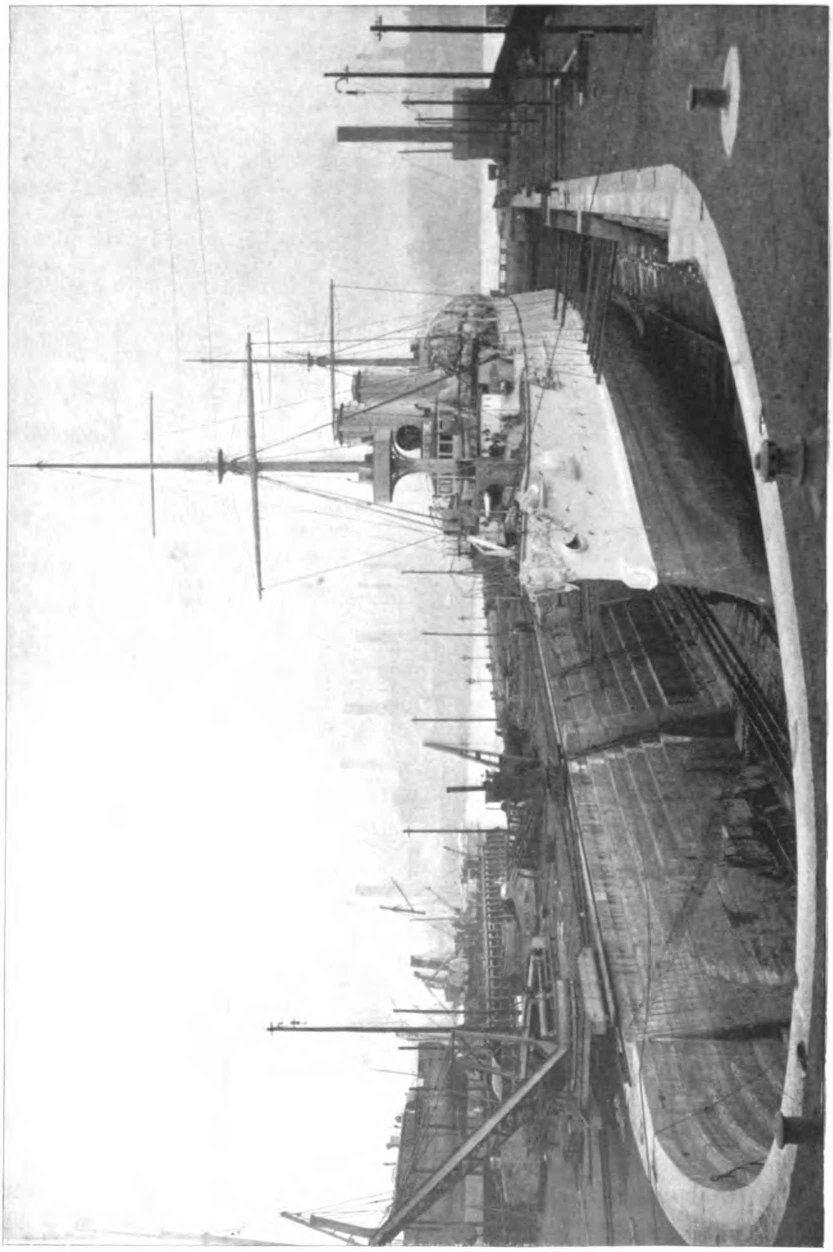
	Vessels.	Tons displ.	Cost £	Cost per ton £
1890	8	22,520	1,230,913	49 0
1891	8	68,100	3,847,596	56 10
1892	9	50,450	2,920,431	58 0
1893	9	32,400	1,729,451	53 0
1894	8	26,700	1,803,576	67 10
1885	8	70,350	4,390,691	60 19
1896	9	71,970	4,287,764	59 12

The question of wages explains better than anything else the decadence of the Thames as a shipbuilding centre, but although it is easy enough to convince a man on the spot, it is difficult to describe the situation to people who know nothing of the conditions which prevail. What we call the "black squad,"—fitters, platers, riveters, caulkers, drillers, and holders-on,—are all pieceworkers, and by the aid of their organisation, which is financially the soundest in the world, they have resisted the efforts of the employers to make time wages the rule. All, or nearly all, the others are time workers, although the shipwrights fought a long and always hopeless battle against the change.

A colleague of mine on the Glasgow *Herald*, acting on a suggestion I made, went recently into the question of wages as it affected each district, and the con-



THE BRITISH BATTLE SHIP "MARS" COMPLETING FOR SEA AT MESSRS. LAIRD BROS.' FITTING-OUT WHARF, BIRKENHEAD.



THE ARGENTINE CRUISER "BUENOS AYRES" IN THE GRAVING DOCK OF THE WALLSEND SLIPWAY AND ENGINEERING CO., LTD.

clusion more than bore out a favourite contention of mine that the rates must necessarily vary in different districts. All are not alike, and the results may be of interest. All the estimates are based on a fifty-four-hour week. In Belfast the average weekly wage of members of the Amalgamated Society of Engineers, — fitters, smiths, turners, patternmakers, and millwrights,—is, at the moment, nearly thirty-four shillings. Members of the "black squad,"—pieceworkers that is,—earn anything from a humble tenner up to an average of £3. Shipwrights make something like thirty-five shillings in six days; and joiners a little less.

On the Clyde, A. S. E. men have about thirty-four shillings a week; the "black squad," as all depends on themselves, nearly as much as in the Irish port, and the shipwrights and joiners about the Belfast rate, with slightly over a 10 per cent. addition for repairs. The wages on the Northeast Coast of England are at about the average of the three districts named, but the gradual development of the Employers' Federations, at the head of which is a shrewd young Scotch lawyer, is tending to equalise not only the rates of wages, but the conditions of labour. All the toilers in shipbuilding and engineering are strongly combined, and opposed to them are two capitalist organisations which, in wealth and influence, are easily superiors of the British Shipping Federation.

But the cold figures which tell most against the Thames have yet to be recorded. What have been given represent nominal remuneration; the others do not. In the Thames district the average wage of members of the Amalgamated Society of Engineers is thirty-nine shillings a week; "black squad" piecework rates are proportionately as high; and shipwrights and joiners average about two guineas.

Add to that the extra cost delivered of material and fuel, and you have the explanation of the failure of the Thames to make ends meet in shipbuilding.

Into an article like this it is difficult to compress all one has to say, but what precedes may induce students of economy to discover for themselves, if it ever will be possible to displace Great Britain as the leading shipbuilding centre of the world.

THE METRIC SYSTEM FROM A MECHANICAL POINT OF VIEW.

By Samuel Webber.

THE revival of the agitation in favour of the introduction of the French, or metric, system of weights and measures into the United States, by a compulsory act of Congress, has led the writer to offer his views and opinions, in objection to it, from a strictly mechanical point of view.

While the decimal character, which is its great advantage in purely arithmetical calculations, renders computations easy in the office, it is not nearly so simple or convenient in the workshop as the old method of continual reduction, by division by two, into halves, quarters, eighths and so on, and for all purposes of practical mechanics, as used in the building of tools or other machinery, the basis of its linear measure, the meter is far too large, and its minimum division, the millimeter, which is very nearly four one-hundredths of an inch, is also too large for any nice mechanical purposes, and must be subdivided again for all such questions as involve the fit of a shaft in its bearings, or still more for the fit of a gear or pulley on a shaft.

This basis of the meter was "evolved from the inner consciousness" of the French scientists and philosophers in the general overturn of all ancient law and order which followed the French Revolution, and was supposed to represent the ten-millionth part of the distance from either pole of the earth to the equator, and though the calculations on which it was based were afterwards found to be incorrect, the measure was so purely arbitrary that it was a matter of no importance whether it was correct or not, since it took a corps of astronomers to establish or verify it. Under the overpowering sway of Napoleon I., dreaming of world empire, and the great part played by France in all the affairs of Europe in the early part of the nineteenth century, the metric system was generally adopted on the European continent, though itwas not until 1840 that it was finally made compulsory in France, and it has never found a footing in Great Britain and among her descendants and dependencies.

The French savants, who established this basis, were good mathematicians and astronomers, no doubt, but they were none of them practical mechanics, and their race, with its conquerors, which in general terms we may call the Latin race, has never developed the skill and capacity in the construction of tools and machines, shown by what we may simply call the English race, in all its variations. The mechanical unit of this race is the inch, in the old French measures *pouce*, the width of a man's thumb, and although in ordinary usage the division of this inch in the old way, by continual divisions by two, down to sixty-fourth, is still in practice, the decimal system has been adopted for all fine measurements and close fits are measured in thousandths of an inch.

Going in the other direction, the inch is not too small to express very considerable mechanical dimensions and is almost universally used in designating the sizes of parts of machines; for instance, we hear of a 72×72 inch planer, a 120-inch steam cylinder for an ocean steamer, or a 36×72 inch Corliss engine. It is very seldom, in purely mechanical measurement, that we hear of any unit but the inch, though its old multiple by 12, the foot, is generally used in civil engineering, and this also is decimally divided in practice.

Lengths of railway tunnels, depths of mines, lengths of bridges, heights of buildings, etc., are always stated in feet, and it is becoming customary to use the decimals of feet, instead of inches, for any additional fractions, and as the eighth of an inch is nearly the hundredth part of a foot, the transposition is easy. When we come to hydraulic measurements, the flow of water is measured in cubic feet and thousandths, and the elaborate tables prepared by the late James B. Francis and others, render all such computations easy.

Now we have here two simple and well known units, the inch and the foot, which although not decimally related to each other, are both, in practice, decimally subdivided to thousandths, and cover the field for all engineering practice,—the inch for the mechanical, the foot for the civil engineer.

Why should we change these units to adopt one which agrees with neither of them, and which, at best, was originally the visionary scheme of a congress of philosophers? We have little to learn or gain by adopting the measures of continental Europe. Three-quarters, or nearly so, of the commerce and traffic of the world is carried on by some form of appliance, whether moved by wind, water or steam, which has been built from English measures by some English-speaking people, and the proportion is all the time increasing. Why adopt another and more inconvenient system which will render all systems of screw threads, gear teeth, foundry patterns, shop drawings, etc., etc., obsolete, as well as shelving the most valuable collection of mechanical literature in the world, and requiring all its tables to be translated into a foreign measure merely to obtain the advantages of a decimal system, which, as I have shown, we already have to all intents and purposes in a far more convenient form than we should obtain from the introduction of the meter and its derivatives? Besides these two unit measures,—the inch, and the foot,—we also use the cubic yard, in civil engineering, for excavations and earthwork; but for mechanical purposes we could get along very well with no other unit than the inch.

When we come to the measures of weight and capacity, there is no such serious objection to the change, although, for a time, the confusion would be very great. The French unit for capacity, the liter, which is one cubic decimeter, is very nearly the same as our quart, or 1.0565 quarts, and the demiliter would be 1.0282 pints, and the adjustment would be comparatively easy.

The matter of weights would be more confusing, for the French unit, the gramme, is taken from the weight of one cubic centimeter of distilled water and is 15.43316 grains avoirdupois, and in none of its multiples approaches any of our weights until we reach one million grammes, or a *tonneau*, which is 2204.737 pounds, or very nearly the old long ton. With our three systems of avoirdupois, troy and apothecaries, a change to one uniform system might here seem desirable, although physicians and apothecaries might be sorely troubled for a while in making up and compounding prescriptions, but so far as it touches mechanical matters the weight of the kilogramme, the one in most common use, is so close to 2 1-5 pounds that it would soon be readily understood.

If the object of the change is to establish a decimal system, why not take the well-known British pound as the unit, and base a new scale on that? My purpose, however, is not to object to the metric system generally, but to its special application to the linear measure used for mechanical purposes, or, rather, to the adoption of its unit as the standard for such measure, and I am very sure that a large majority of the mechanics and engineers of the race which leads, and seems destined to lead, the world in such matters will agree with me in maintaining that nothing is to be gained by such a change, and that our present units, decimalised as they now are in practice, are far more simple and convenient than any which we could substitute for them.

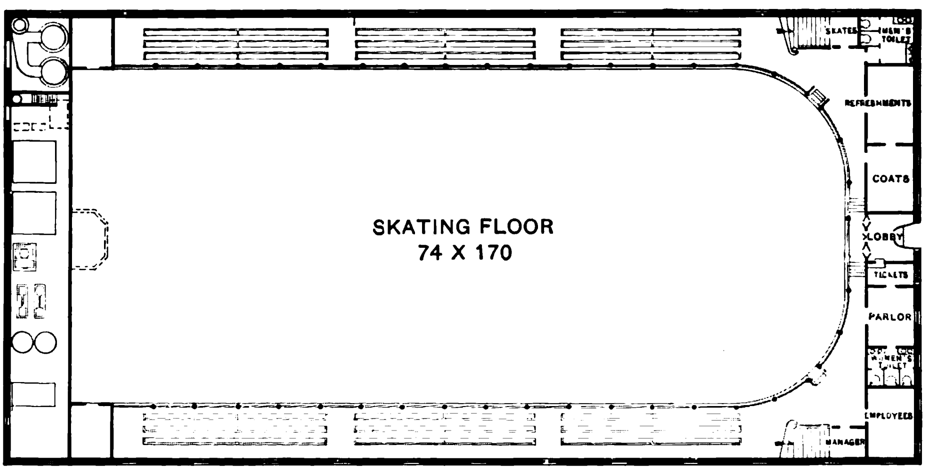
AN ARTIFICIAL ICE SKATING RINK

By George Hill.

THE winter of 1895 and 1896 saw the beginning of the use of artificial ice for purposes of recreation in ice skating rinks. The rinks which were then established proved so remunerative that others have been projected in many places, a number have been installed, and the construction of a great many others is under consideration.

Published literature on the subject is very meagre, and is to be found mainly in the technical journals of the day. The general science of refrigeration, of course, is to be obtained from standard works, but the details, the general proportions which experience has found to be best, the arrangement which will give the best results,—these must be derived from practical experience. In this class of work, as in almost every other, the best results are to be obtained where the entire design emanates from, or is controlled by, some one conversant with all the requirements, so that the building can be designed and constructed, the skating floor made in it, the refrigerating machinery located and installed, and the complete outfit operated as an harmonious whole, rather than as an emulsion of the ideas of various specialists which, after a little time, separates into its component parts, each inharmonious to the other.

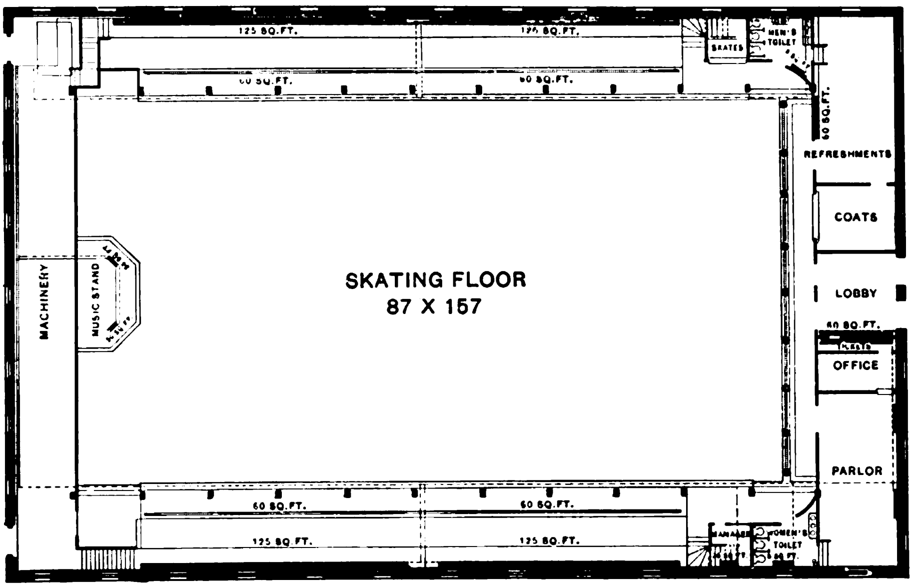
Generally considered, the location of a skating rink should be along the lines of evening travel, and in what would be considered an amusement locality as distinguished from a business locality. As a consequence, the value of the land would probably be sufficiently low to make it feasible to utilise the entire area solely for amusement. This point is important in so far as it influences the



AN IDEAL SKATING RINK PLAN.

character of the building, and particularly the character of the floor. The demands of the skating floor are such that the area below it could not be occupied for any business requiring light or good ventilation without using an excessively high ceiling.

The conditions of proper ventilation demand that the skating rink should have a ceiling at least thirty-five feet in height, and thus a building which would combine stores or offices on any of its floors with the skating rink would be, in itself, expensive to build. Almost every town, however, has use for a hall during the off season and the skating floor, therefore, could be utilised for conventions, assemblies and the like, making it remunerative.



PLAN OF AN ACTUAL SKATING RINK.

Taking the size of the building as limited by a plot of ground measuring 100 by 200 feet, an excellent arrangement would be that shown on the first page. The size of the skating floor proper is the maximum permissible on a lot of this size. It will accommodate at one time about 400 people and leave room as well for a sufficient number of spectators. It should be so placed with reference to the streets as to make the entrance on the more desirable street of the two. The rooms on either side of the entrance would be used for coats, refreshments, ticket offices, ladies' parlour, toilet rooms, employees' dressing room, skate room and manager's office. The platforms at the ends afford a space for the putting on of skates and for skaters to stand and chat with their friends.

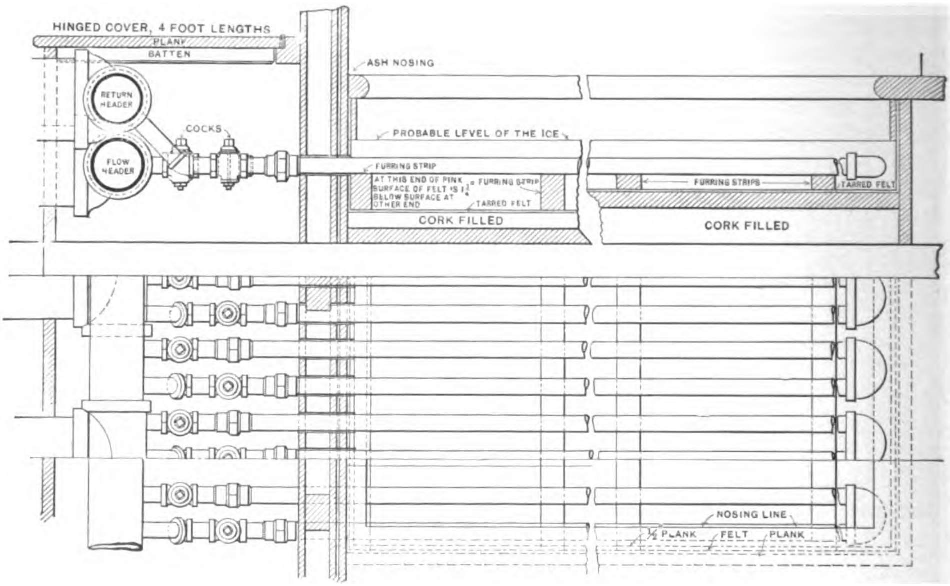
Entirely around the skating floor, a railing should be put, about three feet high, which, with the depression of the skating floor, would make a box to hold the cold air and to produce a temperature for the skaters different from that enjoyed by the spectators. This results in an economy both in initial installation and in operation. At the end of the rink opposite to the entrance, large mirrors may be placed entirely across, increasing the apparent size. These mirrors should be provided with strong netting of about one-inch mesh to lower down in front when hockey games are being played. Entirely around the rink, and at a level of four feet above the floor, there should be a brass, iron or wooden railing, and, at intervals, folding seats for beginners.

In the end of the rink opposite the entrance should be the machinery space with one end excavated to a depth of ten feet below the pavement, and a vault put in for storing coal. Boilers should preferably be of the vertical type. Drip tank, blow-off tank, feed pumps, and feed water heaters should be placed on the level of the boiler room floor and floored over at the level of the engine room floor.

On the engine room floor should be placed the refrigerating compressors, electric lighting engine, circulating pumps, coolers and condensers, cooling liquid tank and engineer's office. This floor should be at least seventeen feet high in the clear. Above it may be placed a gallery. Adjoining the machinery space, and opening on to the ice floor, are rooms for the ice melting appliances, brooms, snow shovels, etc., required for the operation of the rink, and also a small machine shop with repair tools.

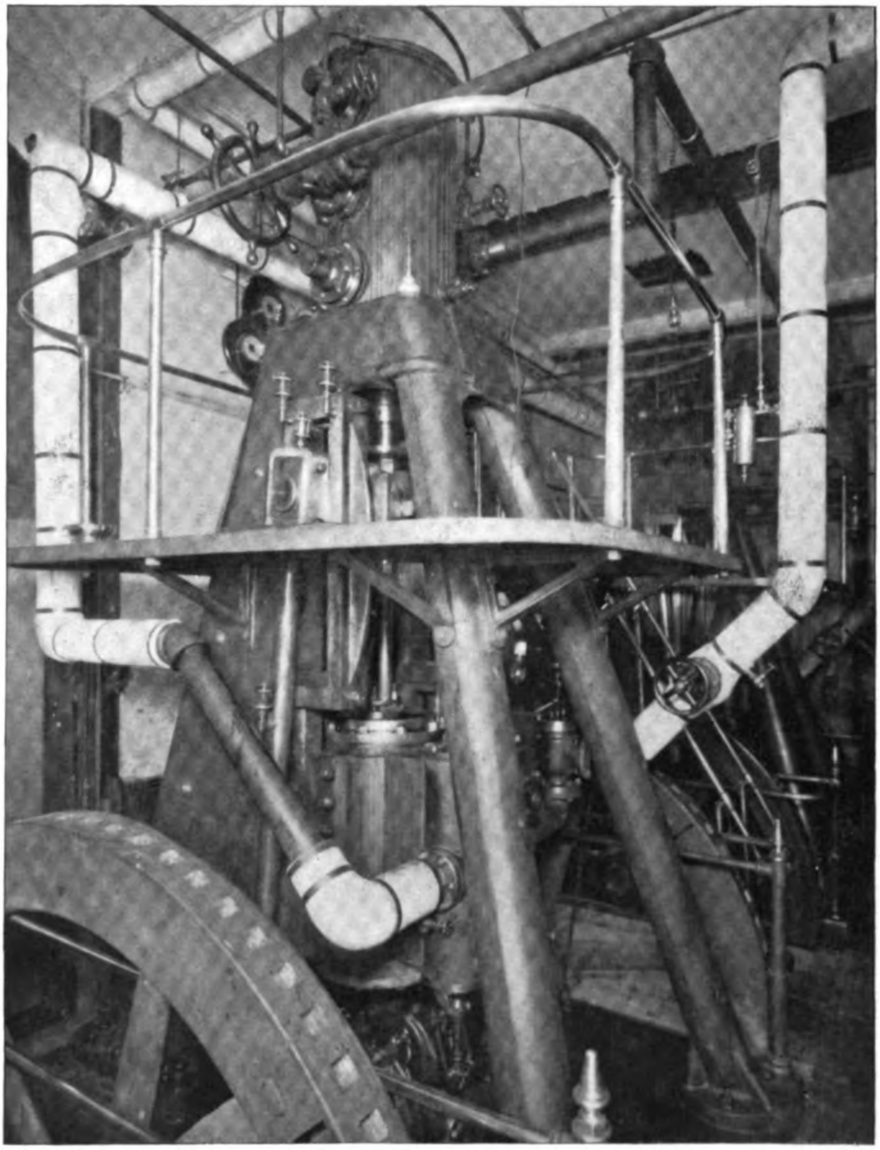
The sizes of the various machines are not designated for the reason that the average temperature of the locality has a marked effect, and what would be quite proper for one latitude would be improper for another.

The plan on the preceding page shows the actual lay-out of the Clermont avenue skating rink in the city of Brooklyn, N. Y. The departure from the standard plan, observed in this, is to be attributed to the fact that the building used was originally erected many years ago for natural ice skating; subsequently it was used for roller skating, and still later for bicycle riding. The subdivision of the various rooms was as given on the plan, and it was necessary that they should be used without change.



DETAILS OF COOLING PIPE SYSTEM UNDER THE ICE SURFACE.

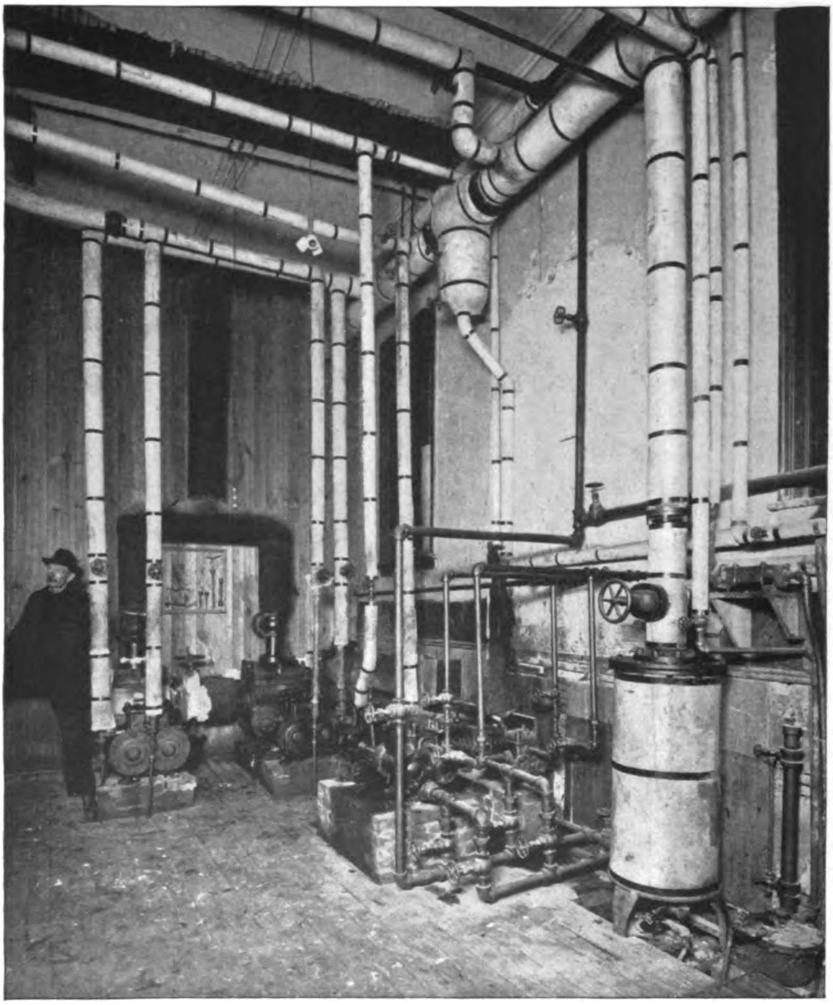
The photograph of the interior of the rink from which the cut on page 456 was prepared, illustrates the general characteristics. It is particularly to be observed that the entire skating floor is practically enclosed in a box about four feet deep. The entrance for the public is from the west end and there the box is diminished in height so that people can look over it, its purpose being to keep the stratum of cold air where it naturally tends to remain, and to prevent unpleasant side draughts from the floor to the spectators.



ONE OF THE COMPRESSORS.

The diagram on the opposite page shows the arrangement of the piping on this floor which may be described as consisting of a flow and a return header between which were interposed loops of one-inch pipe containing a length of 310 feet each. The headers were placed one above the other, the outgoing and incoming pipes being placed side by side, both controlled by means of a cock, and the pipe connected with a union on the outside of the cock. This makes it possible to absolutely control the circulation of the cooling liquid in case any impurities should get into any of the pipes and thus impede the natural inclination to flow uniformly through the system.

In the plant here described it has not

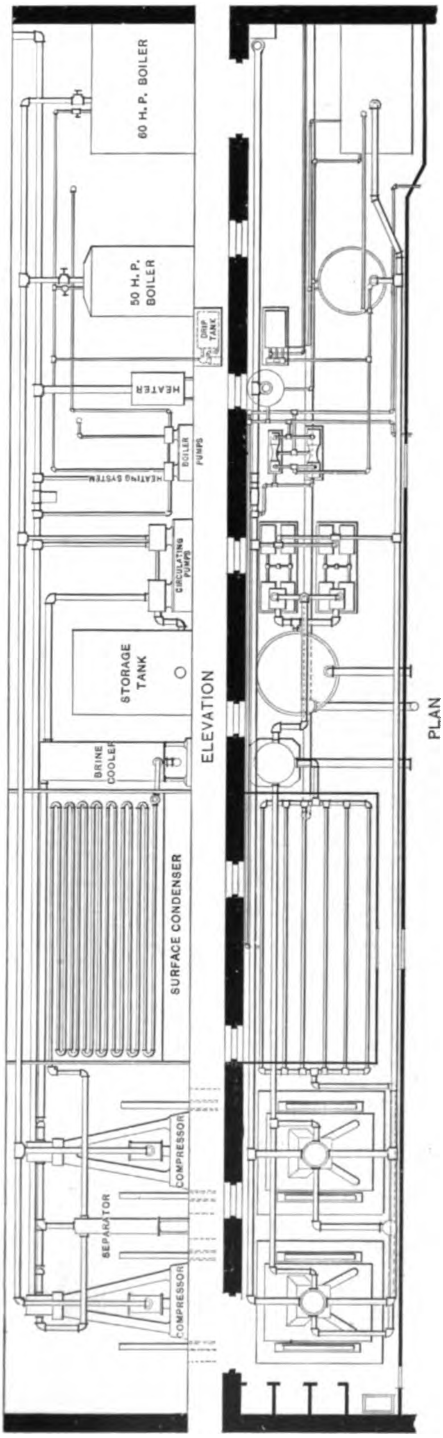


IN THE PUMP ROOM.

yet been necessary to exercise this control. The additional advantage, however, and one which is very great, is the ability to cut off pipes which, on test, are found to leak, or which may develop defects under use, until they can be repaired. In the plant in question, in the eleven miles of piping installed, twenty-six leaks were observed when water was pumped in under pressure for test; they were all remedied. After the ice surface was made, ten additional leaks were observed; these were so minute that they could be detected only by the difference in the character of the ice surface where the leakage took place. They were easily remedied by chopping away the ice and caulking.

The general lay-out of the machinery space is shown in plan and elevation on the page opposite, and also by the illustrations above and on page 453, both of which are self-explanatory. The compressor room is more crowded apparently than actually, the compressors having plenty of working room on their cast iron bases and on the platforms.

The electric lighting plant is not



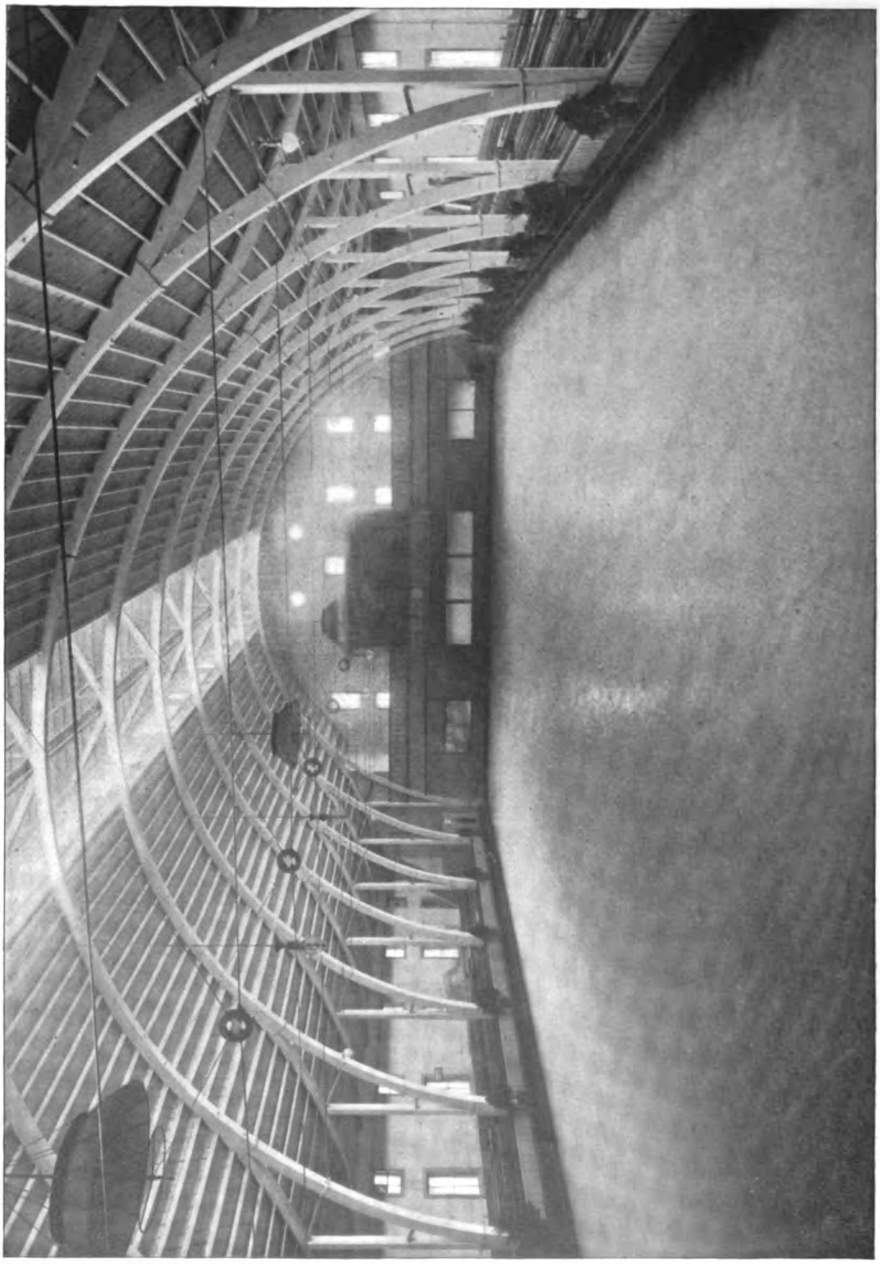
ELEVATION AND PLAN OF THE MACHINERY LAY-OUT.

shown in the cut on this page, but is to be installed in the space near the circulating pumps.

The preparation of the skating floor was accomplished by laying sleepers, about two feet apart on centres, over the entire area of the skating floor proposed, filling in between the sleepers with ground cork. On top of the sleepers, a board floor was laid, of mill-dressed boards, six inches wide, and then a water-tight covering was placed on this, composed of a special asphaltic felt, laid in a specially prepared asphalt, carried up six inches around on all sides. This formed a large shallow pan which was gently sloped to a drainage opening where connection was made with the sewer. The two headers were put on one side of the partition and in the engine room, being boxed in, and the boxing was filled with ground cork. The lid of the box was used as a walkway between the various mechanical devices and was made in short sections so as to afford easy access to the controlling cocks on the circulation system.

A horizontal return tubular boiler of nominally 60 horse-power capacity was already in the building, and was supplemented by a vertical tubular 50 horse-power boiler. These two boilers were placed in the only possible location and were connected up interchangeably to the piping, and in consequence occupied very much more space than should have been used up. The location of the pumps and other machinery was dictated by the fact that the entire plant had to be installed in less than thirty working days, and the second reserve compressor installed while the plant was in operation. Had it been possible to have erected the machinery with plenty of time and without regard to keeping an open passage way for certain additions, it would, of course, have been possible to have kept all of the moving machinery at one end of the engine room space, separating the part where steam is used entirely from the other part.

The total machinery installed for the operation of the plant, then, consisted of 110 horse-power of boilers; one 6 × 4 × 6 inch pump for boiler feeding, ice sprink-



AN ARTIFICIAL ICE SKATING RINK.

ling and condensing purposes, two 7½ × 8 × 6 inch circulating pumps; one nominally 40-ton ice-melting cooler for the circulating fluid; two open-pipe condensers, each containing 1900 linear feet of 1½-inch pipe; two vertical direct-acting ammonia compressors with steam cylinders 16 inches in diameter; ammonia cylinders, 11½ inches in diameter; both 23 inches stroke. The ammonia, after being compressed, passed through an oil drip cylinder into the condensing coils and from the coils into a receiver; from the receiver it was expanded in the cooler. The gaseous ammonia was exhausted directly from the top of the cooler into the compressing cylinder.

The cooler consisted of a cast iron cylinder 24 inches in diameter in which the ammonia was expanded. Through the cylinder the cooling liquid passes into 2-inch pipe coils, the cooling liquid and ammonia flowing in opposite directions. The ammonia suction is from an area of over 500 square inches into a 3-inch pipe. The great advantage of this form of cooler was demonstrated accidentally as the engine ran away, and for a few moments attained a speed of three times the normal, without drawing liquid anhydrous ammonia into the cylinder. This would probably have been the case with some other apparatus, and had liquid ammonia been taken into the cylinder the machine would have been instantly wrecked. At the time when this accident occurred, frost had been showing for several hours at the suction valve beside the cylinder.

The coal consumption for the months of December and January has averaged about two and three-quarters tons of pea coal daily. The water required each day has averaged 4500 cubic feet for twenty-four hours. The arc lights for lighting the rink and for the sign outside, — twenty-nine altogether, — have averaged five hours per day each, and the incandescent lights for lighting in the engine room, offices, etc., ten hours.

For the heating of the rink there were installed in the skating room proper, steam pipe coils aggregating 840 square feet, and in the other rooms an additional amount of 360 square feet. This surface has been found adequate for proper heating under all conditions, maintaining the auditorium at a temperature of about 60 degrees F., the air immediately over the skating floor at about 35 degrees F., and in the club rooms at about 70 degrees F. All the water of condensation is returned by gravity to the engine room and pumped into the boilers. The ventilation, which has been found to be very good at all times, is effected by proper manipulation of the windows and ventilators, and without the use of fans. The lighting of the skating floor is successfully accomplished by the use of eighteen 150-hour enclosed arc lamps with clear glass globes.

In the operation of the plant it has been found that the ice surface is best when it is kept within two and one-halt inches of the top of the pipes. If the ice gets any thicker a very great increase in the amount of work to keep the surface good becomes necessary, because the rate of transmission of heat through the ice is slow. For the freezing fluid, a chloride of calcium solution of a specific gravity of 1,250 was used. This was directly prepared in the storage tank by breaking up the chloride in the tank and circulating the water through the system. It required fifty-four hours to make a proper solution.

The skating floor is open to the public for three sessions daily, from 10 A. M. to 12:30 P. M.; 2:30 to 5:30 P. M., and 8 to 11 P. M. It is rarely found necessary to run the plant after midnight. It is also rarely found necessary to use more than the one circulating pump. The friction head against the pump is so small that it is always necessary to run it very much throttled to prevent the pump from running away, and, in consequence, it would have been better to have used a low-service pump for this duty.

For the maintenance of the ice surface, the employees are required to sweep and scrape it after each session, and a new surface is then put on by sprinkling with a hose supplied with water warmed to a temperature of about 170 degrees. This water is obtained by taking off a branch from the boiler feed pipe on the boiler side of the feed water heater. A three-quarter-inch nozzle is used and the water is delivered through it at considerable pressure so as to form a fine spray. During the time of sprinkling, the compressors are usually speeded up a little to maintain the cooling fluid at a uniform temperature.

The circulation of the latter is from the pump to the cooler, to the distributing header, through the manifolds on the pipe floor into the return header which is placed above the flow header, into the tank, and into the pump again. The temperature of the outgoing fluid, with the external temperature at an average of 35 degrees F., should be 14 degrees F. The tank is at about 19 or 20 degrees F. The speed of the pump is such as to produce a flow of about 150 gallons per minute, sometimes less and sometimes slightly more, depending on the character of the ice surface.

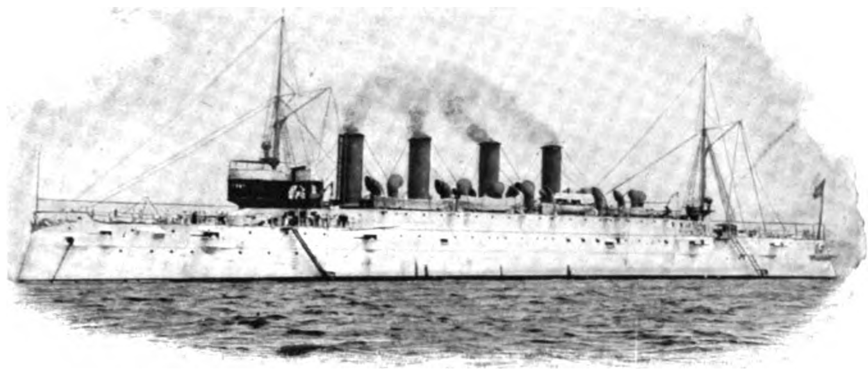
The suction on the gauge is ordinarily about 19 pounds and the discharge about 115 pounds. The water used is delivered at a temperature of about 45 degrees F., and is pumped over again through the atmospheric condensers until its temperature is about 80 degrees F. So much as is necessary is used in the boiler and for sprinkling, and the balance is run to waste. This is not as good an arrangement as could be made, but the time available did not permit of the installation of any form of atmospheric cooler for the condensing water, such as will be installed as soon as the skating season is over.

The installation was carried out under the supervision of Messrs. Hill & Turner, of New York City.

GEORGE WALLACE MELVILLE.

ENGINEER-IN-CHIEF OF THE UNITED STATES NAVY.

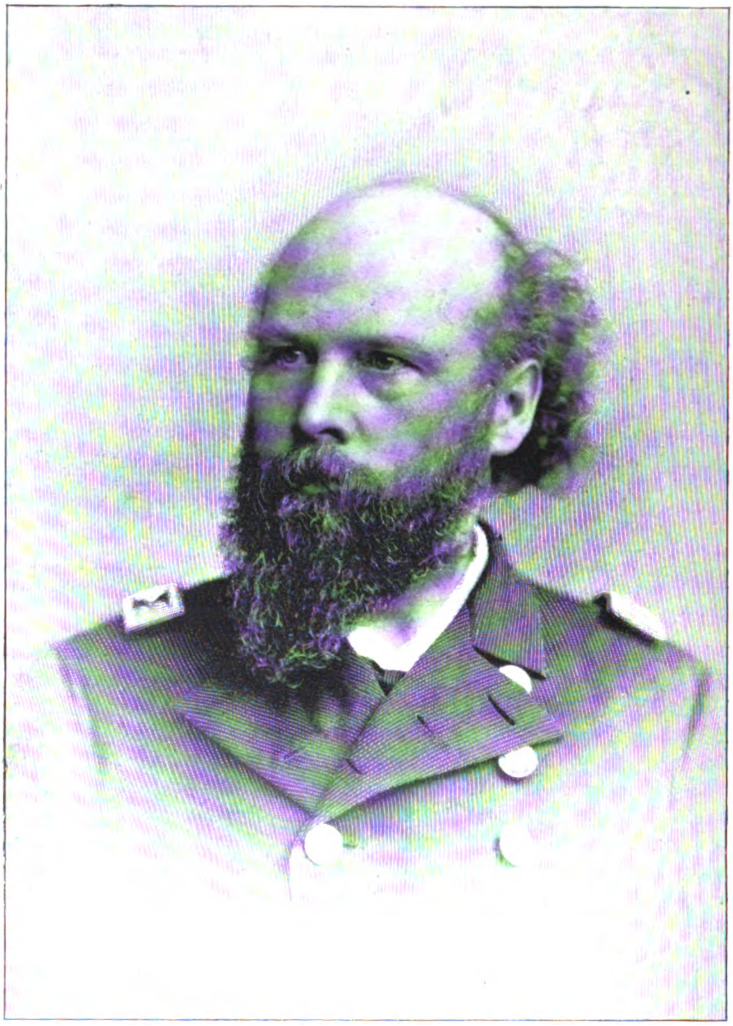
By William Ledyard Cathcart.



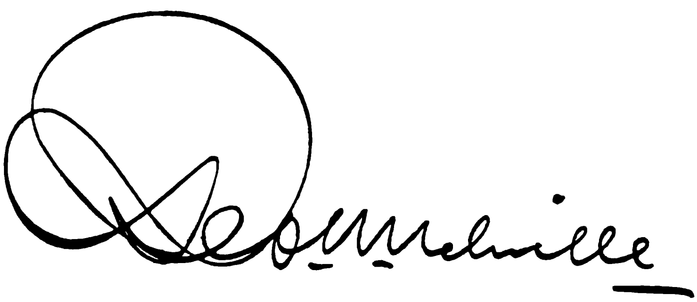
THE UNITED STATES CRUISER "COLUMBIA," TRIPLE SCREW ENGINES, DESIGNED UNDER COMMODORE MELVILLE'S SUPERVISION. TIME OF ATLANTIC PASSAGE BETWEEN THE NEEDLES AND SANDY HOOK—3579 MILES—6 DAYS, 23 HOURS, 49 MINUTES.

THE first half of the sixteenth century was drawing to a close in Scotland with the fires of fanaticism flaming luridly there. The pulses of religious partisans had been stirred to fever heat by the policy of Henry VIII.; and Wishart, "a brave man of an unscrupulous age," had been burned at the stake by the Archbishop of St. Andrews. His blood did not long cry out for vengeance. One May morning in 1546, Norman Lesley, Kirkaldy of Grange, and James Melville, "young gentlemen" all, stabbed to death in his castle the Episcopal murderer, Melville dealing the death stroke. We cannot judge that time by the standards of this. Patriotism, as he viewed it, moved Melville when he played Brutus to the bishop's Cæsar; and, despite his act, the godly John Knox says of him that he "was a man of nature most gentle and most modest."

In the succeeding generation, we have Andrew Melville, — scholar, minister, and reformer—of whom quaint old Scot of Cupar tells. Renowned while yet a youth as "the best philosopher, poet, and Grecian of any young master in the land;" later, regent or professor of colleges or universities at Poictiers, Geneva, Glasgow, St. Andrews, and Sedan; and one of the ablest, as he was the boldest, of the high-thinking and plain-speaking Scottish reformers of his day. James I., the spying pedant of "The Fortunes of Nigel," hated and feared him. When haled before the King and council at London, the reformer told them indignantly that "Andrew Melville is no traitor." And again at Cupar, when reminded by the King that he was the royal vassal, Melville retorted, "Sirrah, ye are God's silly vassal!" Even in those early years, it would seem that the name of Melville was linked with brave words and worthy deeds.



FROM A PHOTOGRAPH BY THE F. GUTEKUNST CO., PHILADELPHIA.



The home of the family from which the engineer-in-chief springs is at Stirling in Scotland, the gateway to the Highlands, near the field of Bannockburn, and the spot in which Sir John Melville, in 1549, died on the scaffold for his faith. The long line of the Melvilles has held an honoured place, from early days, in Scottish song and Scotland's history; and, in this later time, the stout old race loses no glory through such men as the subject of this sketch. In view of his naval and Arctic record, it is interesting to note that, but two generations from him, we find, in his family, Sir James Melville, First Lord of the British Admiralty when the expedition of Parry by Baffin's bay was despatched, and whose name has been given, through this, to some Arctic lands and waters.

In 1804, James Melville, of Stirling, landed in New York City, bringing with him a large family of sons, among whom were James and Andrew—historic Melville names—George and Alexander. The latter was the father of Commodore Melville; and, at sixteen years of age, he was sent again across the sea to complete his education at the old University of St. Andrews, which had trained so many of his line. Returning to New York, he became a professional chemist, with reference especially to dyeing and the allied arts, and acquiring a competence thereby. He was widely known and liked and was a power in the politics of his day. During the American Civil War, he filled to the full the measure of patriotism, giving three sons to the service of the government and raising and equipping a company of volunteers.

He married Sarah Douther Wallace, of New York, and became the sire of stalwart sons. In stature, he and they were of the Anakim, and any one of them could have swung with ease, in cut and thrust, the great two-handed sword of William Wallace which hangs to-day in the armory of Dumbarton Castle. The father—"Big Sandy" as he was called—was six feet, six inches tall; one son was six feet four; another six feet two; and George, the oldest, was but a shade under six feet.

The latter, the present engineer-in-chief, was born on January 10, 1841, in the city of New York. He was educated in its public schools and later, displaying marked mechanical instincts, passed through the Polytechnic school of Brooklyn and received a further course in mathematics in a religious academy of that city, which, in that branch, held high repute. With the hard-headed wisdom of his race, the father resolved that his son should be well grounded in the profession to which his tastes and later training tended; and so, when school days were ended, the lad was entered in the engineering works of James Binns, of East Brooklyn, where Melville laid, broadly and deeply, the foundations of that practical skill which has served him well in many a later hour of trial.

On April 12, 1861, Southern guns were trained on Sumter—the first argument of force to prove that the United States was not a nation. It would seem that the Articles of Confederation had been superseded in vain; that the inscription on the Great Seal of the United States—"out of many (states), one (nation)"—was a mistake; that Washington erred when, in farewell, he spoke of his country's "indissoluble community of interest as one nation;" that Andrew Jackson was wrong when, in his parting words, he referred to "this widely extended nation;" and that Lincoln misquoted history when, later, in the throes of that mighty conflict, he said, at Gettysburg,—"Four-score and seven years ago, our fathers brought forth on this continent a new nation." Honest men, on both sides, differed honestly as to this; and so, a war was begun which was to cost lives by the hundreds of thousands, and treasure by hundreds of millions.

The great wave of loyalty which surged over the startled North could not but sweep Melville with it. He was in the dawn of manhood; devoted to the land of his birth; and there stirred within him as well the blood of the stern race from which he sprung—that race whose wild "pipes of the misty moorlands" have sounded above so many trampled battle sods, from Bannockburn to Tel-el-Kebir, the martial pibroch, "heard so often as earth's latest music by dying men."

His training, with an inborn love of adventure, turned him toward engineering duty and to the sea; and, on July 29, 1861, when but twenty years and six months old, and but ninety days after the war began, he became an officer of the engineer corps of the United States Navy. It was well, indeed, for the nation that, in its extremity, it could command the services, in sufficient number, of men of his profession; for, in the struggle which was at hand, the naval engineer was to play a vital part.

On March 4, 1861, the North was in possession of but two forts,—Sumter and Pickens,—on the Atlantic and gulf coasts below Chesapeake bay, Va. There were three thousand miles of sea coast to be blockaded, necessarily by steamers; and, finally, if this blockade were not early made effective, foreign governments stood ready, after but brief delay, to demand the independence of the Confederacy, with whose people their rulers were in sympathy, and for whose great yield of cotton the mills of the world were waiting.

To meet this emergency, the United States Navy Department had available but sixty-nine vessels of all classes, of which thirty-four were sailing ships. Fortunately, indeed, the tireless genius of Gideon Welles, the greatest of naval secretaries, swayed the helm of the Department, and by him the increase of the fleet was pressed so energetically that, at the close of the year 1861, through the purchase and construction of steamers of every class, the government floated a navy of 211 vessels, bearing 2301 guns, and carrying 20,000 men, although of these the ships of greatest tonnage and battery power were neither steamers nor modern vessels. At the close of the war the force consisted of about 600 ships of all classes, including 100 in service on the Western rivers.

In looking backward through those years, it seems difficult to overestimate the value of the great steam fleet to the Northern arms. Through its early and complete blockade and through the unbroken tenure of Fort Pickens, the government was enabled, in the beginning, to dispute successfully the claim of the Confederacy to possession of the Southern sea coast and to consequent recognition as a nation. Later on, and to the end, there were taken or destroyed by that fleet 1504 vessels of all classes, having a value, with that of their cargoes, of at least thirty-one millions of dollars.

The blockade was, then, one of the main factors in ending the Civil War. While the deeds of the navy on inland waters, with the victories of the *Kearsarge* and *Wachusett* on foreign seas, make a record whose superior in skill, resource, and daring, the ages cannot show, yet it is to that great fleet, lying in long line off the low Southern shore, that history will turn to seek the navy's cardinal service in that time of trial.

Of this, Professor Soley says:—" As a military measure, the blockade was of vital importance in the operations of the war." Through it, supplies from abroad were cut off, King Cotton reigned in vain, and the South and its armies, despite their gallant struggle, were starved into surrender. To achieve these results, within four years, if at all, and with that sun-lit sea coast open to the world, would seem to have been impossible.

That great blockading fleet would have seemed, in 1861, an idle dream to Gideon Welles, if he had not known that it was to consist, not of massive battle ships, but of small and handy steamers whose chief qualities should be speed and sea-keeping powers. Its strength lay, then, in these and not in armour nor in ordnance; and the backbone of that strength was the skill and patriotism of the engineers of the North. If they had not been ready at the nation's call and had not come, as Melville came, the war would have been either greatly prolonged or, with foes so valiant and determined, aided from without, it might have ended swiftly in disaster. There could be no more forceful arguments than these, to show the need of an engineering reserve in this day; for, since that war, naval machinery has grown so rapidly in extent and complexity as to make untrained men of little service in emergency, despite their patriotism, education, and skill in civil occupations.

Melville, although but a junior officer during the war, saw much active service, and faced afloat the stress and shock of conflict in not a few engagements. He was for a brief period on the side wheel steamer *Michigan*, cruising on the Northern lakes, and was transferred thence to the screw sloop-of-war *Dakotah* of the North Atlantic fleet. With her he served at the shelling of Lambert's Point and the capture of Norfolk, Va., she acting as guard ship during the night and morning of the destruction of the *Merrimac* off Craney Island, Norfolk Harbour.

He was then with the fleet that cleared the James river, in Virginia, as far as Fort Darling, Drury's Bluffs, and participated in the long engagement which attended the effort to reduce that work. He served still further in the James with the fleet which covered the retreat of McClellan's army to Harrison's Landing.

After Farragut had made his brilliant passage beyond Forts Jackson and St. Philip and up the Mississippi river, the *Dakotah*, to which Melville was then attached, carried dispatches to the admiral to proceed still further up the river. In returning from this service, Melville was stricken with typhoid fever, contracted in the James, and was transferred to the hospital at Key West, Fla.

After convalescence, he was attached to the fast side wheel steamer *Santiago de Cuba*, and, leaving her, joined at sea the screw sloop *Wachusett*, nine guns, 1032 tons. This vessel proceeded to Philadelphia for repairs, and, pending their completion, Melville served temporarily on the steamer *Tonawanda*, chartered to pursue the Confederate cruiser *Tallahassee*. Rejoining the *Wachusett*, Captain Napoleon Collins, he went in that ship to Brazil, where she was ordered to intercept Confederate cruisers. She remained at sea on this duty, near the equator and off the Brazilian coast, for a considerable period, during which, it is pleasant to note, that the ship, though but a small sloop-of-war, never sighted a sail which she did not overhaul,—a record which speaks volumes for the efficiency of her engineering staff.

While refitting in the harbour of Bahia, Brazil, the *Wachusett* became the actor in one of the most striking and dramatic engagements of the war,—the capture of the Confederate cruiser *Florida* in the neutral waters of that port. The latter vessel was built at Liverpool in 1862 on the model of British gun vessels. She carried a battery of two 7-inch rifles and six 6-inch guns, and, in her brief career, had done much damage to American merchant shipping.

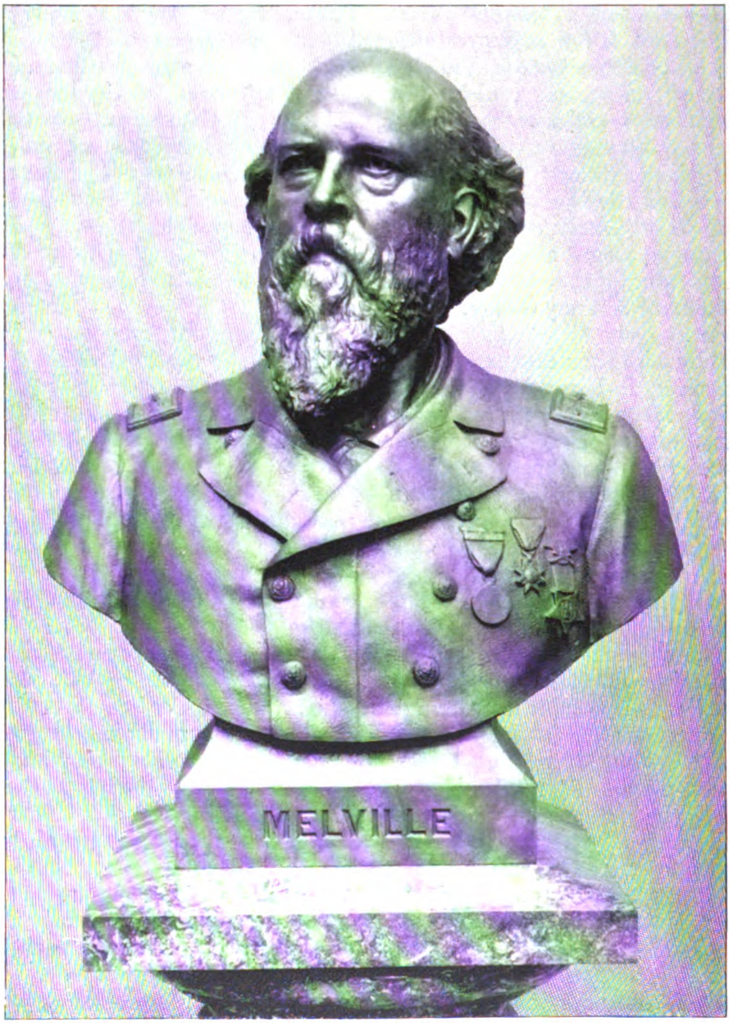
She came into the outer harbour of Bahia on the night of October 5, 1864, revealed her identity boldly when hailed, and, shortly thereafter, although the decks of the *Wachusett* were cleared for action, moved to an inner birth within five-eighths of a mile of that vessel. Between the two, to keep the peace, lay a Brazilian corvette, and there was in addition, ready for this service, a 22-gun sailing sloop with the forts on shore, one of 46, the other of 16 guns.

The *Florida* had received permission to remain for forty-eight hours, during which Captain Collins, of the *Wachusett*, challenged formally the captain of the cruiser to a naval duel, with their respective vessels, beyond the marine league. This the latter officer declined and Collins then determined, before the time limit expired, to capture or destroy the cruiser in the harbour. As such an act was contrary to international law and might be attended with much hazard in the guarded port, Collins called, in his cabin, a council of war, at which Melville, with other officers, was present, to consider the surest mode of attack.

Many methods were discussed, but the choice fell upon that suggested by Melville—to ram the *Florida* where she lay. It was contended by more than one member of the council, that, when the *Wachusett* struck her blow, the shock would start the boilers from their fastenings, thus breaking steam joints and scalding fatally all below. Melville combated this theory and ended the discussion upon it when he said to the captain:—

"I do not think the boilers will break loose; but, if they do, there need be but one man sacrificed, for, after the engines are started, I can work them alone and will order all hands on deck."

While preparations for the attack were making, Melville volunteered to board, in *mufti*, the *Florida* in broad daylight, and ascertain, if possible, the strength of her battery and the location of her machinery. If, in this mission, his identity were discovered, he might have been strung up, as a spy, to the yard-arm; but, notwithstanding this danger, the fearless young officer succeeded in reaching the enemy's gangway in a shore boat, gained her deck, and with a quick glance fore and aft obtained the desired information before the officer in



A BRONZE BUST OF COMMODORE MELVILLE IN THE WAR MUSEUM, AT PHILADELPHIA, OF THE LOYAL LEGION.

charge hustled him over the side and into his boat with the injunction that, if he did not keep off, a shot would be dropped through her bottom, leaving him to sink or swim in the bay.

At 2 A. M., on October 7, the *Wachusett* began her brief but hazardous voyage. Melville, however, was not entirely alone below, one fireman, Bradley, having refused to leave him. She struck the *Florida* on the starboard side, abaft the beam, and cut her down for eighteen inches below the water line, carrying away her main yard and mizzen mast, throwing her after broadside gun down the cabin hatch, and burying her ship's company below the awnings, which were forced down on them by the wreckage.

A boarding party from the *Wachusett* surged on her from forward; there were a few pistol shots from the *Florida* which were answered by a volley from the Union vessel and the discharge of broadside guns; and the victory was complete. A hawser was made fast to her foremast and the *Wachusett* towed her off to sea, running, on the way, the gauntlet of a *pro forma* fire from the Brazilian forts and vessels-of-war. The action lasted but twenty minutes and there were but three men wounded, a bugler, the engineer's yeoman, and Melville himself, who, after the cutting out, received a severe axe stroke across the back of the left hand.

Says Professor Soley:—"The capture of the *Florida* was as gross and deliberate a violation of the rights of neutrals as was ever committed in any age or country. * * * All that can be said is that it was the independent act of an officer and that it was disavowed by the government." He adds, however, as to the approval by the American people of the act:—"The slight regard which, during nearly four years, neutrals had shown for their obligations toward the United States, and the use of their own territories which they had permitted to the Southern cruisers, had aroused in this country a just indignation and a deep-seated sense of wrong and outrage."

The *Wachusett* proceeded with her prize to Hampton Roads, Va.; and there the *Florida* was sunk, according to the official declaration of the United States government, through "an unforeseen accident," after a collision with an army transport—which "accident," it may be remarked, was most opportune in its final settlement of the question as to the custody by the United States of the Confederate cruiser.

It is not strange, in view of Melville's intrepid bearing, before and during this action, that he should be held in honour and affection by the surviving members of that gallant crew, feelings which are returned to the full by the veteran officer. In addressing, on Decoration Day, 1896, a Naval Post at Philadelphia, of which some of the old *Wachusett* men are members, he said, in part:—

"We are gathered here on this May morning to honour our illustrious dead. I say 'illustrious' in all of its broad meaning, for a patriot need not have worn the star of a general on his shoulder or the stripes of an admiral on his sleeve that he should have been illustrious. They were heroes, all, my comrades, to the very least of the sleepers here, who carried a musket, pulled a lock string, reefed a topsail in a gale, or stood a trick at the wheel—who did his duty and who did it well.

"Some of them rest beneath the grass-grown mounds we decorate and honour; and how blessed it is for an old sailor to lie here in peace through that long sleep that knows no waking. It was not so with all. We have laid others of our shipmates away in many a land. Aye, and buried them, too, beneath the lap and roll of every crested sea, from the equator, with its festering fever, to the poles, where the snow-god and the ice king hold everlasting sway."

Leaving the *Wachusett*, Melville volunteered, in answer to Porter's stirring and famous call, in which the admiral used the words, "Death, glory, and promotion." He was assigned to torpedo boat No. 6 and served with Porter's fleet at the capture of Fort Fisher, and subsequently in the hazardous duty of clearing and buoying the channel of the Cape Fear river, that the fleet might advance to Wilmington, N. C. Later he joined the gun boat *Maumee* in the James river, which little craft was the first vessel to cut and ram her way up the James as far as the Rockets below Richmond, the capital of the Confederacy, on the day of its evacuation and while the city was still burning.

When the war had ended, Melville was ordered to the *Tacony*, and, with her, served in the Mexican gulf during the French occupation and evacuation of Mexico; later he joined the gun boat *Penobscot;* then cruised to Brazil in the flagship *Lancaster;* then to the Arctic in the steamer *Tigress;* then to China and Japan in the flagship *Tennessee;* again to the Arctic in the steamer *Jeannette;* and yet again in the *Thetis* for the relief of the Greeley expedition. The latter duty, with a short term on the *Atlanta*, closed his service afloat, which, after the war, was interspersed with brief details to the various navy yards.

It is scarcely necessary to note that, during his cruising, Melville was commended officially in more than the usual form by commanding and senior engineer officers. At almost the beginning of his service, we find the young officer mentioned for "the great assistance rendered in repairing the boilers, often without drawing the fires." Captain Collins, of the *Wachusett*, with justice, but extreme conservatism, gave it as his official opinion that Melville was "a valuable officer to the government." The captain of the *Penobscot* believed him to be "capable of building and running the engines of any of our men-of-war." On the *Lancaster*, it was said officially that he "exhibited an amount of mechanical ability, energy, and engineering skill rarely found." And the fleet engineer of the United States Asiatic Squadron, now the honoured ex-Engineer-in-Chief Loring, U. S. N., wrote officially, as to his service on the *Tennessee*, that experience with Melville but confirmed "the high reputation this gentleman has throughout the service for professional skill, executive ability, energy, and zeal. In all these qualities, as well as in those other essential ones that go to make up true manhood, it is no disparagement to his fellows to say that I believe he has not his superior in his corps,"—an opinion which De Long, in later days, with the *Jeannette* beset in the pack, found occasion, also, officially to write.

It might well be assumed that Melville's tireless and intrepid spirit would not rest easily beneath "the rust of a long peace." With no foes of the flag to fight, he turned, at the first opportunity, to a strife perhaps more perilous, —the war with the "White North."

In 1870, Captain Hall, the American explorer, made his last voyage to the Arctic, reaching the hitherto inaccessible polar ocean. His ship, the *Polaris*, was then forced to the Greenland shore and there, in Thank God Harbour, Hall died. Subsequently, in returning southward, the *Polaris* was almost crushed in the ice and a part of her crew fled in the darkness to the floe, on which they drifted 1300 miles during five terrible months, and were rescued finally, off Labrador, in April, 1873, by the sealing steamer *Tigress*.

When news of this reached the United States, the *Tigress* was chartered at once to return for the remnant of the expedition. Melville volunteered as her engineer officer; and, although the machinery of the vessel was worn and old, he succeeded in driving her as far north as Littleton Island, the winter quarters of Dr. Kane, in a little over thirty days. The camp of the *Polaris* party was found, but they had deserted their stranded ship and gone southward, having been rescued finally by a whaler at Cape York.

Unaware of their safety, and during the fierce autumnal gales of the Arctic, the little *Tigress* pursued gallantly her search, "being able to keep the sea under steam," as, on his return, Commander Greer, U. S. N., stated officially, despite "the miserable condition of the boilers and the cheap machinery found on board," through Melville's "great fertility of resource, combined with thorough practical knowledge."

The ice hunger was fully on him now, —that strange desire, which, for more than three hundred years, has drawn poleward, to "the Ultima Thule of the world," so many of the stern and dauntless spirits of our race, from John Davis, of Sandridge, who in 1588, in his tiny vessels and with his reckless gallantry, made the first great dash toward the Northwest Passage, to Melville, and Greeley, and Nansen of our time. And so, when six years later, the next Arctic expedition left the shores of the United States in the *Jeannette*, we find Melville with it,—an eager and daring volunteer.

The *Jeannette*, a bark-rigged steamer of 420 tons, was purchased and equipped for polar service through the liberality and patriotism of Mr. James Gordon Bennett, of New York. She was commanded by Lieutenant George W. De Long, U. S. N., serving with whom were Melville, two lieutenants, and Surgeon Ambler, of the United States Navy, and twenty-eight others comprising the scientific staff and crew. Melville's detail was not obtained without effort, De Long noting that "the department was very reluctant to attach him to the *Jeannette* from a sense of the extreme difficulty of supplying his place in his absence."

Prior to this voyage, no polar expedition had ever passed through Behring's Strait, although high northing had been made by British ships, sent by that route, years before, in the hope that they might meet Sir John Franklin's squadron. In facing so much that was unknown, the expedition was regarded as but preliminary and experimental in seas which no keel had plowed.

Leaving San Francisco, Cal., on July 8, 1879, the ice was met early in September a short distance northwest of the straits. The vessel never, thereafter, escaped from the floe which held her. She drifted almost steadily to the westward for nearly two years, and, in the end, was crushed and sunk, June 12, 1881, in 77° 15′ N., 155° E., leaving her crew shelterless on the ice floe in mid-ocean.

During the long and dreary months of forced inaction in the ice, De Long learned to know the high qualities of his engineer officer, as the pages of his *Ice Journal* show so often.

"Melville," he notes, "is more and more a treasure every day. He is not only without a superior as an engineer, but he is bright and cheerful to an extraordinary extent. He sings well, is always contented, and brightens everybody by his presence alone. He is always self-helpful and reliant, never worries about the future, is ready for any emergency, has a cheerful word for everybody night and morning, and is, in fine, a tower of strength in himself."

As he wrote his manly words, De Long had no thought of the bitter fate in store for him. He little knew that the genial and stout-hearted man whom he praised would yet, through storm and danger, seek and find him in death. That the strong, sweet voice, whose songs cheered so often that hapless company, when beset in the ice and on the long retreat, would yet chant, in sorrow, his requiem above the lonely tomb on the Lena Delta.

Life in the floe was not wholly one of ease and peace. The ice was restless and the ship met many a jar in her long drift. She had been but four months in the pack when she was "nipped" and strained almost fatally, the water coming in rapidly from forward and freezing, as it entered, in a temperature of 29 degrees F. below. The deck pumps were manned and seemed, for the time, to hold their own; the boiler was filled hastily with snow, slush, and ice from the bilges; and the furnaces were fired long before this was completed. At last, steam drove effective pumps, and the *Jeannette*, for a space, was saved by its power. De Long speaks of Melville's "indomitable energy" in this crisis, and, later, of "Melville who will not sleep or rest," but who, when he does retire, "lies awake, planning some new means of pumping a ship by steam which will be more economical than the main boilers."

The latter question was of vital importance. With a limited coal supply, the large expenditure for pumping meant, if not lessened, abandonment of the ship and facing the perils of the moving pack. The commander of the expedition refers often to Melville's success in devising one mechanism after another to accomplish this; and, in view of his words, General Greeley's comment seems but just that the *Jeannette* " avoided foundering only through the energy and skill of Melville."

With little but the ceaseless pumping to disturb the " unbroken monotone " of life within the pack, the ship drifted for nearly eighteen months from the time she sprung aleak, until, on May 16, 1881, an unknown island was sighted. Eight days thereafter another loomed up, and, although the drift was rapid and the floe was in a swirl, De Long sent, to unfurl the flag on this new land, a small force with Melville in command.

The journey was hazardous in the extreme. There were lanes of water to be ferried over, roads to cut, and chasms to fill that the dog-team might cross. The temperature was many degrees below freezing, the clothes of the party were wet, and their hands frost bitten. Undeterred, Melville pushed on for three days, when the island rose before him; but between them surged a wild stream of ice blocks in constant motion and tumult. " Great bodies of ice were incessantly fleeing, it seemed, from the mad pursuit of those behind; now hurling themselves on top and now borne down and buried by others. And it was through this chaos that we must force our way to the island."

Abandoning their light boat, with much of their provisions, Melville and his men made a dash for the shore; dragging the dogs which, from fear, refused to follow; jumping the sled from one to the other of the rolling floe bits; and reaching, at last, wholly exhausted, the coveted land. Giving his flag to the breeze and taking possession of the new territory—as Henrietta Island—in the name of the United States, Melville made a running survey of the land, with the bearings of the principal promontories; and then, after a short rest, the expedition began its return, during a bitter storm and reaching the ship after five days' absence. Of Melville's reckless gallantry in this, De Long justly says:—" If this persistence in landing upon this island, in spite of the superhuman difficulties he encountered, is not reckoned a brave and meritorious action, it will not be from any failure on my part to make it known."

In the early morning of June 12, 1881, the *Jeannette* met her fate. Thirty-six hours previously, the motion of the ice had become violent; later, the floe split and the ship righted; then it closed in again and she began slowly to fill. At 4 A. M., she sank suddenly. The yardarms were stripped and broken upward, parallel with the masts, and so, like a great, gaunt skeleton clapping its hands above its head, she plunged out of sight. The situation was one to chill the stoutest heart,—out on the split and moving floe in mid-ocean; 500 miles in a direct line from the Lena Delta, the nearest hope of succor; 150 miles from the nearest known land, the desolate New Siberian Islands; with some sick men; and able to transport but a limited supply of food. Of a portion of the retreat from this point, General Greeley says:—

" Lieutenant Danenhower had long been disabled, Lieutenant Chipp and three men were sick, and, under these conditions, De Long retreated south to the New Siberian Islands, 150 miles distant. In this fearful journey, Melville was full of energy and expedients."

Forty-one days after the march began, a hitherto undiscovered land, named, by De Long, Bennett Island, was reached. The journey, thus far, had been entirely by sledging and had been attended by herculean toil. Throughout it, roads had to be cut, bridges built over narrow leads, and rafting resorted to where bridges would not serve. The force was, in addition, too small to haul more than one sled at a time, and, therefore, to advance all of the baggage, the course must be traversed, to and fro, thirteen times.

Melville led the working force during the greater part of the distance to Bennett Island, acting as a lead horse in setting the pace, or tugging in the harness and putting his shoulder to the sled, when need arose. De Long writes of this:—"There is no work in the world harder than this sledging; and, with my two line officers constantly on the sick list, I have much on my hands. In Melville, I have a strong support as well as a substitute for them, and as long as he remains as he is, strong and well, I shall get along all right."

A stay of nine days on Bennett Island recruited the exhausted men, and, as the Arctic winter set in, they started southward again. There were many water leads in sight, and De Long embarked his crew in the three boats, commanded respectively by himself, Chipp, and Melville. The latter's orders were explicitly "to take command of the whale boat;" and this was emphasised thus:—"Every person under my (De Long's) command at this time, who may be embarked in that (whale) boat at any time, is under your (Melville's) charge and subject to your orders."

The journey, while now less fatiguing, was still attended by great toil and suffering. Sailing, for any distance, was impossible. Again and again the shifting ice would block a lead, and the boats must be discharged, hauled up, and dragged, perhaps half a mile, to their relaunching. While in the boats, the men were cramped, cold, and wet; their scanty clothing was in rags; and they had no covering for hands or feet. Once progress was totally stopped and the "Ten Day Camp" was made upon the floe. Several times they touched at islands, but lingered briefly, for food was failing and delay meant death.

At last, after five weeks of this, we find the three commanders, on the evening of September 11, at the edge of the ice, with the open sea before them, and the Delta but ninety miles away. They communed together long and earnestly. Help seemed near and hope surged high. And yet, all unaware, there clung, about these stern and gallant men, the shadow of death. They had come to the parting of the ways.

The little squadron was in motion with the dawn, Melville attending the sheet and retaining then, as always, the command of his boat. The wind and sea arose, and by evening it was blowing a living gale, before which the boats ran. The swifter whale boat forged ahead and could not keep the position, with regard to him, that was indicated by De Long. With great seas following and threatening to comb over on her, she must either increase her speed, heave to, or be swamped. De Long, seeing her peril, waved her onward; and, with that last signal in the misty twilight, Melville and he parted for all time.

"Looking backward," later on, Melville writes of Chipp's boat:—"Once more she appeared; an immense sea enveloped her; she broached to. I could see a man striving to free the sail; she plunged again from view; and, though wave after wave rose and fell, I saw nothing but the seething white caps of the cold, dark sea." Chipp and his men had gone to seamen's graves.

On the whale boat there were eager eyes watching to sight the stream of running ice in which she might find shelter. For her to outlive the gale it was, as Melville tersely puts it, "A case of 'Night or Blücher—ice or heave to!'" There was no ice, and, at last, the boat, with danger and difficulty, was put about and lay, head to wind, held by a rude sea anchor which had been hastily made. In suffering and peril, her hapless crew pitched and rolled until the next afternoon, when they were again under way, entering, after many hours at sea, one of the mouths of the Lena river, and reaching, after many privations, the Russian village of Geeomovialocke. In about 100 days and transporting 290 pounds per man, they had completed an unparalleled retreat, aggregating, in its many windings, over 2200 miles.

Their condition was pitiable. Feeble, ragged, and starving, with frozen limbs, painful as though scalded from knees to toes, they clambered ashore, Melville himself being unable to stand for fifteen days. The village was poor and desolate. The only food was geese and fish, both well advanced toward decay, and there was little even of these. With enfeebled men on such a diet and without anti-scorbutics, scurvy became a

THE PARTING OF THE BOATS OFF THE SIBERIAN COAST.

REPRODUCED FROM "IN THE LENA DELTA."

present danger, and departure inland a vital necessity. It was, however, only after a lapse of three weeks that it became possible to send a native courier through to Bulun, the nearest official Russian settlement. Two weeks later, he returned bringing some supplies and what seemed to Melville a message from the dead—a dispatch from two seamen of De Long's crew.

Their boat had landed September 17 and they had followed southward the barren shores of the Lena, retarded by snow, young ice, and the sick. De Long and Ambler, to their everlasting honour, had held fast to their feeble and dying men, and, when game and food failed, had sent two of the party in advance to seek relief. From these the message came. Melville set out, at once and alone, for Bulun, and there met the two seamen. He was still far from strong. De Long and his men were dead. Although he did not know this to be so, his judgment told him that, after such delay, a search would be fruitless in saving life. And yet, "it was duty." Like the heroic Richard Chancellor, of early Arctic history, his noble rule was "either to bring that to pass which was intended, or else to die the death!" An eloquent writer has said of Melville's unflinching fortitude and fidelity at this time:—

"To the southward, toward Yakutsk, whither he had ordered Danenhower to proceed, a warmer sun was shining, and there lay the great Russian road leading to the borders of civilisation; to the railway, to the blue sea, to home! Few men, after passing through all the perils that Melville had survived, would have thrown away that seeming last chance of personal safety; but he, being cast in rare, heroic mould, turned his back upon the means of saving himself and set his rugged face to the northward, forcing his way into the darkness and the awful silence of the Arctic winter like one deliberately invading the dominions of death."*

And so, starting out with two natives, two dog-teams, and five days' food, he began a search which extended through

* Bennett's "The Steam Navy of the United States."

twenty-three days and over a thousand miles of travel, in the deadly cold of the Arctic winter, at a time when there were but two hours of daylight in the twenty-four, and through the fierce gales which then swept the treeless *tundras*.

It is not possible to detail fully herein the peril and the suffering of that search. Melville early became disabled from the cold, his feet and limbs swelling, blistering, and the skin cracking. While he stopped occasionally at settlements, food was scarce there and it failed often in the field, necessitating the use of reindeer bones, fish heads, and other refuse, gathered on the march. The faces of the natives became blistered and sore, the dogs were worn to mere skeletons, and even Melville himself grew careless as to whether he lived or died—and still he pressed on! Inured to the cold as they were, his men flagged often in their march; but by entreaty, by argument, by intimidation with the sight and sound of fire arms, the half frozen, helpless, but dauntless leader, kept them moving. Once they mutinied outright, saying: —

"We have no food. We cannot go. We shall die!"

The only answer was:

"I will go on. We shall eat the dogs first; and, after that, I will, if necessary, eat you Yakutsk; but I will go on."

And the mutiny was crushed.

The journey extended to the shores of the Arctic ocean where he found the instruments and records *cachéd* by De Long, whose track he followed for some distance inland, until, misled by the chart, he lost the trail. Then, exposed to a pitiless storm, attacked by an enervating dysentery, and worn to a shadow from cold, hunger, and slow starvation, he returned to Bulun.

STARTING ON THE SEARCH FOR DE LONG.

REPRODUCED FROM "IN THE LENA DELTA."

With the earliest spring, despite fierce gales, Melville was again in the field, leading then a well equipped party. On March 23, 1882, he found his dead shipmates,—De Long lying on the river

FROM THE ORIGINAL OIL PAINTING BY ALBERT OPERTI.

MELVILLE FINDING THE BODIES OF DE LONG AND AMBLER IN SIBERIA.

bank, Ambler with him, and the rest gathered near. Apparently Ambler had been the last to die. He lay with a loaded pistol in his hand, as if defending the dead before him, keeping "his lone watch to the last—on duty, on guard, under arms."

Of him,—a Virginia gentleman of the old and courtly school—Melville speaks with deep tenderness, for the ties between them were warm and brotherly, born of regard, each for the other's fortitude, fidelity, and honour. An incident which shows the manly traits of both may well be given here. The dark horrors of the Franklin retreat, which were revealed when the seekers, years after, found human bones in the camp kettles of that hapless company, had been discussed between them and powders of cyanide of potassium had been prepared on the *Jeannette* to be carried by both, that they might end their lives, if, in the famine of a long retreat, such a temptation should ever come to them.

Again, when near the ending of that last march, De Long broke down—physically, but never mentally,—and, in noble self-sacrifice, asked that his men leave him and go on, Ambler's stern answer was:—"If you give up, I take command! And no one shall leave you while I live." They were knightly to the last, these wan shadows of living men.

There remained but to bury the dead. If left on the lowlands the coming floods would sweep them to the ocean. In the foot hills, miles away to the southward, there was a rock, "a bold promontory, with a perpendicular face, overlooking the frozen polar sea," and, on its summit, Melville built a tomb of massive timber capped with a heavy cross. Then, turning tenderly the dead faces "toward the East and the sun rising," as he writes, "in sight of the spot where they fell, the scene of their suffering and heroic endeavour, where the everlasting snows would be their winding sheet, and the fierce polar blasts would wail their wild dirge through all time,—there we buried them, and surely heroes neyer found fitter resting place."

It was done. The working party turned to go, but Melville lingered. He was worn physically, brain weary, and heart sick; and, for a moment, the reaction came. The stern eyes that the snow glare could not blind grew dim, as memory, in full tide, surged backward through the years. He had been the singer of the *Jeannette*, and, leaning on the tomb, there came from him, half unconsciously and yet in noble pathos, his last song to the dead:—

We thought, as we hollowed the narrow bed
And smoothed down the lonely pillow,
That the foe and the stranger would tread o'er their heads,
And we—far away on the billow.

Lightly they'll speak of the spirits who're gone
And, o'er their cold ashes, upbraid them;
But little they'll reck, if we let them sleep on
In the grave where a comrade hath laid them.

Slowly and sadly we laid them down
From the field of their fame, fresh and gory,
We carved not a line, we raised not a stone,
But we left them alone with their glory.

The mourner, alone there on the *tundra*, at the bitter ending of his heroic *Odyssey* of wandering in the North, was proving again, all unconsciously in his last song, a truth as old as time:—

"The bravest are the tenderest,
The loving are the daring."

His words, too, rang truer than he knew, for it was not so long after that the dead commander was "upbraided," that his conduct of the expedition was questioned unjustly, and that Melville appeared before a Congressional commission, his defender in death as he had been his "tower of strength" when ice beset.

De Long and his silent company have been borne since then across the sea and sleep in peace with the dust of their kin. Without detraction from that dead leader's fame, in his masterly retreat and in his intrepid march to death, it may be said that Melville's name glows brilliantly on many a page of the history of that expedition, inscribed there often by De Long's unselfish hand.

Glance at the record of the engineer officer! In the beginning, the *Jeannette* avoided foundering only through his energy and skill; and she would have been abandoned long before she sank, but for his inventive genius and resource. He was the first, through many dangers, to unfurl the flag on unknown Arctic land. He led the working force during the greater part of the fearful march to Bennett Island. He commanded one of the three boats in the subsequent retreat; one of the two which reached the land, and was the only commander to bring his crew through safely.

While yet enfeebled, he made a search, without parallel in Arctic history, for De Long, through wild storms and deadly cold and in the sunless day of the Arctic winter. In earliest spring time, amid fierce gales, he found and buried his dead comrades. He recovered and brought back, while ill and partly frozen, all the records of the expedition. And, finally, before turning his face homeward, he made a last search for Chipp and his men, outlining with his party, the entire coast of the Delta and entering the mouths of all its streams. Surely, the force of duty, of honour, and of friendship could no farther go than this.

Melville's achievement, in this expedition, retreat, and search, met cordial acknowledgment from competent authorities. The Hon. William E. Chandler, Secretary of the United States Navy, referred to it as "untiring and intrepid." In 1890, the Hon. James R. Soley, Assistant Secretary of the Navy, delivered an address at the unveiling of the *Jeannette* monument at the United States Naval Academy at Annapolis, Maryland. While stating that "it is not to the living, but to the dead, that this day is consecrated," the speaker said:—

"First of all come his (De Long's) two right hand men, the executive officer and the engineer, of whom he writes:—'Aided by Chipp and Melville, whose superiors the navy cannot show, with their untiring energy, splendid judgment, and fertility of device, I am confident of doing all that man can do, to carry the expedition to a successful termination.'"

And again of the search, he said:—
"There is more yet to be told of this expedition, but we may not dwell upon it here. * * * How Melville heard from Noros and Nindemann of his captain's cruel plight, and how, before he had regained his strength, he braved alone the Arctic storms and cold and hunger, traversing the Delta down to the very coast, freely putting his life again at hazard in the faint hope that he might bring relief; how a second time he scoured the plains in March and found the bodies, and, laying them in the earth to rest, built over them the cairn and cross, in whose likeness this stone has been erected here."

The naval Court of Inquiry which, in 1883, investigated all facts as to the *Jeannette* expedition, after stating in its report that Melville, in his search, nearly sacrificed "his life from hunger and cold," said that especial commendation was due him "for his zeal, energy, and professional aptitude, which elicited high encomiums from his commander."

Brigadier-General A. W. Greeley, U. S. A., the commander of the Arctic expedition to Lady Franklin Bay, in his work "Explorers and Travelers," makes mention of Melville's "indomitable energy and great professional skill" in getting under control the leak in the crushed *Jeannette*; of how, "at the risk of his life, through the moving pack," he landed on Henrietta Island; and of how, "exhausting all practicable means," he pressed the search for De Long.

As to the retreat over the pack in which Melville played so important a part, this eminent Arctic authority says:—

"Lieutenant Danenhower being disabled and Lieutenant Chipp sick, De Long's main dependence was in his chief engineer, Melville, who was well, strong, energetic, and fertile in expedients. * * * It is unnecessary to dwell on the dangers and hardships which this unprecedented journey entailed on the members of this party, which were met with fortitude, courage, and energy that made its successful issue one of the most notable efforts in the history of man, overcoming obstacles almost insurmountable."

In reporting favourably a bill giving Melville promotion for his heroic service, the naval committee of the United

States House of Representatives of the Fiftieth Congress said:—

"The qualities, as officer and man, displayed by Chief Engineer Melville throughout the cruise of the ill-fated *Jeannette*, and especially during the retreat of her crew over the ice and waves of the Polar sea, to the desolate shores of Northern Siberia, and more strikingly during the search for the remains of Lieutenant Commander De Long and his party during the perils and privations of an Arctic winter, have invoked the admiration of the world."

In the Fifty-first Congress, the Senate naval committee reported on this bill as follows:—"In view of such a record, the committee feel that the proposed promotion, so long after the deeds which it is intended to recompense, is an act of tardy justice and hardly adequate."

The bill, as passed finally, stated that the promotion was given as "a recognition of his (Melville's) meritorious services in successfully directing the party under his command after the wreck of the Arctic exploring steamer *Jeannette*, and of his persistent efforts, through dangers and hardships, to find and assist his commanding officer and other members of the expedition before he himself was out of peril."

With a glance at the reward for Melville's Arctic work, we close the tragic story of the *Jeannette*. In 1881, the United States dispatched the Lady Franklin Bay expedition, under Lieutenant Greeley, U. S. A. The scientific results were of the highest value, although the expedition ended in tragedy through no fault of its commander or his men. The gallant Greeley, in reward, was advanced from a captaincy to a brigadier generalship and made chief signal officer of the United States Army.

After Melville's return, his friends in Congress introduced a bill advancing him thirty numbers and giving him the thanks of that body. The measure was bitterly fought and was passed, only after a delay of nearly ten years and then in modified form, omitting the "thanks" and promoting him but fifteen numbers. During the American Civil War, an advancement of thirty numbers was given often for a single gallant act and his reward, after ten years, was but fifteen for an *Iliad* of brave deeds in the retreat and on the Delta! It is noted herein with regret that the opposition to a just recognition of his service arose, to some extent, from that strife between the branches of the United States Navy which has eaten like a canker into the generous impulses of so many gallant men.

Melville reached home on September 13, 1882, just one year after the parting of the boats in the gale, and, for him, a year of danger and of strenuous toil. On May 1, 1884, we find him northward bound again, this time with the squadron dispatched to the relief of the Lady Franklin Bay expedition, whose inception has been hereinbefore mentioned.

This expedition had been in the Arctic since August 11, 1881, and, having no means of transportation by sea, was to have been relieved, at a predetermined time, by vessels from the United States. The relief ships not appearing in due season, the expedition began its retreat, which was effected, in health with records and all essentials excepting full food supplies, to Cape Sabine in October, 1883. There, hemmed in and daily expecting succor, Greeley made what proved to be the death camp of many of his men, and there the feeble and starving remnant of his heroic command was rescued, June 22, 1884, by the United States ships *Thetis* and *Bear*.

His expedition "failed not in aught entrusted to it" and "perished through others;" for, as Melville states, the United States Government's efforts for relief, made in due season, "were thwarted by carelessness, incompetency, or inexperience." On September 14, 1883, while Greeley's men were still in good condition, Melville wrote the United States Navy Department, volunteering, if landed at Cape York, to lead a party to Littleton Island, to communicate with Greeley, and, if the latter's men were sufficiently strong, to conduct them to the base of supplies at Cape York.

This proposition was rejected by a naval board as impracticable, mainly on the ground of the lateness of the season, although whalemen had been known to cruise as far north as Cape York up to October 20. General Greeley himself said afterward, as to this:—" I have already officially concurred in the views of Chief Engineer Melville and the opinions of the sealers of Newfoundland that our relief was practicable during the autumn of 1883."

With the rejection of Melville's project, which his experience and courage would, doubtless, have made successful, the ill-starred expedition was left to its fate for another winter, another spring, and well into another summer. When, finally, a relief squadron was organised, Melville volunteered; his knowledge of the needs of such an expedition was utilised largely; he was among the first to reach the dying men at Cape Sabine; and, with this mission of mercy, there closed fitly his Arctic service, and, in effect, his service afloat.

Commodore Melville has served as engineer-in-chief of the United States Navy for over nine years, having begun his tenure of that office in characteristic fashion. The rebuilding of the fleet had been started and four vessels, designed by United States naval engineers and constructors, had been completed by contract in the yards of John Roach, a skilled and famous shipbuilder of Chester, Pa.

For reasons, which it is not within the province of this paper to discuss, the ships of Roach were bitterly attacked and were reported upon adversely by official boards, ignorant or prejudiced apparently, since, in many a gale since then, these vessels have proved themselves staunch and seaworthy and have vindicated the ability of their designers and the workmanship and integrity of their great builder. As an apparent sequence of this assault upon United States naval designers, there were purchased in Europe for the government, by officers who were neither engineers nor constructors, the plans of several vessels for further addition to the fleet.

In 1887, the secretary of the navy resolved to change the foreign policy which these purchases indicated; and he instructed Chief Engineer Melville to prepare, at Philadelphia, Pa., special designs for the machinery of two 1700-ton gun boats, and original drawings for that of a 4100-ton cruiser. When completed, those of the cruiser were accepted by the Union Iron Works, of San Francisco, Cal., which company guaranteed their success, preferring them to foreign designs offered as alternatives. From them, the machinery of the cruiser *San Francisco*, a highly successful ship, was built; and there was ended thus the regime of imported plans, those of the bureau of engineering having been accepted, as a whole, without question by contractors in all subsequent work.

The energy with which, in a few brief weeks, this task was done, with its wholly successful outcome, met due recognition; and, on August 9, 1887, shortly after its completion, Melville was nominated as engineer-in-chief of the navy, with the relative rank of commodore. His success in discharging the duties of this high office, with his administrative ability and his sterling integrity therein, are too widely known to need comment here. During the years in which he has been the engineering head of the United States Navy, machinery aggregating over 350,000 horse-power has been designed for over sixty vessels of all types, from battle ships to torpedo boats. In the building of these, with the routine work of the bureau and of the various shore stations, he has passed upon expenditures approximating thirty millions of dollars, without a question as to his efficiency or a suspicion as to his integrity.

The term of his office is four years, and that he is now serving through his third appoinment indicates the national appreciation of his worth. It is proper to say that, throughout this work, Commodore Melville has had at command the services of a limited, but brilliant, staff, drawn from the ablest officers of the corps of engineers. It is pleasant to note, also, that he has acknowledged, on due occasion, the efficiency of this staff and its value to him and to the American nation. In referring to the reconstruction of the United States fleet, *Engineering*, of London, has said:—

"The Americans, too, have set about the work in a characteristically shrewd and intelligent manner. They, for long, systematically collected and digested all the information that could be obtained as to what was being done by other nations in naval matters."

From this, it might be supposed, that, in this *renaissance*, every facility had been given that wisdom and generosity could dictate; that the work was projected and progressing without impediment, and by methods wholly untrammeled and business-like.

The state of affairs at Melville's entry into office has been referred to previously herein. In the issue of this magazine for October, 1896, there were set forth, in detail, some of the onerous conditions under which his corps has wrought. These need not be recapitulated here, but it may be said, in addition, that the collecting and digesting of engineering information from other countries has been done almost wholly on the American side of the sea and by the staff of the bureau of engineering.

It is true that, during this period, the United States has had naval attachés at various legations in Europe, but these have been officers of the Line. It is also true that there is at Washington an office of naval intelligence whose function is the gathering of information from abroad on all branches of naval science; but, for some years, its staff also has been drawn wholly from the Line. The various officers referred to are highly educated, but their knowledge of engineering, in detail, is limited necessarily to ordnance subjects. Men do not "gather grapes of thorns or figs of thistles;" and such a system, in respect to naval engineering, is fundamentally wrong and practically useless.

Moreover, the education of engineer cadets at the naval school has been, during much of this period, defective in that they have had, throughout a four years' course, but one year of detailed instruction in professional branches. While able engineer officers have acted as instructors and the curriculum during this closing year is most excellent, it is too brief to be of full service and it has been necessary, therefore, to complete the training of young engineer officers by various post-graduate methods.

Commodore Melville has not the arts of the diplomatist. Like many strong men, he is wholly straightforward. He has met these obstacles, therefore,—in deeds, with a toil and vigilance which have won high professional success; in words, when need arose, by protest, frank, manly, and wholly resolute. There can be found, in fact, no more strong and fearless statements as to the responsibility and field of the naval engineer of to-day, as to his right and privilege, and as to the danger to the nation which an inadequate engineering force involves, than are included in the official reports of the engineer-in-chief. Snatching victory from the jaws of defeat in the beginning of his term of office, he has served his country since with fidelity, with honesty, and with untiring labour.

In April, 1884, the "Jeannette Inquiry" was held by a sub-committee of the committee on naval affairs of the United States House of Representatives. Its purpose was "to investigate the facts connected with the *Jeannette* Arctic expedition." The resolution authorising it was based upon a petition which, as the then secretary of the navy stated, contained "aspersions * * * upon the heroic Lieutenant Commander George W. De Long, the untiring and intrepid Chief Engineer George W. Melville," and others, which aspersions, he further stated, were "untrue and unjust."

The opinion of that committee, formed from most ample investigation, may be given in a single phrase from its report, which declared that the officers referred to, with all others of the expedition "well deserve the most generous praise of their country, which does and will continue to entertain a just pride for their noble qualities."

In this investigation, the heirs of De

Long were, with Melville, represented by counsel, to whom was opposed the counsel for the petitioner. Melville's testimony— or rather argument—before the committee excited comment for its clearness, its unbroken flow, and its sustained power during long hours. After referring to it as "vivid and beautiful," the opposing counsel stated:—

"I have this to say with reference to Melville, that he is mentally so constructed as to be an extraordinary and remarkable man; and, in that wonderful oration which he delivered here, under oath, from half past 10 in the morning until 6 at night, I have never witnessed, in my experience, more physical and mental endurance."

These words—from, for the time, a formal foe—indicate partially Melville's power in written and spoken thought. He has, in high degree, the faculty, so essential in literature and art, of minute observation as to, and persistent memory of, details; with further, a vocabulary unusual in its extent, and instant and fluent in its application. Combine these with a wide reading which crops out here and there in simile and quotation, with an imagery drawn from scenes which not all have viewed, and a toil and suffering which few have met, and with the further fact that his honour and that of the dead had been questioned; and it will not, then, seem strange that the "oration" ranged from fierce invective to the deep tenderness and refinement of feeling shown herein as to the burial in the Delta, and that the learned counsel found it "vivid and beautiful" and "wonderful" in its "physical and mental endurance."

As is the case with many men of action, Melville has written little, preferring to leave to others the record. In the sorrowful labours which closed the *Jeannette* expedition, he was, however, the central figure and they could have no competent historian but himself. This it was which impelled his authorship of the work, entitled "In the Lena Delta." The few extracts therefrom which have been given herein, will indicate his epigrammatic and, not seldom, eloquent use of words. Wilkie Collins, in selecting from the whole range of English literature ten books of adventure, included this work. Melville's published writings embrace also an account of the Greeley relief expedition and a polar monograph.

His inventive genius has shown itself in many ways. It is but a corollary of his resourceful nature, engineering training, and wide experience. His reputation as a marine engineer makes unnecessary here more than a reference to the numberless mechanisms, in that branch of science, which he has designed and applied, afloat and ashore, —many of which, though regarded as but mechanical contrivances, cross the border land of invention.

In other fields, he has not been idle. In 1859, while yet a lad, he designed a heavy gun with a breech closing wedge, capable of ready removal and return through attached mechanism. During those early years, he devised also the system of electro plating a steel gun tube that a closer union might be made between it and the brass to be cast around it.

Early in his service afloat, he made drawings of the tracks for a pivot gun, fitting them with depressed gear teeth, meshing with gears journalled on the carriage, and rotated through suitable cranks. This system would have made possible a more expeditious training of the gun than was effected through the blocks and falls then in use, and is now, more than thirty years later, applied to every ship of the new American fleet.

Again, the 100-pounder Parrott gun in use during the Civil War, was dangerous to friends as well as foes, six of them bursting, it is said, in the first assault on Fort Fisher. The gun tube was of iron, the trunnions were cast with it, and there was a forged jacket shrunk on the breech. The defect, it is said, lay largely in forming the tube and trunnions in one piece. Melville proposed correcting this by making a gun tube, cast or wrought, and having integral therewith a thrust collar for taking the recoil, but omitting the trunnions which were forged on the jacket. The latter was bored for the tube, counterbored for the collar, and shrunk on —not so tightly, however, as to compress the metal or destroy its integrity. This method is now applied to great guns, excepting that the one recoil collar has been replaced by several, and the trunnions are omitted.

In torpedoes, he had several systems, one of which was the fitting of a composition block, cast with hinge and clamp, and secured to the fore foot of the vessel. The block was recessed to form a guideway for a curved arm hinged to it, said spar or arm, carrying the torpedo on its outer extremity, being capable of oscillation in a vertical plane through an arc of about 90 degrees, and being provided with suitable tackle to effect such oscillation, and back stays to hold it firmly. When retracted, the pivoted spar was raised parallel with the stem and holding the torpedo beneath the curve of the bow. When lowered into action, the spar projected beneath the surface of the water, carrying the torpedo in advance of the ship and below the level of her keel.

As to the inventions described above, which fall properly within the scope of the ordnance engineer, it may be said that they were far in advance of the methods of their time and contained, to a considerable extent, the elements of the successful practice of this day. While no applications for patents were filed, drawings of some of these, with others omitted here, were submitted, during the war, to the proper authorities, —apparently to be pigeon holed and disregarded.

In recent years, despite the laborious work of his bureau, Melville's mind has been otherwise active. Among his patented inventions may be mentioned an "artificial horizon," in a closed box, for the use of the navigator; a water-tight bulkhead door, moved by electric, hydraulic, or pneumatic power, and operated automatically by indication from the officer on the bridge, who can close one or many of them on the approach of danger; and, finally, an ingenious system of dredging scows, propelled by their own power, for use in the harbours of large cities.

In his homeward journey from the Delta, Melville was granted a private audience by the Czar and Czarina of Russia at the palace of Peterhof, near St. Petersburg. In New York, he was received by the mayor and council and given the freedom of the city. Later, a public reception was tendered him in the governor's room at the City Hall and a public dinner. He was given a public reception by the mayor and councils of the city of Philadelphia and a military escort and public reception at Washington. He was elected a member of the National Geographical Society of the United States, an honourary member of the Royal Swedish Society of Anthropology and Geography, and a member of the Geographical Society of Philadelphia.

Subsequently, he was made an honourary member of the Institution of Naval Architects of Great Britain—a somewhat exceptional distinction, since this society had, in the year 1896, but fourteen honourary members and associates, among whom were the Prince of Wales, the Duke of York, Emperor William II. of Germany, and the Duke of Palmella. In 1896, Stevens Institute of Technology, one of America's foremost technical colleges, conferred upon him the degree of Doctor of Engineering, an honour which has been granted, by institutions of learning, to but three other eminent engineers of the United States. He has several times, by invitation, addressed the students of engineering at Harvard University, and in the year 1896 delivered there a notable oration on "The Military Duty of Engineering Institutions."

As has been noted, he became gold medallist, by act of Congress of the United States, with promotion, for heroic services in the Arctic. The regard in which he is held by, and in which he holds, the veterans of the American Civil War, makes him an active member of the Grand Army of the Republic, of the Naval Order of the United States, and also of the Military Order of the Loyal Legion, an organisation composed of the commissioned officers who served in the Civil War. The latter order has shown Melville much honour. He has held high rank in its Pennsylvania commandery, and in its War Museum at Philadelphia there has been placed a noble bust in bronze, illustrated herein on page 464, which preserves for coming generations the resolute features of the man who has won distinction in so many fields of labour. A replica of this bust has been presented by friends to Grammar school No. 3 of the city of New York, at which institution, more than forty years ago, the future engineer-in-chief, as a student, gained his first triumphs.

Melville would command attention in any assemblage. He is but a shade under six feet in height, with an erect and stalwart frame, inherited from a long line of Caledonian forbears. He has a massive head with hair and beard grown white in active service. His eyes are blue and his complexion fair. His face, in repose, is grave and stern, an expression which is, however, but the mask of a warm and cordial nature.

A story of him, current in Washington, shows, to some extent, the effect of his picturesque personality. He passed, in his daily walk there, during the warm summer days, a famous art school. As, day after day, there went slowly by, on the shady side, the powerful figure—hat in hand and lost in thought, with drooped head and white hair floating—the girl students opposite noted it all with artistic eyes and the silent officer, all unaware, was made to serve as model for their studies of King Lear.

In speech, the engineer-in-chief is quick and decisive, and his purpose, once formed, is seldom changed. He is reticent as to his own deeds, but ready and kindly in his acknowledgment of the achievement of others. While quick and stern in resenting a wrong, he is, in friendly intercourse, as John Knox said of the Melville of the old time, "a man of nature most gentle and most modest;" and his steadfast character answers to the full that test which some one has prescribed that "a man's worth is measured by the duration of his friendships."

In this brief record it has been possible to give, in outline and in typical incident only, Melville's many-sided career. Its purpose will be met, however, if it shall aid his countrymen in their appreciation of a life which has been marked by lofty patriotism, by heroic endeavour, by strenuous toil, and by more of sorrow than is its share.

STEAM ENGINES FOR MODERN POWER HOUSES.

By Richard McCulloch.

Extracts from a paper entitled "The Modern Power House," recently read before the American Street Railway Association.

DURING the past four years the street railroad generator has undergone a radical change. Since 1893 there have been few large power houses built in which direct-driven generators have not been installed, and some of the large systems have found that economy of operation required a change from the belt, counter shaft and unit of small size to the large direct-driven generator. At the present time, the West End Railway Company, of Boston, which may be considered the pioneer in the United States in electric traction, is changing its central power station, which had originally been equipped with a very complete and elaborate system of belting and counter shafting, to a direct-coupled plan.

The first cost of the direct-coupled generator is about 35 per cent. more than the belted generator of 500 kilowatts, which is the largest standard size in which the belted generator is made; but when the expense of the belt, belt tightening device, and the floor space is taken into account, the direct-connected generator will be found the cheaper. Besides obviating the necessity of the costly and cumbersome belt, the direct-connected generator offers the following advantages:—In large sizes and in connection with large engines it has a much higher efficiency than the belted unit; it requires a small floor space; it aids supervision by bringing the working parts of the engine and generator close together; it reduces danger; it is almost noiseless in operation, and it may be installed in a larger unit than the belt-driven generator, which is limited in size by the width of the belt and pulley which may be employed.

The main objection which was urged against the direct-connected generator, was the fact that the shocks resulting from overhead loads were thrown directly on the engine, and that there was none of the cushioning effect that a belt connection might supply. While this is undoubtedly true, the best argument which may be submitted against it is that none of the installations of direct driven generators can trace any trouble to this source. The large, slow speed, multipolar, direct-driven generator has become perhaps the most prominent feature of the modern power house, and while there may be special services which would necessitate a belted arrangement, it is difficult to imagine a power house thoroughly up to date without direct driven dynamos.

By varying the number of poles and the number of armature conductors in the construction of a dynamo, the machine may be designed to run at almost any reasonable speed, the slower the speed, however, the greater being the cost of the dynamo. In the matter of speed it is necessary for the dynamo maker and the engine builder to effect some sort of a compromise, because it is not good practice to run such large engines at too high a speed.

The speeds which are most common are 75 revolutions per minute for the 1500-kilowatt dynamo, 80 to 120 revolutions per minute for the 800-kilowatt dynamo, and speeds ranging from this to 150 revolutions per minute for the smaller sizes.

These speeds are what would have been considered four years ago quite out of the range of the Corliss valve gear, but now there are many large Corliss engines driving generators at speeds up to 100 revolutions per minute, and some have even higher speeds. Several other types of engines have been adapted to this work and are running quite successfully. Outside of the question of valve gear, most engines made for this work possess the same characteristics; the heavy bed plate, the solidly constructed fly-wheel—now being made of steel plate—the wide cross-head, the large connecting rod and the mammoth main bearings.

The choice between horizontal and upright engines is chiefly one of space. The horizontal engine is the cheaper, the simpler, the easier to inspect and the easier to repair. Outside of the advantage of requiring less space, the upright engine has the advantage of less wear on the cylinder, and a more direct strain upon the foundations.

The usual practice in the most modern power houses is to install compound engines. Most of these plants are so favourably situated that condensers may be operated in connection with the engines. This is undoubtedly good practice; but in case condensers are not used, the cost of fuel must be very high for the gain in compounding to pay for the extra investment.

Where power houses are favourably situated on bodies of water, condensing becomes a very simple problem, but in case the power house cannot be built on a body of water, then, in order to use condensing engines, some sort of arrangement must be designed to cool a quantity of water so that it may be used over and over again for the purpose of condensing the exhaust steam.

In the use of large, direct-connected units, a great deal of the economy gained depends upon the selection of the proper sizes of machines. The efficiency of a generator will be good when it is operated at more than 75 per cent. of its capacity, but the efficiency of an engine drops off very rapidly when it is running below its rated load. In order to achieve the best economy from the use of large direct-connected units, the sizes of the different generators should be so proportioned that it is always possible to operate one or more units at their rated capacity.

The railroad generator, as at present built, will stand an overload of 50 per cent. for several hours without trouble and at a maximum efficiency. This should be taken into account in the estimate of the dynamos required, but it should always be the aim to have at least one idle machine to throw on the line in case of failure of any of the others. The actual size of the units depends upon the character of travel which the road possesses and the number of cars, and this must be determined for each road independently. In choosing machines, however, standard sizes should always be adopted, as this obviates any trouble in obtaining supplies and repair parts.

While each individual engineer has his own ideas concerning power house construction and while each road building a power house may purchase different apparatus, there is one general design which has been followed in many of the plants recently installed. It has been adopted by so many different engineers and in so many different places that it might almost be called the modern power house.

The engine room and boiler room are divided by a brick wall and under different roofs; both are brick buildings, covered with an iron truss roof; the boiler room is set on the grade of the street, and the engine room ten or twelve feet above this grade, the space below the engine room being utilised for the piping and condensers; the engine and boilers are set at right angles to the wall between them, with the engines next to the boiler room, so that the piping is made as short as possible and the condensation lessened. The switchboard and feederboard are set on the opposite side of the room from the boiler room, so that the length of the dynamo cables is equalised as much as possible.

As a means of comparing different kinds of machinery, figures as to cost of operation have been collected from some of the large modern power houses, and their comparison shows that less depends upon the refinements of the machinery than upon the condition in which the apparatus is kept and upon the supervision to which it is subjected. Among those having the lowest cost of operation was a power house, equipped with direct-coupled generators, but operating single cylinder, non-condensing engines, burning soft coal and using hand firing, while among those having the highest cost of operation are several power houses supplied with compound condensing engines, and burning anthracite coal.

The lowest results are about three-quarters of a cent per kilowatt-hour, some records running slightly below this, while the results from some of the large stations are as high as one and a quarter cent per kilowatt-hour. These figures include the cost of coal, water, supplies, repairs and all labour, but do not include anything for taxes, insurance, interest or depreciation. The cost of operation depends largely upon the cost of coal and upon the relation of the average load to the total capacity of the power house; the higher this ratio, the less will, of course, be the cost of operation.

A TEN-TON PNEUMATIC TRAVELLING CRANE.

W. G. Starkweather.

THE increasing use of compressed air as an efficient and economical method of transmitting energy finds its greatest adaptation in plants extending over considerable area, and where the material to be handled is too bulky to be moved to the machines, such as, for instance, ship yards, boiler shops, abbatoirs, railroad yards and crossings, bridge and structural works, etc. In all these, and for other plants as well, convenience, combined with safety, is the desideratum. Belting and shafting is not desirable on account of the extent of this class of plant.

Electricity could probably compete, but might be dangerous where the labour is of a low order of intelligence, or where the material handled is a good conductor, like iron and steel. Air is familiar to every one and, when in use, does not short circuit, burn or explode; is clean, and is admirably adapted for special uses in the above mentioned plants. The duty in these plants is mainly either raising weights, as in the ordinary hoists and cranes, or the doing of work against the molecular resistance of metals, as in caulking, riveting or punching, and for this service it seems unsurpassed.

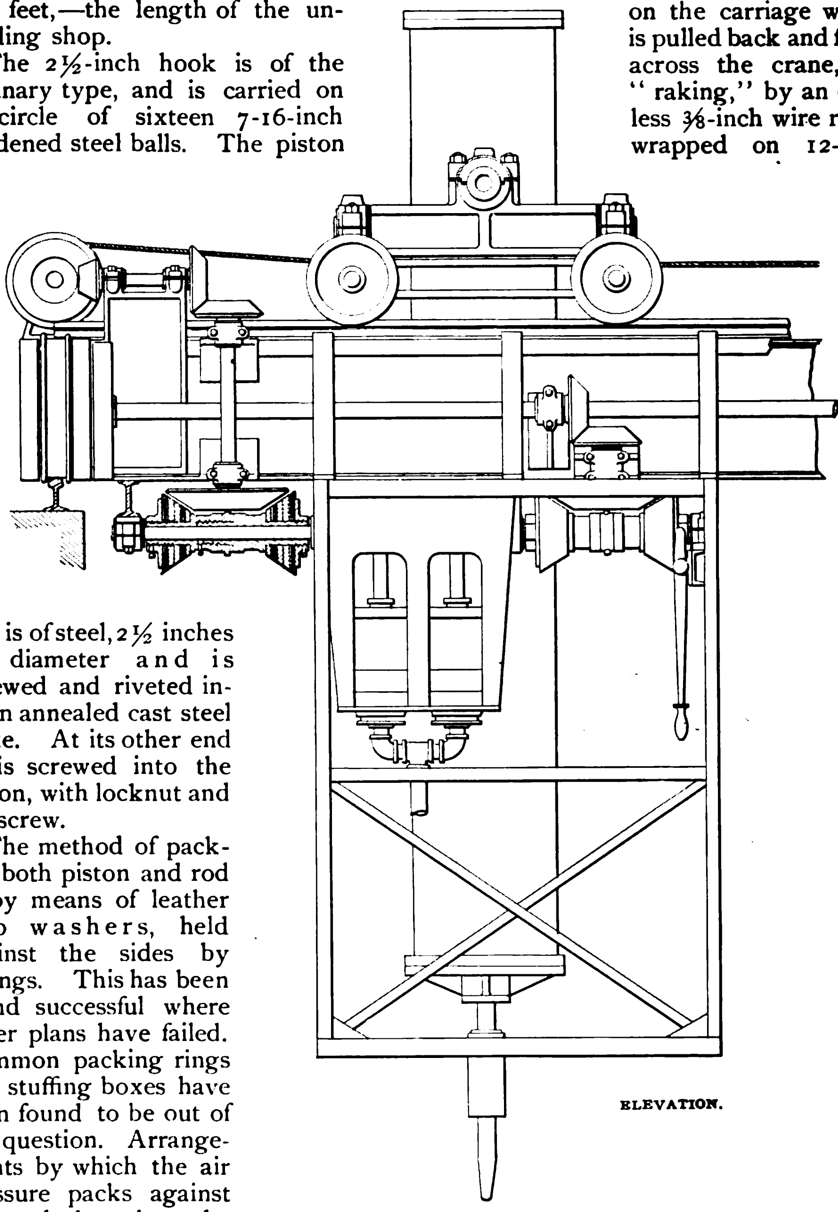
A compressed air system consists of three parts,—the compressor, the receiver and distributing piping, and the machine for utilising the stored energy of the air. Not considering either of the first two parts, the description given refers to one of the special uses to which the air may be advantageously applied in the form of travelling cranes.

The illustrations show the general arrangement and a few details of this type of crane. Two of these were recently designed for the North Milwaukee (United States) shops of the Wisconsin Bridge and Iron Company, and have some features which, if not entirely new, are perhaps interesting. They are built to lift and carry a load of ten tons across a 40-foot span, and to travel 166 feet,—the length of the unloading shop.

The 2½-inch hook is of the ordinary type, and is carried on a circle of sixteen 7-16-inch hardened steel balls. The piston rod is of steel, 2½ inches in diameter and is screwed and riveted into an annealed cast steel yoke. At its other end it is screwed into the piston, with locknut and set screw.

The method of packing both piston and rod is by means of leather cup washers, held against the sides by springs. This has been found successful where other plans have failed. Common packing rings and stuffing boxes have been found to be out of the question. Arrangements by which the air pressure packs against its own leakage have the same disadvantage as in the steam engine, the varying pressure in the cylinder producing corresponding degrees of tightness and consequent wear. Springs have the advantage of comparatively constant pressure.

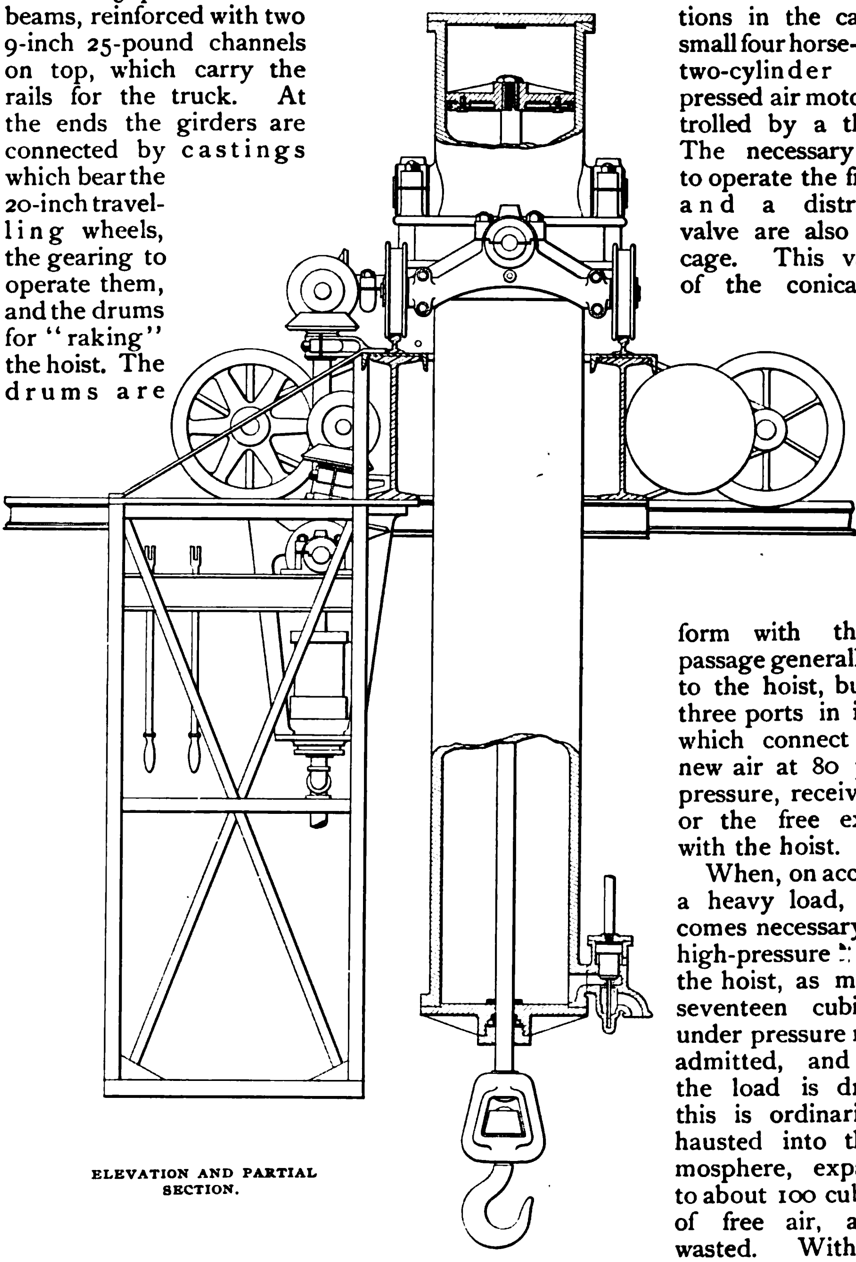
The hoist cylinder is 18 inches inside diameter, has 1¼-inch walls, and is swung by two 4½x4½-inch trunnions on the carriage which is pulled back and forth across the crane, for "raking," by an endless ⅜-inch wire rope, wrapped on 12-inch horizontal drums at each end of the crane. A universal joint is used to carry the hoist cylinder, so as to avoid any danger from side strains. The



ELEVATION.

frames of this joint are of cast steel, and are carried on a truck having 12-inch wheels, and tied together by ¾-inch rods. The girder consists of two 20-inch 85 pound steel I beams, reinforced with two 9-inch 25-pound channels on top, which carry the rails for the truck. At the ends the girders are connected by castings which bear the 20-inch travelling wheels, the gearing to operate them, and the drums for "raking" the hoist. The drums are driven by bevel and mitre gears, and receive motion in either direction from a 15-inch friction bevel and 10-inch cones in the cage, each of these having 5-inch faces. Another set of similar frictions on the same shaft is connected with the travelling gearing as shown.

Between these frictions in the cage is a small four horse-power, two-cylinder compressed air motor, controlled by a throttle. The necessary levers to operate the frictions and a distributing valve are also in the cage. This valve is of the conical plug form with the end passage generally open to the hoist, but with three ports in its face which connect either new air at 80 pounds pressure, receiver air, or the free exhaust, with the hoist.



ELEVATION AND PARTIAL SECTION.

When, on account of a heavy load, it becomes necessary to use high-pressure air in the hoist, as much as seventeen cubic feet under pressure may be admitted, and when the load is dropped this is ordinarily exhausted into the atmosphere, expanding to about 100 cubic feet of free air, and is wasted. With the system here adopted, however, the operator passes the air out from the hoist through the distributing valve into a large receiver, which is carried on the crane, until the pressure in the hoist and receiver are balanced; he then exhausts the remainder into the atmosphere. In this way part of the air is saved for future use, either for smaller loads on the hoist, or regularly for use in the motor. As the motor also uses the air somewhat expansively, air is still further economised

Another way in which air is ordinarily wasted, and which is also attended with considerable danger, is in neglecting to shut off the air before the piston reaches the top of the hoist. It may then strike the cover and strip the holding bolts, or cause other damage. If the hoist is left with the piston at the top and the valve partly open, air will continually leak away. Again, if the piston is pressed against the cover by the air and, for any reason, the operator attempts to twist the piston rod it may result in bending the rod, or loosening the piston.

To avoid this, an automatic stop valve is placed in the supply pipe. This remains open at all times except when the piston passes an opening at the upper end of the cylinder, which is connected by a pipe to the upper side of a differential piston valve. When air passes down this pipe, it forces this valve shut, and no more air is admitted to the hoist until enough leakage has taken place to permit the piston to descend a little and cover the port. The greater pressure on top of the valve being then removed, it is opened by the pressure underneath and is ready for exhaust. The same end is also attained in other hoists by levers, which, when struck by the rising hook, shut the admission valve. Another method is to entrap air in the upper end of the hoist, which, in being compressed, absorbs the inertia of the piston and balances the pressure underneath, bringing the piston to rest before damage is done. Both of these methods have disadvantages which are here avoided. Rubber buffers are placed at both top and bottom, as a final safeguard.

A feature has been made of reducing friction throughout the crane by means of roller and ball bearings wherever possible. The hook and thrust motion are fitted with the latter, while the carriage and girder are fitted with roller bearings. These are not at all of a delicate or complex nature, but are very simple and durable.

Initially the air is supplied through several loops of hose attached at the "shore" end to the supply pipe, and at the other to a pipe on the crane leading to the distributing valve. The supply pipe ends at about the middle of the crane's travel and the loops of hose slide on wires from that point to compensate for the crane's motion up and down the shop. As the engine is under control of the throttle valve, and reversible frictions are used in transmitting its motion, the speeds of raking and travelling may be anything up to the limits. These are 130 feet per minute for raking, and 165 feet for travelling. The crane, complete, weighs about 5000 pounds and is designed with a factor of safety of about seven.

COMMERCE ON THE GREAT AMERICAN LAKES.

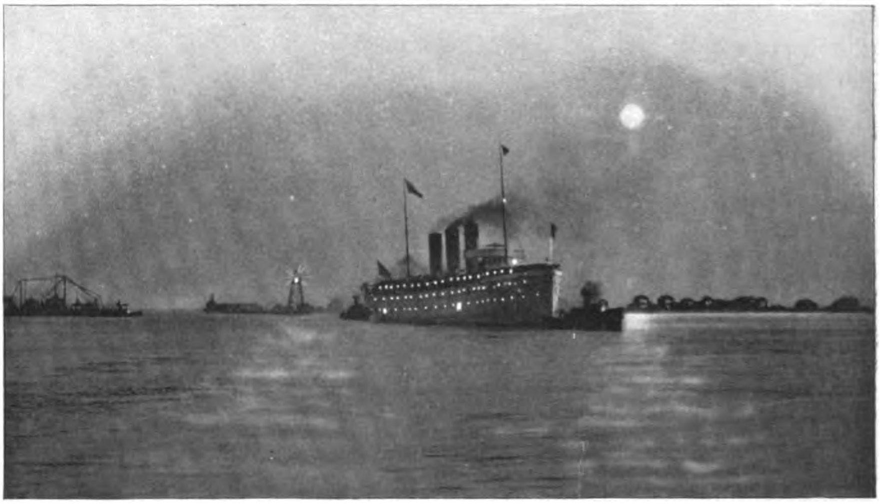
By John Birkinbine.

IN nearly every nation, and often in different portions of one country, peculiar forms of vehicles for land transportation are employed, and similar variations are noted in vessels which traverse bodies of water in different portions of the earth. Most of these are the outgrowths of local conditions either as to the motive power, and the character, and grade of roads in one instance, or the industrial development, the available materials for construction, depth of channel, the extent of water surface, etc., in the other.

It is, therefore, natural that existing conditions should cause the development of special forms of vessel construction and peculiarities of transportation upon areas as extended as those of the Great American Lakes,—bodies of water which are of sufficient area and of ample depth to accommodate vessels of the largest size and greatest draught. But the rivers connecting the various lakes, and those at whose mouths harbours are formed, have placed limitations upon the dimensions of the lake marine, and have encouraged the construction of certain forms of vessels, some of which are peculiar to this district, while the quantities of material handled, the climatic conditions which restrict the shipping season and the progressive spirit of the people have combined to present numerous interesting problems.

The passage of vessels from the Atlantic ocean into the lowest of the Great Lakes, Ontario, is limited by the size and draught in the various canals of the St. Lawrence river, which by their locks make it possible to bring craft of moderate size to an elevation of 248 feet above tide, while the Welland canal, with its "hydraulic staircase" of twenty-five locks, controls the size of vessel which can be elevated the 325 feet additional from Lake Ontario to Lake Erie. The Detroit and St. Clair rivers and the shallow Lake St. Clair, have also, by the depth of channel, limited the passage between Lakes Erie and Huron, but the difference of but 8 feet in level between these two bodies of water forms no serious obstruction to navigation. The St. Mary's river, however, through which the greatest of fresh water lakes, Superior, delivers its volume of outflow (over 90,000 cubic feet per second) into Lakes Huron and Michigan, presents a total fall of 21 feet in some 50 miles, 18 feet of which are in the rapids at Sault Ste. Marie. From 1855 to 1880 the sizes of vessels passing between Lake Superior and the lower lakes was limited by the length 350 feet, and the depth on mitre sill, 12 feet, of the two tandem locks which were constructed as part of the St. Mary's ship canal to overcome this 18-foot fall.

Subsequent to 1880 a single lock, 515 feet long, with 16 feet of water on the mitre sill, was considered the controlling influence upon the size of lake craft, but the connecting rivers have not been able to pass vessels of as great draught as the canal. A new lock, 800 feet long, and 100 feet wide, with 21½ feet of water on the mitre sill, constructed by the United States government at a cost of $5,000,000, and another lock, 900 feet long, and 60 feet



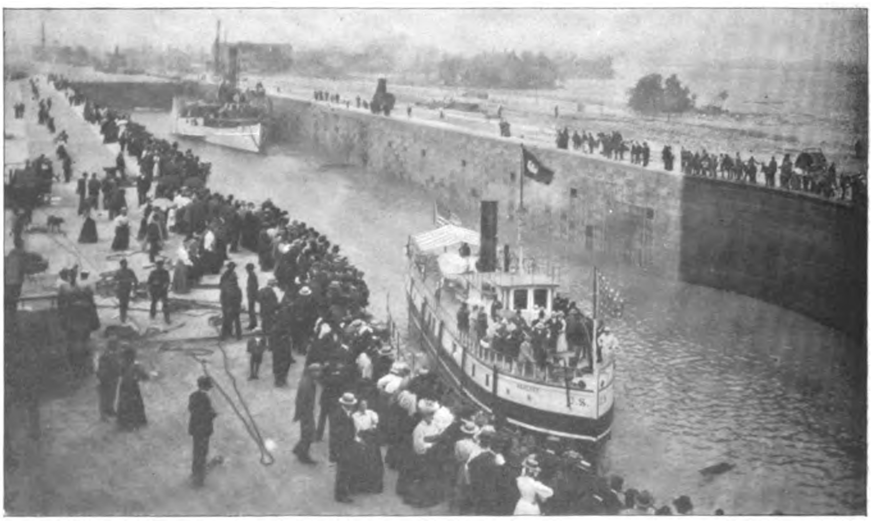
THE LAKE STEAMER "NORTHWEST" COMING INTO PORT AT NIGHT.

wide, constructed by the Canadian government, wili, in the future, pass any vessel which the improved channel, now in course of deepening to 20 feet, will accommodate.

The report of the Manchester ship canal in England shows that in 1895 the tonnage passing through it was but one-tenth of that passing the St. Mary's ship canal. Since 1891 the traffic through the Suez canal in twelve months has been below that of the St. Mary's canal in less than eight months, the number of vessels for three years being:—

	1893.	1894.	1895.
Suez canal...........	3,341	3,352	3,334
St. Mary's ship canal.	12,008	14,491	17,956

At the St. Mary's ship canal exact records are maintained, and an examination of the figures demonstrates the



U. S GOVERNMENT VESSELS MAKING THE FIRST PASSAGE THROUGH THE COMPLETED NEW LOCK OF THE SAULT STE. MARIE CANAL CONNECTING LAKES SUPERIOR AND HURON.

character, volume and value of freight transported between Lake Superior and the lower lakes; but, unfortunately, similar data for the traffic on the entire lake system are not available, which may be roughly estimated as treble that given for the canal.

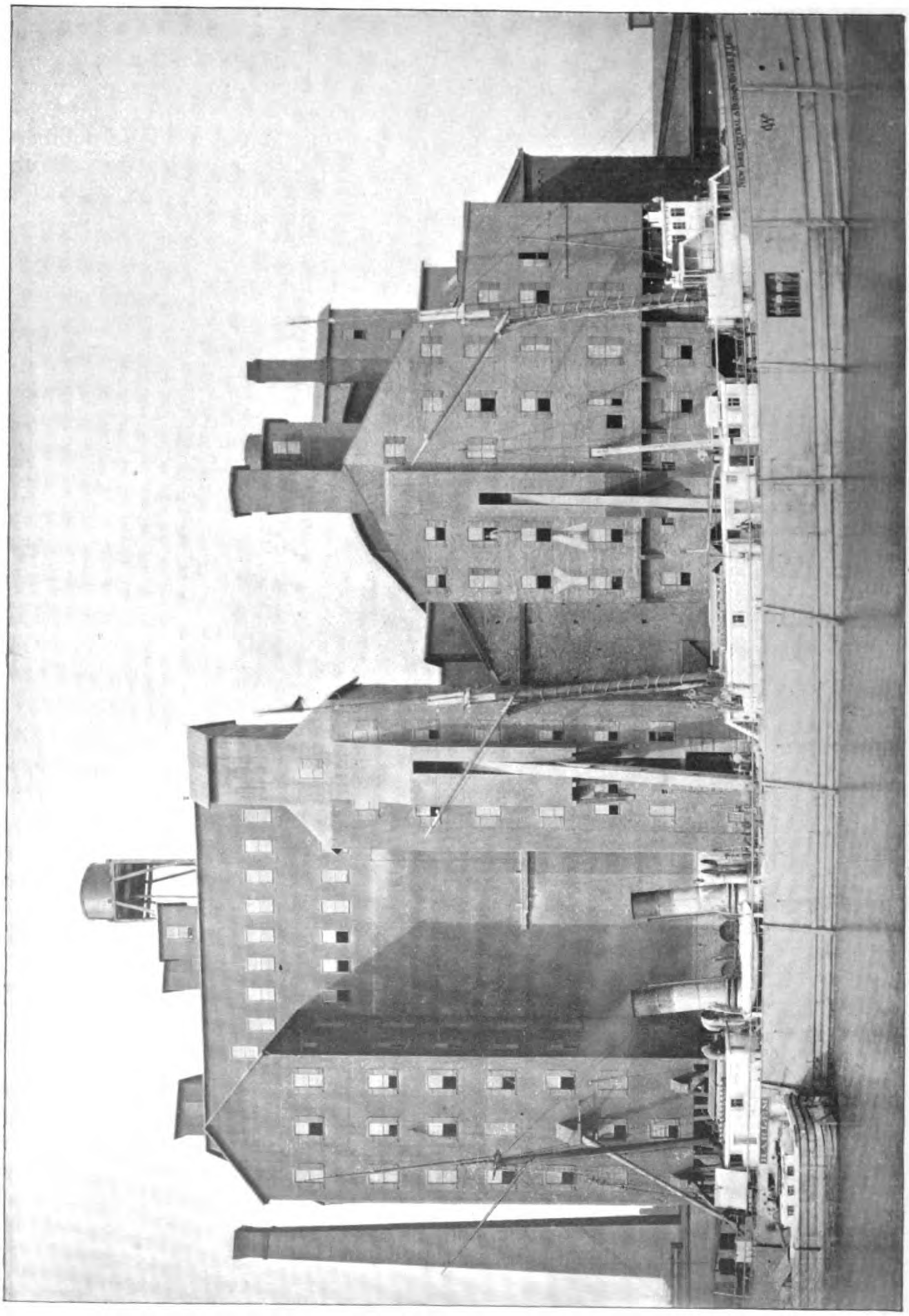
During the year 1895, navigation to and from Lake Superior was open from April 25 to December 11, the 17,956 passed, to the close of navigation, 1163 vessels of 600,000 tons register.

The official statistics, issued on June 30, 1895, give the number of steam vessels of 1000 gross tons and over on the lakes as 359, and their aggregate gross tonnage 634,467; the number of vessels of this class owned in all other parts of the country was 316, and their tonnage 642,642, so that one-half of

LAKE VESSELS AT BUFFALO, N. Y.

vessels passing the locks having a registered tonnage of 16,806,781 tons, and the freight representing a value of $159,-575,129. The average distance which this freight was carried was 830 miles, equivalent to a total ton mileage of 12,-502,548,892, costing for transportation $14,238,758.02, or 1.14 mills per ton mile. These figures include the traffic through the new Canadian lock which was opened on September 9, 1895, and the large steamships of the United States are found on the Great Lakes.

The freight which passed through the St. Mary's canal in 1895, as represented by values, may be generally subdivided thus,—40 per cent. flour and wheat, 14 per cent. iron ore, 13½ per cent. copper, 6 per cent. lumber, and 4 per cent. coal, the balance being unclassified and diversified freight. An idea of the quantities moved, however, may



A LAKE STEAMER TAKING IN A GRAIN CARGO AT BUFFALO, N. Y.

be had from the two and a half millions tons of coal, eight million tons of iron ore, nine million barrels of flour, fifty-four and a half million bushels of grain, one-quarter million barrels of salt, one hundred thousand tons of iron, one hundred thousand tons of copper, seven hundred and forty-one million feet B. M., lumber, etc. Corresponding figures for the year 1896 were not available when this article was written.

In anticipation of the improvements in channels connecting the Great Lakes, radical changes in construction have been made in late years, and vessels of larger carrying capacity and greater draught have been constructed. There are, however, a number of forms of craft which may be considered as peculiar to the lake marine. A quarter of a century ago few vessels traversed the lake waters with registers as great as 1000 tons; to-day a number are afloat, which, when increased draught is available, will carry from 4500 to 6000 tons. A quarter of a century ago, sailing vessels were the rule; to-day steam is largely the motive power, and is applied through engines of high economy, and improved construction. A few side-wheel steamers are still doing service, but the propeller, and, in some instances, twin screws are utilised for most vessels.

FOUR VESSELS IN THE NEW LOCK OF THE SAULT STE. MARIE CANAL, GIVING A GOOD IDEA OF ITS SIZE. LENGTH, 800 FEET. WIDTH, 100 FEET.

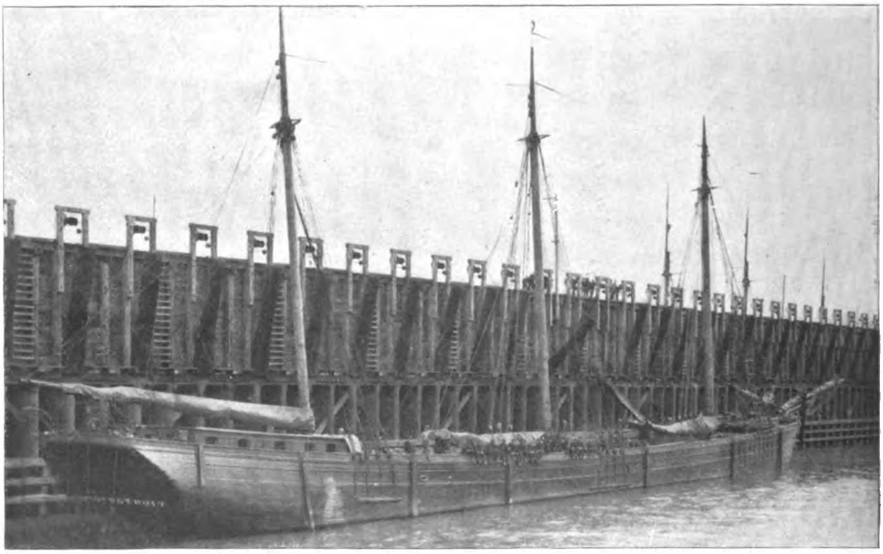
In a conversation the late Colonel James Pickands, who spent his business life in the Great Lake region, stated that "in 1869 the largest vessel reaching Marquette, Mich., was of 700 tons burden, the traffic being almost entirely in wooden schooners which averaged from nine to ten trips per season between Marquette, Mich., and Cleveland, O., the average freight rate exceeding $3.50 per ton." As the head of the largest shipping firm in the United States, Pickands, Mather & Co., which now controls a lake fleet aggregating over 100,000 tons burden, and during the shipping season leases probably as much more, Colonel Pickands drew the interesting comparison, that the average is now twenty-seven trips between the points named, and stated that as many as thirty trips had been made in a season by steam vessels.

The magnitude of the transportation problem on the Great Lakes may be summarised thus:—The three thousand three hundred vessels now afloat have an aggregate of one and a quarter million tons register, and are being rapidly added to. The season of 1895 showed an aggregate transportation of about forty million tons. Eight important ship yards were busily engaged in the increase of the lake vessel equipment, and new vessels under construction aggregate over one hundred thousand tons. The season of 1896 shows an increase of thirty or more large steel vessels averaging 4000 tons each, of which about two-thirds will have steam propelling power of high economy, the balance being tow barges.

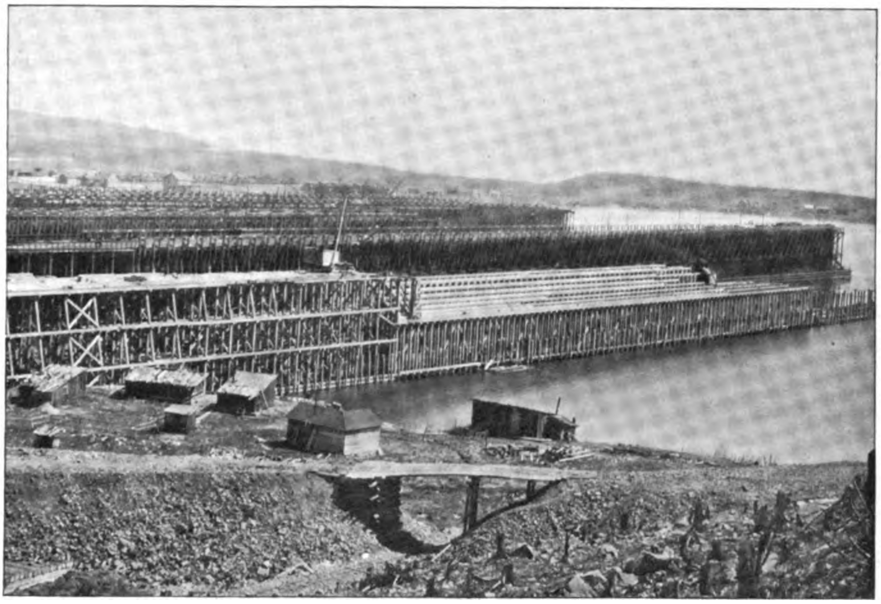
The New York *Press* states that the shipyards of the Great Lakes had ninety vessels of various classes and dimensions under construction when the season of 1896 opened. Only twenty-four were less than 100 feet long, and there were eight that will carry 5000 tons each, and twenty others that will carry 4000 tons or more, all on a draught of fifteen feet.

This new fleet will cost, when finished, a trifle less than $10,000,000, and it will have a carrying capacity of close to 200,000 tons at a single load. There were under construction on the United States seaboard, east and west, seventy-one vessels, most of them steel steamers, but many of them of moderate size. Only one, the cruiser *Brooklyn*, is 400 feet long. Of the Lake list there are thirteen that are 400 feet long or more. The total length of the new American ocean fleet is 12,500 feet instead of the 20,000 feet of the unfinished Lake fleet.

It was the writer's privilege in 1887 to examine the first McDougall "whaleback" steamer, then in course of construction at Duluth, and to be familiar with the prophesies of success on the one hand, or of failure on the other, which were made by those who had faith in, or who were skeptics concerning this novel form of vessel, which, while far from being attractive in appearance, seems to have filled the purpose for which it was created. A fleet of forty vessels of this class, with an aggregate carrying capacity of over 100,000 tons now in active service, illustrates one feature of development of the lake marine. It is claimed for this construction that with the same weight of hull, made from similar framing and plates, the carrying capacity is 20 per cent. in excess of that of other forms of vessels, that with little superstructure, rounded deck and ends, the vessel rolls moderately, and withstands heavy seas comfortably. On the other hand, those who favour the more common type of



LOADING ORE AT ASHLAND, WIS.



TYPICAL ORE DOCKS AT TWO HARBOURS, MINN.

vessel argue that this advantage claimed for the whaleback is less pronounced than its champions believe. Of the total fleet of whalebacks, one-third have steam motive power, the practice being to have a motor craft tow two or three consorts, thus securing low cost of carriage for rough heavy freight, as evidenced by the following:—

During the season of 1895 one of the steam whalebacks, towing two consorts, made nineteen trips of an average of 1720 miles each, and delivered 57 east-bound cargoes aggregating 131,735 gross tons, besides carrying a considerable amount of west-bound freight, the consumption of coal for the season being 5403 net tons. Another one of these steam whalebacks, with two, and sometimes three, consorts, made seventeen round trips, delivering 54 cargoes, amounting to 126,389 gross tons on a consumption of 4585 net tons of coal. The engines on these steamers are triple expansion, of 1000 horse-power; Scotch boilers are used. This shows that the work was performed with a consumption of 4-10 of an ounce of coal per ton-mile for the round trip, which, equated for the east-bound trip only, is claimed to be ¼ ounce per ton-mile.

Many of the 1755 steam vessels embraced in the lake marine are excellent examples of modern marine architecture and lately craft of large dimensions have supplanted others of smaller size which have been retired from service. Thus, a vessel lately built at Cleveland is 432 feet long, 48 feet beam and 28 feet in depth, and is equipped with triple expansion engines. This boat has carried over 4400 gross tons of iron ore, and when the connecting channels are increased in depth, its capacity is rated at over 6000 tons of iron ore, or 200,000 bushels of wheat.

The short shipping season, due to the protracted and severe winter, encourages very active operations during the months that navigation is open, and the vessels comprising the lake marine are given little rest, the time spent in port prohibiting any general overhauling or repairs until after navigation has closed. Unexcelled facilities for loading and discharging cargoes permit of quick dispatch, and it is not unusual for a vessel of considerable size to enter a

A WHALEBACK ENTERING THE SAULT STE. MARIE CANAL LOCK.

port, discharge a cargo, reload and start on a return journey in the same day. As an instance of this quick dispatch a round trip of the steamer *Victory*, a vessel 400 feet long, and of 48 feet beam, with a present carrying capacity of 4000 tons, was loaded with coal at Ashtabula in ten hours; proceeding to the head of the lakes, this cargo was discharged in fifteen hours, and the boat was loaded with iron ore in five hours, at the rate of 800 tons per hour. Returning to the lower lakes, the ore was unloaded from the vessel on to cars at the rate of 560 tons per hour.

Another vessel which has attracted attention, was built throughout of steel at Chicago, a system of channels being used instead of plates and angles, and it has the distinction of being the first to be equipped with the water-tube type of boiler.

Some large wooden vessels are still constructed, and an interesting test of the operation of one of these was lately published. This boat, with a length over all of 335 feet, beam 43, depth 26 feet, has triple expansion engines and boilers working at 160 pounds steam pressure. The test which was made while carrying a cargo of 80,000 bushels of wheat, using ordinary run of mine Ohio coal, showed a speed of 12.75 miles per hour, at a cost per ton-mile for fuel of 0.63 of a mill, the coal costing $2 per ton.

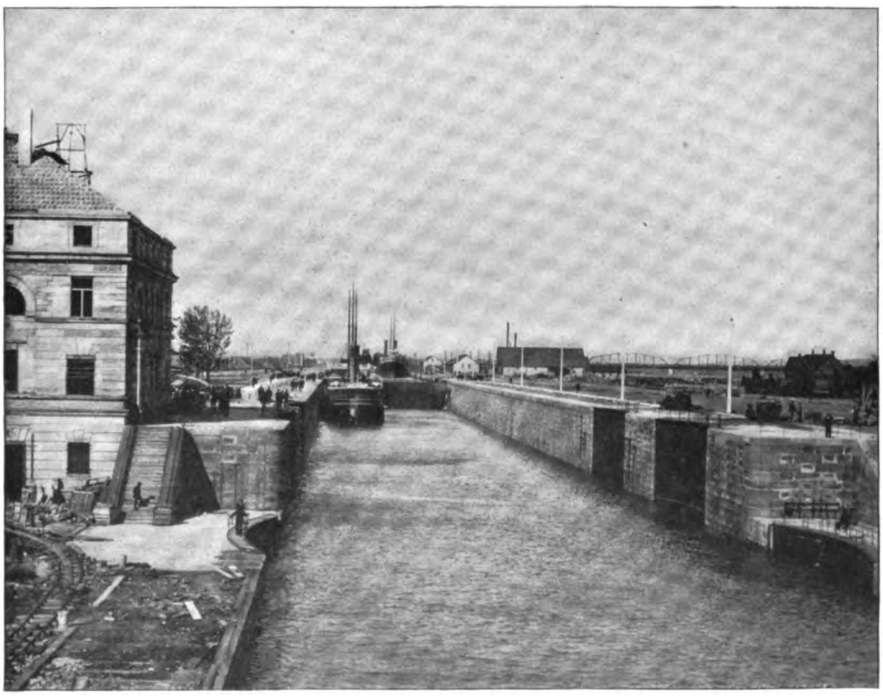
A statement of the commerce of the Great Lakes must include reference to the large and magnificent fleet of passenger vessels plying between the important cities located on the shores of the lakes. Many of these boats are superbly fitted up, and of large carrying capacity, and the coming season will introduce some important additions to the fleet. The whaleback steamer *Christopher*

Columbus commanded a great deal of attention as a passenger boat during the World's Columbian Exposition, and the two boats of the Northern Steamship Company, which ply between Buffalo and Duluth, are generally recognised as the queens of the lake marine. These boats are constructed of steel with water-tight compartments, and have twin screws, driven by quadruple expansion engines of 7000 horse-power. The vessels have a displacement of 4500 tons, can make twenty miles per hour, and are furnished and administered in a style equal to the first-class vessels crossing the Atlantic.

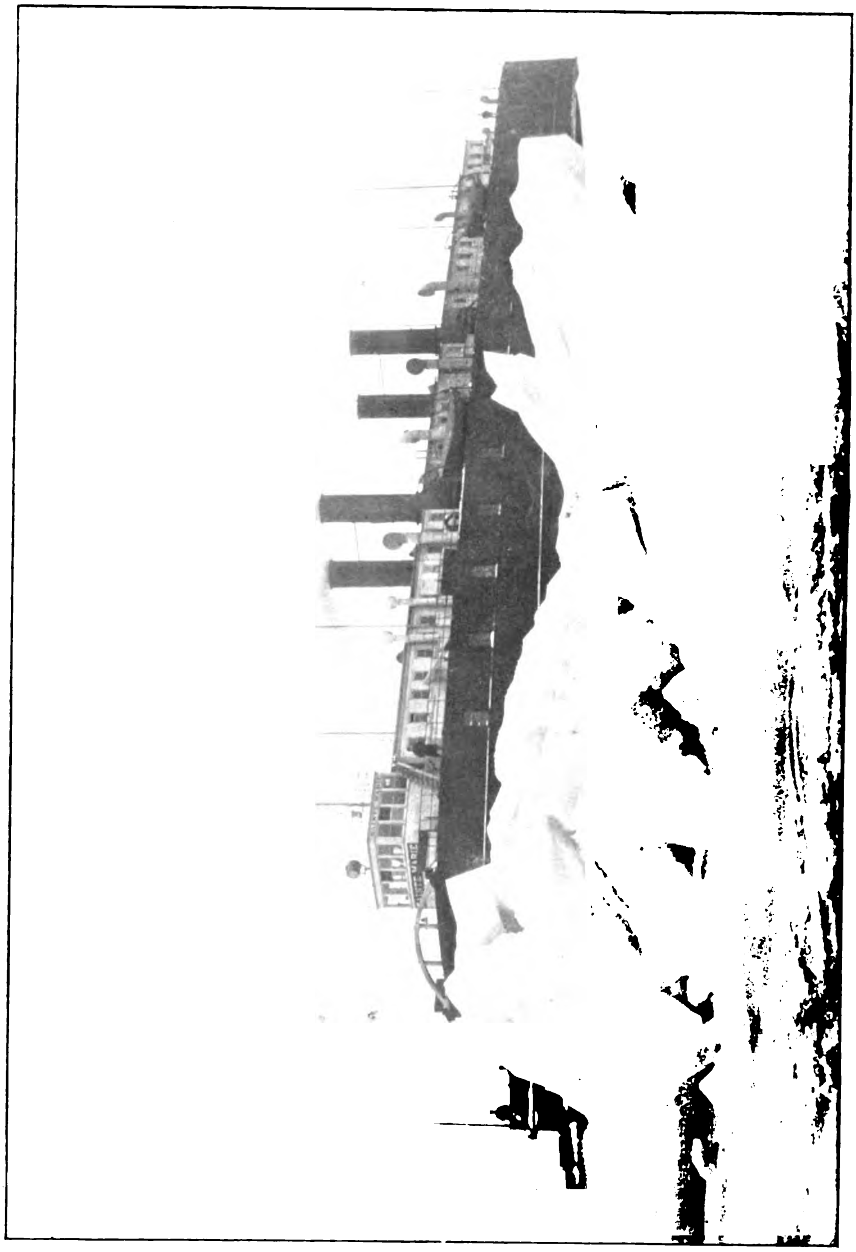
What has been said shows that the carrying equipment for commerce on the Great Lakes has reached enormous proportions and has kept abreast of the times in improved construction and equipment. As the water transportation facilities have increased, improvements in transporting by land have kept pace. The shores of the lakes are practically encircled by railroads, while at nearly every port of importance terminals of several independent lines are assembled. To facilitate connection by railroad, ferries are maintained, which not only carry whole trains, but the boats are so constructed and equipped as to be capable of forcing their way through great fields of ice which impede navigation.

The quick dispatch of vessels above referred to is made possible by expensive loading and unloading appliances at coal and iron ore docks, grain elevators, flour mills, etc. The methods employed for economically loading coal, include discharging the material from cars into bins, from which it is spouted into vessels; the use of pivoted derricks on car trucks, and several plans of discharging full car loads through hoppers direct into the holds of vessels.

One such appliance which has met with favour consists of a pivoted beam, or cantilever, carried on tracks laid parallel to the dock face. A series of railway tracks, laid at right angles to the dock,



ANOTHER LOCK VIEW.



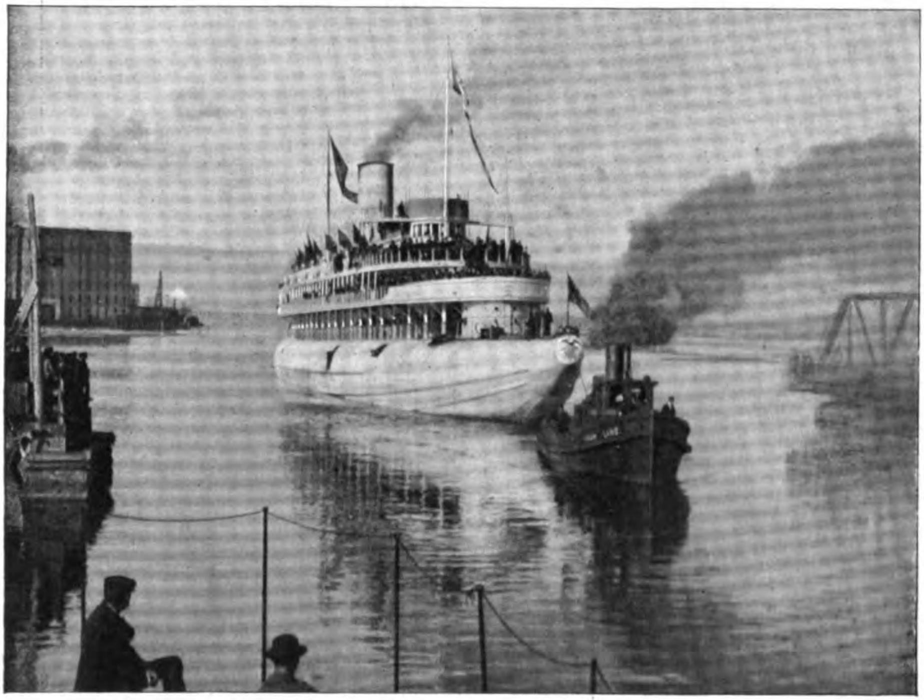
THE TRAIN FERRY BOAT "ST. IGNACE" BREAKING THROUGH ICE, THREE FEET THICK, IN THE STRAITS OF MACKINACK, MICH.

hold the loaded coal cars and receive those emptied.

When a vessel is ready for a cargo of coal, the cantilever is moved opposite a hatch by its own steam mechanism, and a gondola car of coal is raised up the incline by similar means to the hopper end of the cantilever when the end gates of the car are removed; the beam is then tipped so as to bring the hopper end close to the vessel hatch, when the gate is opened and the coal slides into the hold. The beam returning to its former position, the car descends the incline to the tracks, the immense beam see-sawing at a rate to load 350 to 450 tons of coal per hour. The tracks, parallel with the dock, permit the cantilever to move from hatch to hatch, and from one right angle track to another, trimmers meanwhile adjusting the cargo in the filled hatches.

Another method is to run a loaded car into an elevated cage in which it is secured. The cage, in revolving, turns the car through 135 degrees, discharging its contents into a hopper from which the coal flows by spout into the vessel's hold.

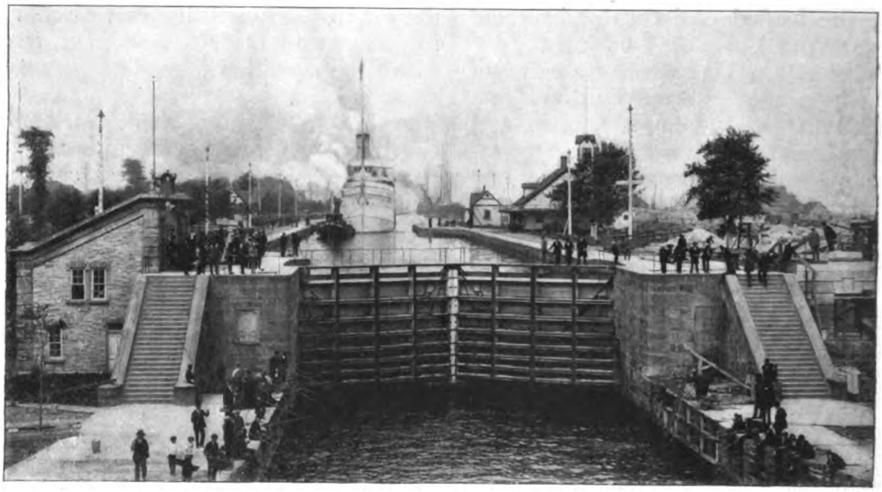
A third installation receives the car at the dock level, on a platform boxed on the side towards the water. Mechanism adjusts the hopper to suit the vessel and raises the car to the desired level, then turns the car and boxed platform 135 degrees, chains holding the car in place.



THE PASSENGER WHALEBACK LAKE STEAMER "CHRISTOPHER COLUMBUS."

The apparatus first described dumps the coal from the car end; the others dump the car sideways. Another installation will discharge the coal into large buckets, which, when lowered into the hold, open at the bottom, so as to deliver the coal with a minimum breakage.

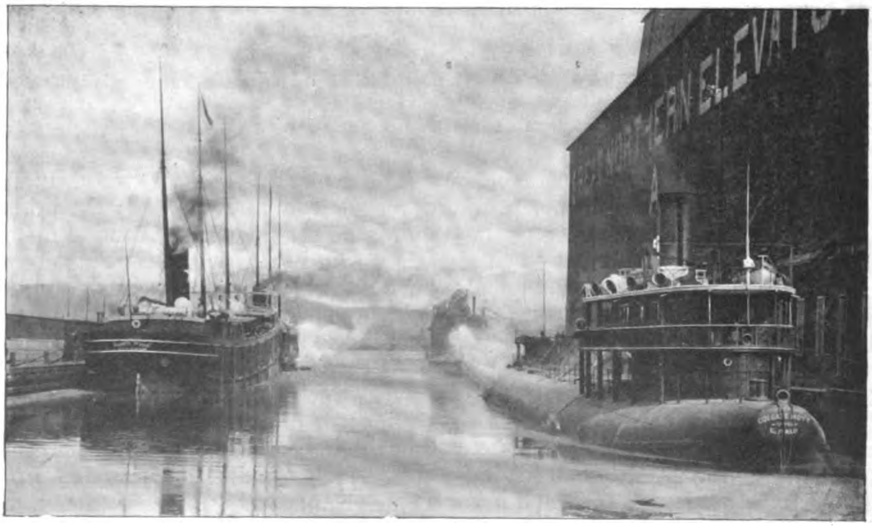
At the head of the lakes are coal receiving docks of large storage capacity, equipped with various devices for handling the 2,500,000 to 3,000,000 tons of coal which annually are carried from Pennsylvania and Ohio to the Lake Superior district. Most of these equip-



A LOCK IN THE SAULT STE. MARIE CANAL, MICH., SHOWING THE STEAMER "NORTHWEST" READY TO PASS THROUGH.

ments may be described as having a steam hoisting arrangement to lift the loaded buckets from the vessel's hold sufficiently high to drop their contents into cars which run back on trestles and dump automatically, although in some cases the pockets are carried over the stock pile. One plant at Superior, Wis., has immense dome-shaped storage sheds into which the coal is delivered and from which it is discharged by mechanical conveyors. Cantilever unloading devices have taken from 50 to 56 tons of coal per hour per hatch from vessels and placed the material on cars at West Superior, Wis.

The facilities for loading and unloading iron ore are even more costly and elaborate than those provided for handling coal, a score of large docks being provided at the ports of Duluth and Two Harbors, in Minnesota; Ashland, and Superior, in Wisconsin; and Marquette, St. Ignace, Gladstone and Es-

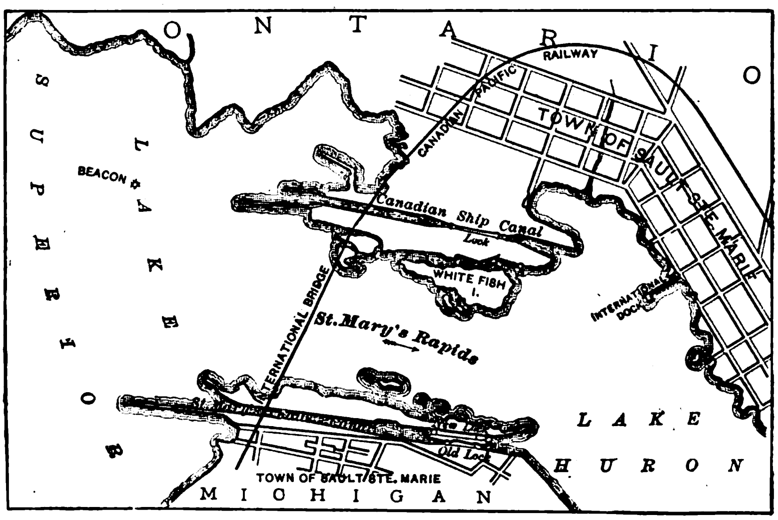


A WHALEBACK STEAMER LOADING GRAIN.

canaba, in Michigan, at a cost of $6,-850,000. These docks are wooden structures, carried on piles, and are from 550 to 2300 feet long and from 45 to 57 feet high above the water level, accommodating from 90 to 384 pockets each, the capacity per pocket ranging from 100 to 180 tons of ore. The combined lengths of the ore shipping docks on Lake Superior and Lake Michigan exceed five miles, and the total capacity of the 4600 pockets is 634,000 long tons.

Trains of loaded cars are run on the decks of these docks and the ore is discharged through the car bottoms into the pockets from which it is delivered by metal chutes into hatches of vessels. By using a number of hatches simultaneously, the vessel receives her cargo rapidly and 800 tons per hour is not an unusual rate. Where the bins are filled with the special ore desired, and all conditions are favourable, greater dispatch is secured, one record being 2350 tons of ore loaded in forty-five minutes.

For unloading ore, there are large storage docks, controlled by various railroads on the lower lakes, and also others in connection with blast furnaces. At these docks vessels are unloaded by special machinery which takes the ore after the stevedores shovel it into buckets, raises it from the vessel's hold, and delivers the ore on to stock piles, or on cars, at a cost of from ¾ to 1½ cents per ton for labour, fuel, repairs and supplies.



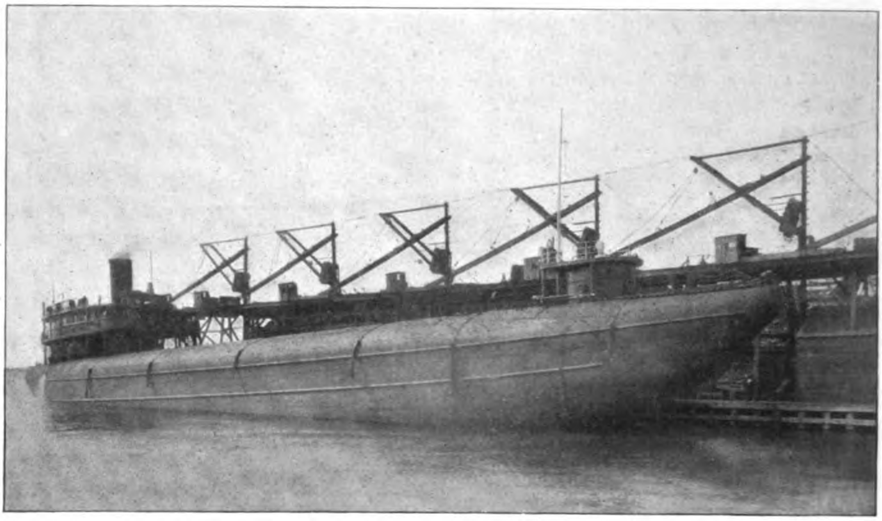
MAP SHOWING THE SAULT STE. MARIE, OR ST. MARY'S FALLS, CANAL AND ALSO THE CANADIAN SHIP CANAL.

Five general types of machinery are employed for moving the iron ores from the holds of the vessels to the ore docks.

First.—Swing-boom derricks, operated either with engines placed on them, or driven by wire rope from steam engines at a distance, the mast being either stationary or carried on trolleys. The iron buckets are lowered into the holds of vessels where the navvies shovel the ore into them, steam machinery raising the buckets and swinging the boom to the point where the ore is to be deposited.

Second.—A similar arrangement of swing-boom derricks, which discharge the ore into hoppers from which it is fed automatically into tram cars carrying the ore from the dock front to stock piles located at a considerable distance from the water.

Third.—An A frame, which lifts with the buckets and discharges them into tram cars, that run to the stock pile or dump the ore into pockets and thence into railroad cars.



A CHARACTERISTIC MANNER OF LOADING A WHALEBACK STEAMER.

Fourth.—Aprons, which project over the holds of vessels. The buckets travelling up the incline of this apparatus, are dumped into tram cars, which run by gravity, discharge, and return automatically.

Fifth.—Booms or aprons, upon which the buckets are carried, and continue their journey either over cables or on trussed bridges, the buckets dumping automatically at the point desired, and returning to the hold without detaching from the machinery.

Two of the receiving docks at Cleveland, O., are each half a mile in length and have a storage width of 350 feet; one at Fairport, O., has a water front of one mile and a width for storage purposes of from 180 to 350 feet. As the ore is stored in piles from 25 to 50 feet in height, the capacity of each of these docks is from 1,000,000 to 1,500,000 long tons, and the average storage capacity of the receiving docks is from 300 to 500 tons per foot of water front. During the shipping season, from May to October, the ore is brought to these ports, unloaded, a portion being handled directly to railroad cars and the balance stocked, being shipped to the blast furnaces during the winter months. The stocks of iron ore held on Lake Erie docks at the close of a season have reached an aggregate of nearly five million gross tons.

Recognising the vast importance of the commerce of the Great Lakes district, numerous plans for improvement of its water ways, and for connecting these with the Atlantic ocean, with the Mississippi and Ohio rivers, and with the Red River of the North and Winnipeg lake are proposed. For the improvement of lake navigation and increasing the depths of harbours, a dam which will raise the water surface of Lake Erie to the level of that of Lake Huron is proposed, while canals across peninsulas are suggested to improve the connection between lakes Erie and St. Clair, Lake Michigan and Lake Superior, etc.

To give the advantage of unbroken bulk in shipping, a canal connecting Lake Erie and the Ohio river has been surveyed, and the Chicago drainage canal is expected ultimately to give deep water connection between Lake Michigan and the Gulf of Mexico, *via* the Mississippi river. Other projects, which have not advanced beyond preliminary surveys, are designed to connect Lake Superior with the upper Mississippi and with Rainy lake.

The importance of securing more advantage from this lake commerce has encouraged the State of New York to expend $9,000,000 in enlarging and deepening the Erie and Champlain canals, and the advantage of unbroken bulk is being tested by a fleet of steel canal boats now in service between Cleveland, O., and New York city, *via* the Erie canal. The record of the first trip of the past season is that one steam canal boat, towing five barges, made the trip from Cleveland to New York in eight days and eighteen hours, the cargo consisting of 653,000 pounds of nails, and 375,000 feet of lumber and miscellaneous freight.

A deep water commission, comprising representatives of the United States and Canada, is now considering various projects, among which is that of the North American maritime canal to connect Lake Erie with the Atlantic ocean by a canal capacious enough to accommodate the largest ships.

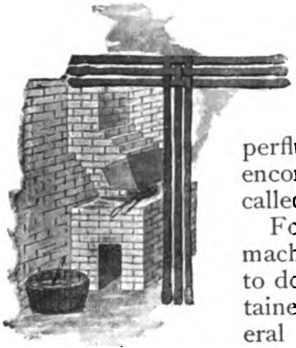
The statements concerning the shipping and receiving appliances provided for iron ore and coal are introduced to indicate the ingenuity displayed and the capital invested in improvements to the commerce of the Great Lakes, for there are equally excellent arrangements provided for handling the enormous quantities of other freight which go to make up the grand total of about 40,000,000 tons annually.

The facilities for shipping or receiving grain at immense elevators, in quantities measured in millions of bushels, or for the receipt of grain and shipments of flour at mills producing over 5000 barrels per day, or for the handling of lumber, billed by millions of feet board measure, while probably more familiar than those for the heavier freights, are worthy of a more extended notice than is here given. But what is chronicled is at best an imperfect statement of the marvellous and rapidly increasing commerce carried on for about eight months of each year at levels above the highest buildings in the Eastern cities of the United States, Lake Superior being 602 feet, and lakes Michigan and Huron 581 feet above sea level.

The volume, value and variety of products composing this commerce, the localities from which they are assembled and their destination, demonstrate that the American nation as a whole is interested in its development and improvement, and places the expenditures made by the general government upon the canals, harbours and channels of the Great Lakes as truly of national importance.

THE IDEAL ENGINE LATHE.

By W. D. Forbes.



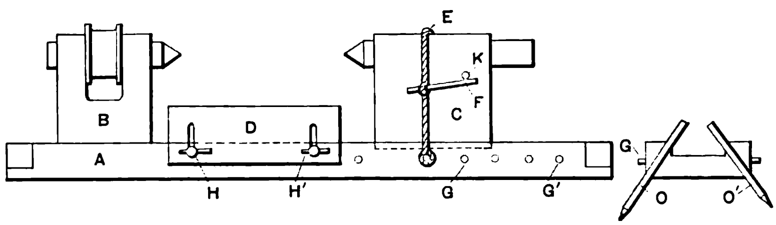
THE art of the machinist is to remove only the superfluous metal which encompasses the form called for by a drawing.

For years the various machine tools employed to do this work have retained their present general design, and the tool builders have gone on refining these accepted designs with little or no departure from hem. The oldest and most useful of these tools is indisputably the lathe.

The writer has seen a lathe made not less than seven hundred years ago, and its counterpart is still used in many parts of the Levant. It had a horizontal bed, a head and tail stock and a tool rest. Add to this an automatically moved apron, with cross feed and screw cutting gears, and you have the lathe of to-day.

The above lathe, shown in the annexed rough sketch, had a spool on the spindle of the head stock around which a turn of bowstring was taken, which the lathe hand moved back and forth with his left hand in order to get the rotary motion, while he guided the tool with his right hand and the big toe of his left foot. His right foot was curled under him for a seat. In the accompanying diagram *A* represents the bed of the lathe; *B* and *C* are the head and tail stocks, respectively; *D* is the tool rest; *E* is a cord which was laid over the pegs *G G′* and brought over the tail stock; and *F* is a stick which was twisted into it and, when tight enough, was prevented from unwinding by a peg, *K*, driven into the side of the tail stock. The tool rest *D* had two slots in it, as sketched, and was raised and lowered by driving in or out the two taper pins *H H′* which passed through pegs fastened in the bed. This lathe, when seen by the writer, was used flat on the ground and was secured by four pegs *O O*. The oldest self-acting lathe ever seen or used by the writer produced work of a fair quality, and for a certain class could compete with any now made.

Since this old lathe was used, almost every lathe that has been put on the market or designed and heard about, has been used or inspected by the writer, and always with a feeling of great disappointment at first glance, as beyond a better or varied distribution of metal, a higher grade of workmanship and ease in handling he has seen no improvement in general design. No doubt this statement will be looked upon as absurd by many, and especially by lathe builders. From them the writer looks for little



A LATHE 700 YEARS OLD.

in the line of real improvement, as they seem content to herald to the world the birth of a new lathe whenever they have designed a new lock for the carriage, or have changed the number of steps on the cone or have strung the change gear on a rod.

There seems to be something about lathe building which convinces a man, beyond all earthly power to change his opinion, that the size and thread on the spindles of his lathes are the only right ones, and the taper which he uses possesses merit which all should copy; and even if he does make a change he would not think, with rare exceptions, of making anything to meet the practice of any other builders. If, in a matter of such importance to the lathe-buying public as this, nothing can be hoped for from present lathe builders, there is small hope that any of them will ever produce the ideal lathe.

Just what would be embodied in a lathe which would deserve the name of ideal is open to discussion, but some points are well fixed. It is evident that revolutions should be infinite up to the point determined for the size of the lathe. To-day we use the clumsy shipper for starting, stopping and reversing the lathe, and the step cones for changing speeds, which are rarely more than ten in number. It is evident that this is entirely inadequate.

This is most apparent when we consider truing off a face plate. It is generally done at one speed, which is right for only one single diameter of the infinite diameters thereon. If, now, revolutions are to vary continually, the variations must be controlled by the cross feed, as by it the tool is advanced or drawn away from the work, and if automatically controlled, exact speed for all changes of diameters would be obtained. Thus, if a 2-inch shaft were reduced to 1-inch, the speed would be corrected for either when the tool reached it.

The cross feed should control more; it should stop the revolutions and start them. This would save much time and wear and tear, as the work would come to rest when the tool was drawn away from it, and so could be readily calipered or inspected. Of course, the cross feed should act at any angle, allowing a core to be bored on any taper turned.

As now made, the tool posts are abettors of a curious mechanical absurdity, as it is, so to speak, a steel tower through which a tool is thrust, and at its overhung end it is expected to do good and quick work in removing metal. Instead of this, the ideal lathe should have a tool post allowing the cutting edge to be on the end of the tool which should stand as nearly vertical as clearance will allow. This allows the tool to be ground on its end only, preserving its form.

The writer has often obtained the desired stiffness in tools by setting them low and running his lathe backward, as he could then use the end of the tool and send the strains of cutting on to the cross feed screws; but these are generally so small that they soon wear out.

When boring operations have to be done the overhung tools must be used in many cases, but if the work admits of a hole through it the boring should be done by means of a bar, which would extend from the tail stock into a bushing in the spindle of the head stock; in other words, the apron should not be used for boring as it now is, but the tail stock should be used as it is in the Fox and in the pattern makers' lathes.

The tail stock should be able to feed its spindle at all angles automatically, within certain bounds. It should be hollow and provided with bushings, to be used at times in place of centres. The set-over of the tail stock should be by power, and the spindle should be able to rotate; power should advance it to and from the head stock.

The head stock should, of course, impart motion to the work at all times, except when the tool has advanced close enough to the face plate to interfere with the dog, when the latter should be removed and the revolutions of the tail stock should rotate the work until the entire cut is made.

Before going into the head stock design, the question of screw cutting should be considered. For short screw cutting, up to six inches in length, say, for a 12-inch lathe, lead screws should be used for inside work, and these lead screws should be on the spindle of the tail stock and not in the apron; but, for outside work, they should be changed to the apron. In both cases a half-nut should engage with the lead screw. This would obviate the necessity of running back, which has so often to be resorted to now. For long threads a regular lead screw should be used, of at least four times the diameter now generally employed.

Returning to the head stock, the spindle should be fitted with a "drawing-in chuck" and have a very large hole in it, allowing a sliding centre to be fitted, and this sliding centre should have "drawing-in chucks" also. This would allow a small rod, say ½-inch in diameter, to be put on the sliding centre, and after an inch or so was turned, the turned part could pass through a bushing in the tail stock, and, as the turning was done, the rod would advance through the tail stock very much after the manner of the wood dowel machine now used.

The bed of the ideal lathe should not have its sliding and, so to say, working surface, horizontal, but vertical on the face or front of the lathe. The head stock would overhang the front, allowing the apron to run under it and the tail stock should also be thus designed.

The writer is not going into the lathe-building business, and he feels quite sure that if he built such a lathe as he here suggests, and depended upon its sale for bread and butter, he would certainly starve to death; yet, he wants it distinctly understood that every feature here hinted at can be accomplished, and satisfactorily in a practical way. He has made drawings, to no end, of ideal lathes, and has worked out every feature practically.

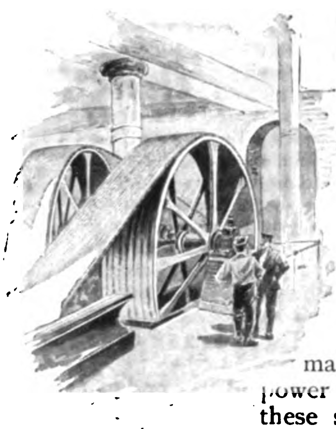
The thoughts of engineers have so long run in vertical or horizontal planes that it is difficult to get them to think that work can ever be done as well, or better, if the plane is changed. For instance, a lathe to turn shafting should stand on end, as, by so doing, more perfect results would be obtained. This is recognised in cylinder boring.

That the question of infinite speed is gaining ground is evident by the appearance of several devices which are now on the market to accomplish this end. It is a good sign.

MODERN METHODS OF ELECTRIC ENERGY TRANSMISSION.

By Dr. Louis Duncan.

An extract from a paper entitled, "The Present Status of the Distribution and Transmission o Electric Energy," recently read before the American Institute of Electrical Engineers.



SOME of the most important stations supplying incandescent lamps are operated on the three-wire, continuous-current system. In the last few years a considerable advance has been made in the sale of power for motors from these stations, and this has increased the revenue andhas given better average output. The tendency in the United States has been in the direction of using storage batteries in such stations, and in Europe practically every continuous-current station uses batteries.

As in the case of traction systems, it has been the custom in large cities to build a number of separate stations, instead of building a single plant and distributing from it. The batteries have been placed in the stations themselves, and no attempt has been made to decrease the amount of copper used by employing a number of centres of distribution and giving the main feeders a steady load.

The same considerations that apply to stations for traction work will also apply to stations used to supply lights, and the same methods of distribution may be used. It would unquestionably be more economical, in many instances, to use single stations, to transmit power from these stations to centres of distribution, where batteries may be located, and to distribute from these centres on a three-wire system.

A case in point is the system used at Buda-Pesth, where the energy is distributed from the central station to rotary transformers at sub-stations, these rotary transformers feeding batteries, current being distributed from these batteries on a three-wire system. The reports of the operation of this station show that it is both economical and successful, and it might well be copied elsewhere.

The gross receipts of some of the large illuminating companies bear such a large proportion to the company's stock, that a comparatively small saving in operation would mean a considerable increase in the dividends, and there is no doubt in my mind that by using one power station, with battery sub-stations for distribution, the operating expenses can be considerably decreased.

Alternating currents have been employed for lighting in the United States, and they have been especially valuable where a district is to be supplied in which the distances are considerable as compared with a number of customers. It has been almost the universal custom to supply small transformers for each consumer, and while the average size of transformers is greater now than it was a few years ago, yet they are comparatively small. No power has been supplied from such stations, and although alternating arc lamps are used to a limited extent the number is not increasing, and in some cases continuous current arc lamps have been substituted for the alternating.

Under these conditions the load on the station is even more variable than in the case of a continuous-current supply where motors may be employed, and the constant loss, due to the large number of small transformers used, places this system at a disadvantage as compared with the continuous-current system. The great advantage it possesses lies in the increased area of distribution rendered possible by the high voltages that are used, together with the possibility of locating the stations where power can be cheaply made.

In Europe, in the last few years, most of the new stations that have been built use continuous currents, although some years ago the greater proportion of them were alternating current stations. It is also European custom to use sub-stations with large transformers for distribution, thus doing away with a considerable part of the constant loss due to the small transformers used. It is not possible, at the present time, without greatly complicating the system, to obtain a steady load on the station, and the cnly question that arises is the value of sub-stations, and the possibility of using some form of alternating current other than the single-phase.

Coming to the question of transmission of electrical energy, as distinguished from the supply to customers from distributing centres, great advances have been made in the last few years, and these mainly through the introduction of multi-phase alternating currents. Single-phase alternating currents permit the transmission of power to long distances and its distribution for lighting purposes. It is also possible to supply power from such circuits to large motors working under a steady load. It is not possible, however, to distribute power economically for ordinary uses.

As most long-distance transmission schemes contemplate the substitution of electric motors for steam engines, and as their success will, in many cases, depend upon the possibility of such substitution, single-phase alternating currents are not, at present, able to comply with the conditions imposed by the desired service.

The introduction of multi-phase alternating systems, where two or more alternating currents are employed, the currents differing in phase, has completely changed the situation with respect to long-distance transmission. I shall consider briefly the possibilities of such systems and their value as compared with any direct-current system.

The first long-distance transmission plant was operated by the continuous-current system, and even now plants are being built in which continuous currents of high potential are used to transmit energy to distances up to fifteen miles. As compared with transmission by means of alternating currents, we will find that the continuous current system possesses some advantages and some disadvantages.

The continuous current has a marked advantage over the alternating current system as far as the cost of copper is concerned. There are, however, certain practical disadvantages belonging to this system. The high voltages necessary for long-distance transmission make it impossible to distribute the current at the receiving end without first reducing the voltage. With continuous current this can be done only by employing a rotary commutator of some kind.

A plan which has been practically and successfully used has been to run a number of dynamos in series at the generating end of a line, while at the receiving end are a number of motors, also arranged in series, which are used to drive other generators to give the required type of current and the desired voltage. It has not been found possible to make either dynamos or motors of any great output, as there are practical difficulties in running dynamos of high potential where the current taken from them has a considerable value.

M. Thury has installed a number of continuous-current transmission plants that have apparently given excellent results. At Biberist, a transmission of fifteen miles is employed. At Brescia, 700 horse-power are transmitted over twelve miles at a maximum of 15,000 volts. M. Thury states that generators for forty-five amperes can be constructed up to 3000 volts, and he thinks that 4000 could be successfully used. These machines, however, are small when compared with the 5000 horse-power dynamos in use at Niagara, for instance, and where the transmission is a large one, the great number of machines necessary would be a serious objection to this type of transmission.

It will be seen that the greatest possibility of trouble, in such a transmission, lies at the ends of the line, in the generating and receiving apparatus. It is necessary, no matter what the voltage is, that both the dynamos and motors shall be directly subjected to it, and this with commutated machines will always be a source of danger.

If we are to do any considerable amount of lighting from such a station, the energy for this purpose undergoes three transformations before it reaches the lamps, and the efficiency would not be so high as in a corresponding alternating current system. It would hardly be possible to supply motors for ordinary work at the high voltages used for transmission, and the current for them would have to be transformed in the same manner as the current for the lamps. It must be recognised, however, that this system has been successfully used and has given excellent results in a few cases of transmission. Its great advantage lies in the decreased amount of copper as compared with the alternating systems, and in the absence of induction effects, which are a drawback to alternating current transmission.

Current Topics.

THE advantages of independent driving of machines in any shop,—that is, without the use of the traditional long lines of shafting,—are never so well appreciated as when figures are available, designed to show how much power is ordinarily used up in simply turning the shafting,—in the friction of the transmission between driving and working points. A good many experiments have been made in the past to determine what this waste amounts to, and the results nearly always have indicated tremendous losses, relatively speaking. Still, one is not quite prepared for the figures given in a paper on the subject, recently presented before the American Society of Mechanical Engineers by Professor C. H. Benjamin. The trials of which they are the outcome were made at sixteen different establishments, with horse-power totals ranging from 8 to 400 and with percentages lost in friction from 14½ to 80, the average friction loss amounting to over 55 per cent. These figures, it is proper to add, include, in every case, the friction of the engine itself, but even if a liberal deduction be made for this we have still a formidable remainder. What a fruitful field there is here for the electrical engineer! While small steam engines are used in some cases for driving single machines, and form a part of them, it is to the electric motor that we will eventually be indebted for a wider application of the independent driving system. There are a few shops,—models in their way,—where this system is in use, and has been for several years, and year by year fresh proofs are given of its manifold advantages. In these shops machine tools of all kinds, travelling cranes, elevators, each has its own motor, big or little, and the line shaft, the countershaft and the multitude of pulleys are, indeed, relics of a past régime.

ONE of the latest oddities of design in the steam engine line, recently turned out by a Scotch firm, Messrs. Fleming & Ferguson, Limited, of Paisley, is a four-cylinder, quadruple expansion engine with only a single crank. The engine is of the vertical type, with the cylinders arranged in pairs, tandem fashion. The high-pressure and second cylinders are placed, respectively, over the third and low-pressure cylinders, the diameters being 9, 12, 16 and 25 inches, with 21½-inch stroke. The two cross heads are connected by links to the top end of a steel triangular connecting rod. Corliss valves and a shaft governor are used. The engine is intended to work condensing, but should the available water supply for this become short, the engine can easily and quickly be converted into a compound high-pressure engine of nearly the same power by simply disconnecting the valves of the upper cylinders, leaving the two lower cylinders, 16 and 25 inches in diameter, to do the work. The condenser, in that event, is shut off by a valve on the exhaust pipe.

To what limits the inventing of bicycle improvements has gone is shown by the patent office records in the United States. Up to 1876, accordingly to recently published figures, approximately three hundred patents for cycles had been issued from that office. In 1876, invention revived on account of the excellent exhibit of English cycles at the Centennial Exhibition. Since 1876, over four thousand cycle patents have been granted in the United States, and nearly or quite one-half of this number have been issued since 1890. In 1890, one assistant examiner of patents was able to dispose of all applications that were filed. In November, 1896, it required the labour of eight expert assistant examiners to handle the applications for cycles, and even with this force working at them, there have been lately one thousand applications constantly on hand awaiting action. At the present time, it is said, no country in the world is granting so many patents for cycles and cycle improvements as the United States.

IN the forest of the Bridal Veil Lumbering Company, at Bridal Veil, in Oregon, there is a railroad which does business without cars. Hauling great logs from a log pond to the saw-mill is the nature of the business, and the way in which it is performed is portrayed effectively in the illustration on this page. The train, so-called, is made up of an ordinary locomotive and a string of logs, each one as large in diameter, and some even larger, than the boiler of the engine. Boards are nailed to the sleepers between the rails and on these the logs slide. Except on descending grades, the boards are greased, and the train moves at good speed. Where the road is level or slightly ascending the engine pulls the logs, and where it is descending it holds them back. At the

FROM A PHOTOGRAPH BY BROWNING, PORTLAND, OREGON.

A RAILROAD WITHOUT CARS.

mills of the company the manufactured lumber, regardless of size, is run into a flume and this is carried about two miles to the planing mill and shipping yard, the flume descending about 1200 feet in that distance. Economy in rolling stock seems to have been carried to a maximum on this road, but the service is quite as well performed as the conditions demand.

DISCUSSING in these pages, several years ago, the economic element in technical education, Professor L. S. Randolph remarked that no more exasperating thing can occur to the young graduate leaving college, with his brain filled with thermodynamics, neutral axes, radii of gyration and the like, than to be asked the price of a 6-inch pulley and to have no idea of the answer, nor to know where to get the information. The condition which prompted this statement is as much in evidence to-day as it was at that time. Business training is sadly neglected in the preparation of the engineering student for practical work in later days, and he should make good use, therefore, of any available opportunity afterwards to acquire his training, partially at least, by actual contact with business methods. Engineering success to-day demands business faculties at ready command. In substance, this is what Mr. G. F. Goodhue recently emphasised in a paper read before the Purdue Society of Civil Engineers:—"I have often noticed," he remarked, among other things, "how great was the deference paid to the accounting officer of a corporation, either public or private, by its employees. Usually, a city clerk gives you to understand that he is the city, and the auditor of a railway company would make you believe that an inaccurate account sent to his office will have the immediate effect of derailing the limited express which runs over his road. Both are very exacting in their financial demands upon those who are accountable to them, sometimes arbitrarily so, but as a rule they are excellent business men—good models for the engineer to pattern from."

STEAM pressures have been steadily climbing. From considerably below the 100-pound mark to over 200 pounds has been the rise, in only a few years, and latterly there has been agitation for the adoption of something even far beyond the latter figure, especially for marine practice, with the promise of further and exceptional economy in the coal pile. Unfortunately, however, for what progress there might be in this higher direction, costly and troublesome difficulties beset the path,—difficulties with boiler gauge glasses, joints and packings, greater first cost of the engines and boilers, greater expense of maintenance, etc.,—so that, in the end, steam of exceptionally high pressure is a much disguised blessing. Greater coal economy may be gained, even now, by other means, less difficult to manage. All this has called forth the following from the London *Engineer*;—"We recently met with a case in which the average back pressure was six pounds, or just twice the condenser pressure. This was due mainly to crooked passages and somewhat contracted ports in the slide valve. We venture to assert that not nearly as much attention is paid to the getting of steam out of a cylinder as the matter deserves. * * * Steam in a low-pressure cylinder is always charged with moisture; it is not 'lively,' and every facility for its movement to the condenser must be provided. The gain wrought by reduction in back pressure has no alloy. It costs nothing. It is all clear advantage, and that being the case, it seems strange that the last pound should not be fought for. When all has been done in this direction that can be done, it will be time to talk about reverting to the days of Jacob Perkins and one thousand pounds steam."

THE manufacture of the first armour plates has recently been claimed for the Parkgate Iron Works, of Rotherham, England. This firm rolled many of the heavy plates for the *Great Eastern*, in 1857, and one of these was 27 feet 3 inches long, 3 feet 3 inches wide and weighed 41 hundred weight. When the French armoured ship *La Gloire* appeared and a demand arose for a better protection for British ships, this firm supplied 2000 tons of plates, from 3 to 4½ inches thick, for H. M. S. *Terror*, launched in 1856. Mr. Charles Stoddart, managing director of the Parkgate works, is credited with saying that Sir John Brown, to whom is usually ascribed the invention and first rolling of armour plate, did not see *La Gloire* until 1860, and plate of this type was not rolled in Sheffield until 1862.

SELF-PROPELLING fire engines are becoming the fashion. Boston has just added one to her fire fighting equipment,—not the first, by the way, that has been turned out in the United States,—and it will probably not be long before other cities will follow suit. The needs of thorough municipal fire protection have received almost proverbially careful attention in America, and the new departure, therefore, has not been prompted by a craving for the novel, of which Americans are so often accused, but by the promise of better service,—the more likely saving of property. With the growing demand for greater water-throwing capacity, fire engines have gone on increasing in size and weight year after year, until the heaviest now in use, somewhere about the 10,000-pound mark, and capable of handling 1100 gallons of water a minute, require three horses for reasonably rapid getting around. But the demand for even larger engines still remains. To meet this, the Boston self-propeller was ordered, which, in general appearance, seems to bear a pretty close resemblance to the typical American steam fire engine. Its service weight, however, is 17,000 pounds, and its water capacity 1850 gallons a minute, so that it is decidedly a more formidable fire-fighting apparatus than its various prototypes. Successful animal traction for so heavy a machine was out of the question. Obviously, some other form of power was necessary, and in making the machine self-propelling, its builders set an example which is pretty well assured of imitation. It remains to be seen, however, whether fire engines of so great a weight as this one will prove as all-around satisfactory as is evidently expected. Great weight, even if coupled with great capacity, may not be exactly conducive to best service.

In an under-water shooting experiment which was made a short time ago at Portsmouth, England, a stage was erected in the harbour within the tide mark, and on this a 110-pound Armstrong gun was mounted. This was loaded and aimed at a target during low tide. A few hours after, when the gun and the target were both covered with water to a depth of six feet, the gun was fired electrically. There were two targets, but only one was erected for this special experiment, the other being the hull of an old vessel, which lay directly behind the target in range of the ball. The target itself was only twenty-five feet from the muzzle of the gun. It was composed of oak beams and planks and was about twenty-one inches thick. To the hull of the vessel, in direct range with the gun, a 3-inch thickness of boiler plate was riveted. On all these—the oak target, the boiler plates, and the hull—the effect cf the shot from the submerged gun was startling. The target proper was pierced through and through, and the boiler iron target was broken into pieces and driven into its "backing," the ball passing through both sides of the vessel, making a huge hole through which the water poured in torrents. The experiment was an entire success, and was held to demonstrate very satisfactorily the feasibility of placing submerged guns in harbours in time of war as a protection against an enemy's ships.

An accident occurred a short time ago to a paraffine induction coil which was sufficiently unique as well as ludicrous to be worth relating. The story is told as follows in the American *Electrician* :—The induction coil had just been completed and its performance was all that could be desired, when a prospective buyer of apparatus appeared on the scene. On being shown the new coil and its performance he declared himself suspicious of "these electric fixins," for "thar's no tellin' when they mought blow up." The builders of the coil, in their superior knowledge of its construction, laboriously explained that such was an impossibility, and it may safely be said that their opinion would be confirmed by any electrical expert. Nevertheless, while the explanation of the impossibility of such a catastrophe was at its height, the coil did blow up with a rattling report, and the whole construction was shattered. The utter amazement of the electrical experts and the triumphant delight of the rural delegate at this unexpected demonstration of his asseverations can better be imagined than described, and for the dignity of electrical science we will leave this phase of the picture and pass to the cause of the accident. On examination of the ruins, the centre of the explosion seemed to be a large cavity or blow hole in the paraffine, and as this cavity was the size of an egg or larger, the analysis was easy. This hole had become filled with a mixture of hydrocarbon vapour and air which, as is well known, is highly explosive. A spark penetrating the chamber did the rest. Of course, all explanations were lost on the rural gentleman, whose triumph overshadowed all else, and he left declaring that electrical engineers didn't know as much about electricity as they thought they did, and, as for the engineers themselves, they began to be of the same opinion.

What a pound of coal would do in the way of steamship propulsion at different epochs of steamship evolution was outlined recently by Mr. A. J. McGinnis in his presidential address to the Liverpool Engineering Society. In 1840, it appears, this amount of coal, burned on an ocean steamer, propelled a displacement weight of 0.578 ton eight knots, or an actual earning weight of 0.057 ton, the hull representing 40 per cent. and the machinery and fuel 50 per cent. of the displacement. In 1850, with iron vessels and the screw propeller, a displacement weight of 0.6 ton was propelled nine knots, but the earning weight was increased to 27 per cent., or 0.16 ton. In 1860, with higher boiler pressure and the surface condenser, a displacement weight of 0.82 ton was propelled ten knots, and the earning weight was 33 per cent., or 0.27 ton. In 1870 the compound engine so reduced the fuel carried, that a displacement weight of 1.8 ton was propelled ten knots, the earning weight being 50 per cent., or 0.9 ton. In 1880, when passenger and cargo steamers had separated, the record of the purely cargo steamer was 2.1 displacement tons propelled ten knots the net earning weight being 50 per cent., or 1.05 tons. In 1890, when steel hulls and triple expansion engines had become universal, the work on the cargo boat was 3.33 displacement tons, propelled ten knots, and the earning weight had risen to 58 per cent., or 1.93 tons. In 1895 there were two classes of cargo boats. The work on the ocean "tramp" was 3.4 displacement tons, propelled eight and one-half knots, with an earning weight of 60 per cent., or 2 tons; on the huge cargo vessels of the North Atlantic 3.14 tons were propelled twelve knots, the earning weight being 55 per cent., or 1.7 tons. The express passenger steamers show more clearly the penalty of speed. On these the earning weight propelled for each pound of coal per hour was reduced from 0.16 ton in 1881 to 0.09 ton in 1895; while the increase of speed from nineteen to twenty-one and a quarter knots was obtained only by raising the daily coal consumption from about 300 to 500 tons.

One of the points in horseless carriage construction which now appears to be about to receive the attention that it deserves is the amount of power necessary for the best service. Many of the carriages hitherto in experimental use, ran along very well on a level, but hill climbing generally was too much for them, and in some cases even the more roughly paved streets were quite discouraging, giving all the proof necessary to show that the need for power in these vehicles had been underrated. Sir David Solomons, who has studied the subject of self-propelling carriages probably more enthusiastically than any one else in England, laid particular stress on this circumstance some time ago in an article in *The Engineer*, London. He maintained there that if it be desired to travel on the level and up hill at an unvarying speed of, say, twelve miles an hour, which speed would hold good for down hill also, since greater speed would probably not be tolerated, and when it is taken into consideration that, except in a few districts, the roads are rarely what may be termed good in the strict sense of the word, a carriage should carry an engine capable of giving from two horse-power up to twelve horse-power. Since the majority of the carriages in question are fitted with engines incapable of giving more than four horse-power, the desired uniform speed of twelve miles an hour will, therefore, be reduced to one-third, viz., four miles an hour, where a 10 per cent. incline is reached. This is what they realise in practice.

Sir David Solomons further emphasised as two important facts, which are essential when a given average of speed is required, that no vehicle is of much service for heavy work unless an engine capable of giving out not less than thirty horse-power is fitted; and that for light traffic the engine should give not less than twelve horse-power. If a light petroleum-driven carriage be required to run at an average speed of twelve miles per hour on good and bad roads, where inclines exist up to a 10 per cent. rise, the carriage, laden, will probably weigh not less than one and one-half tons and require a maximum of not less than eighteen or twenty horse-power. Where one is content with a lower speed, there may, however, be a corresponding reduction.

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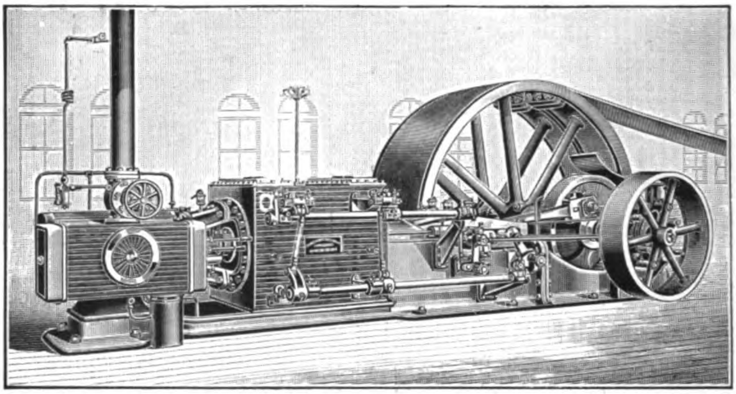

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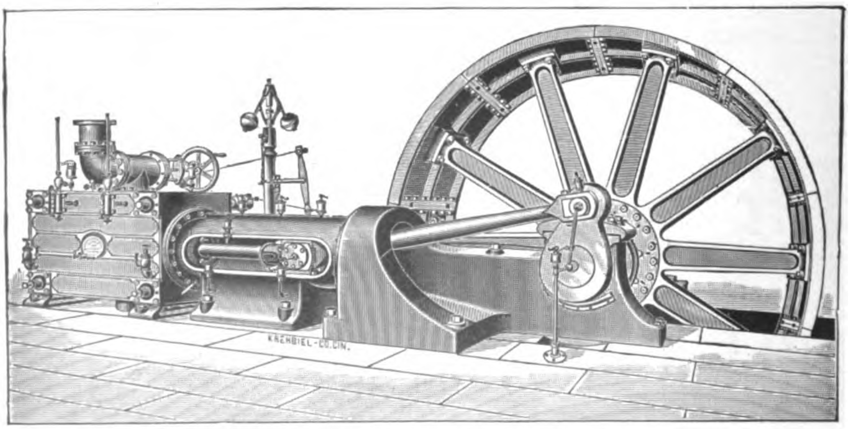

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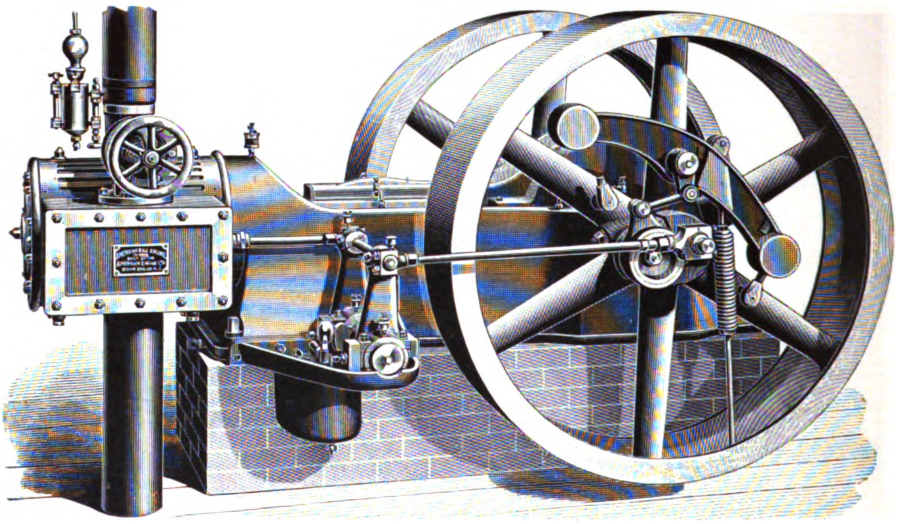

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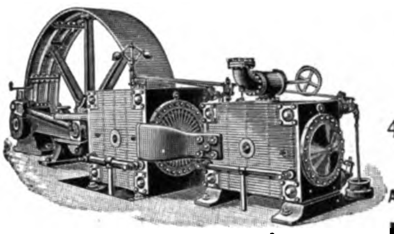

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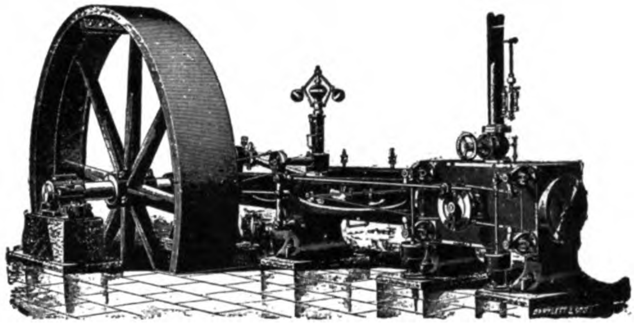

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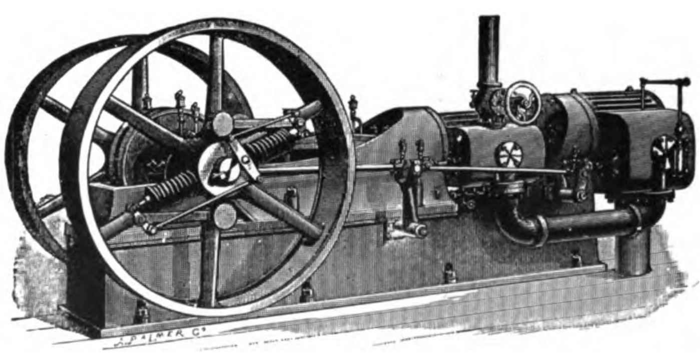

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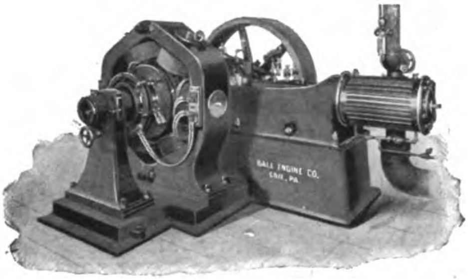

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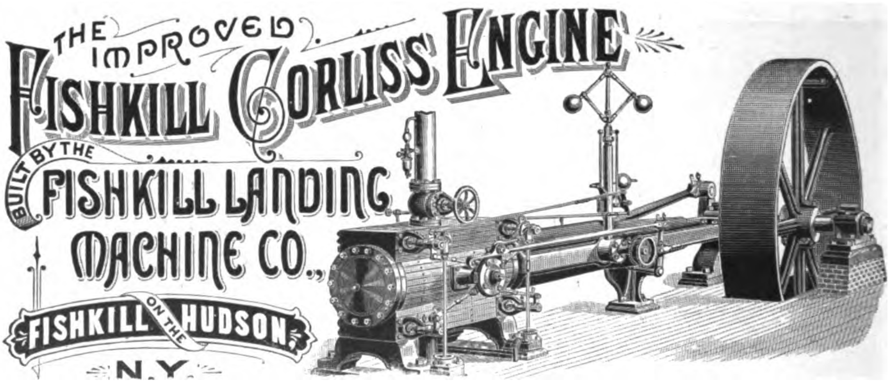

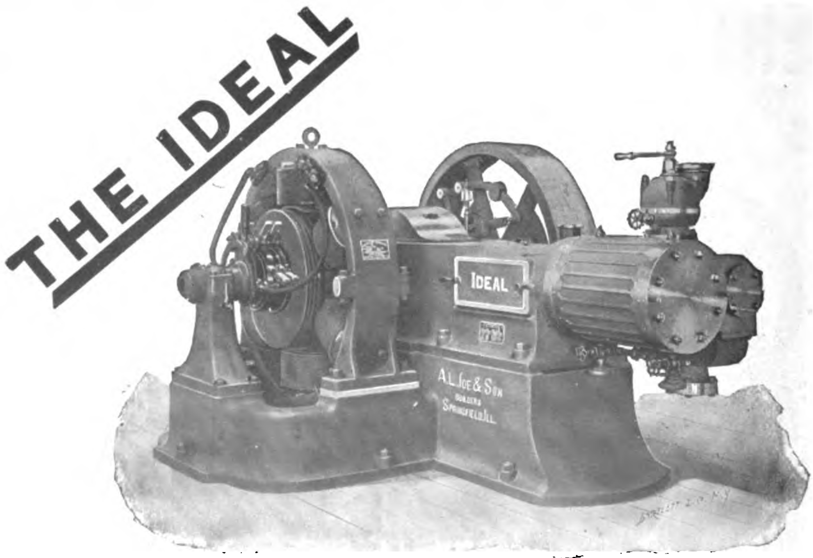

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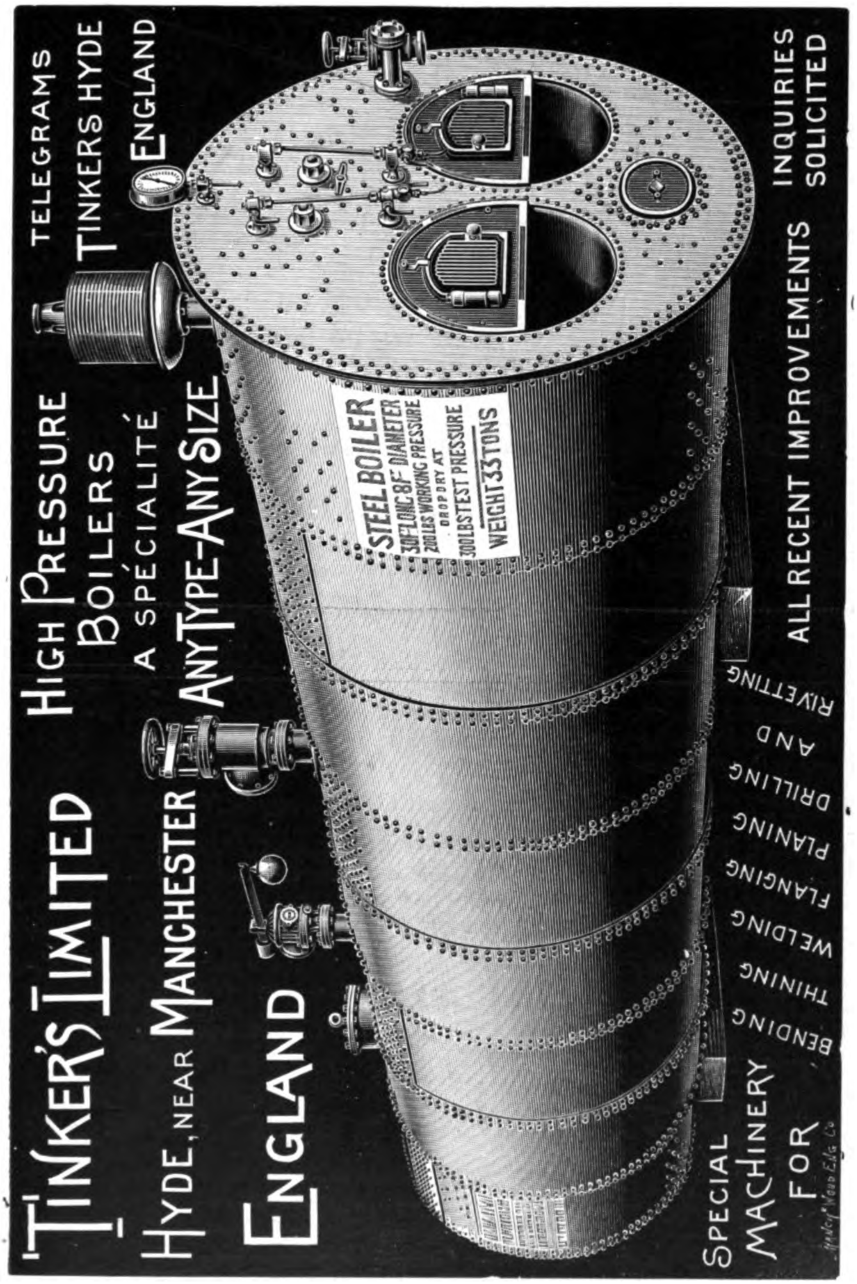
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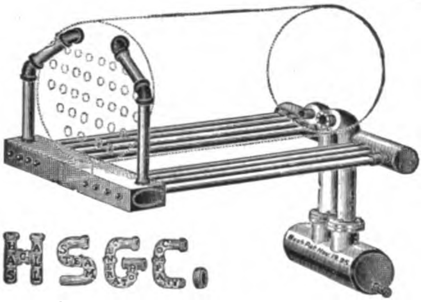

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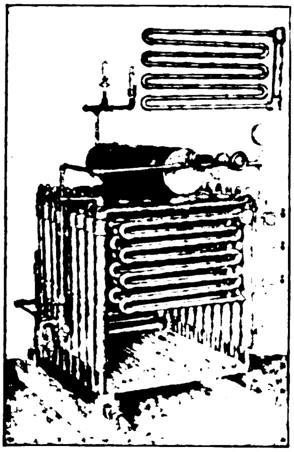

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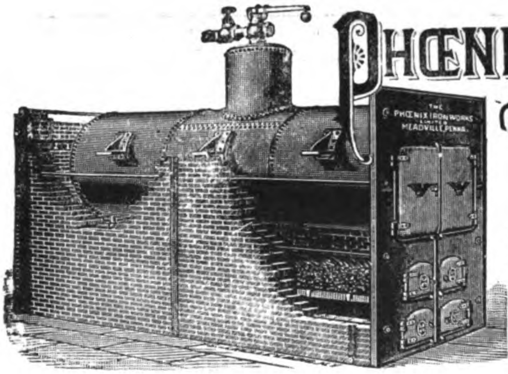

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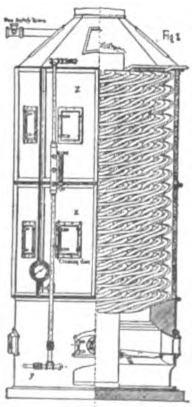

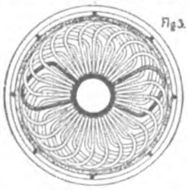

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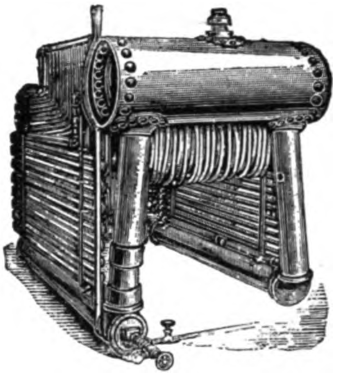

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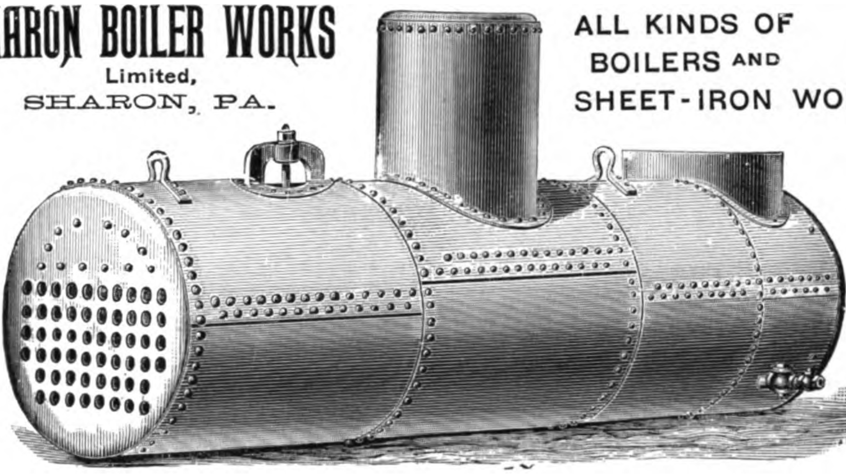

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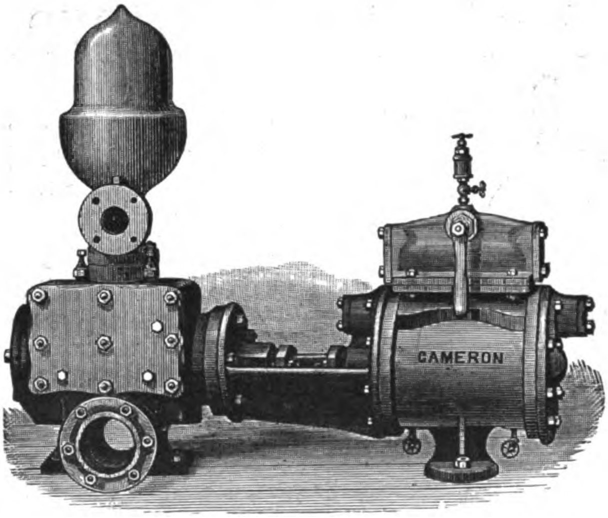

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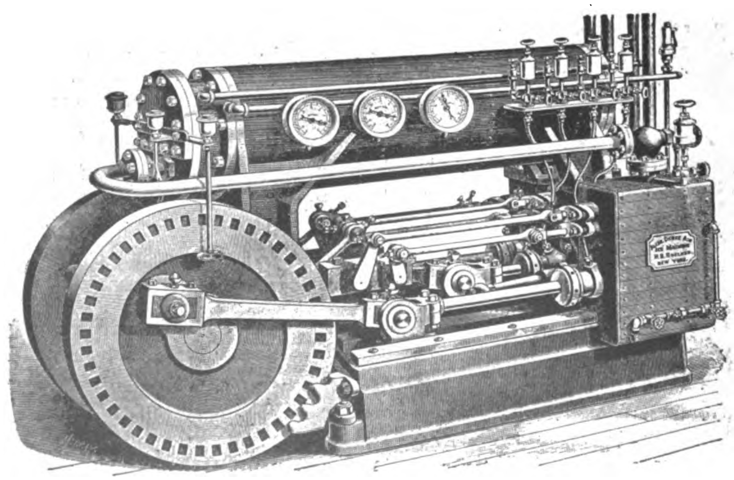

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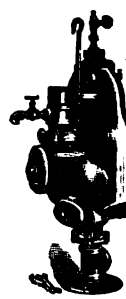

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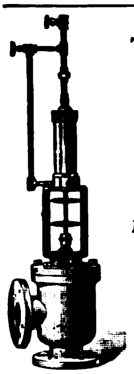

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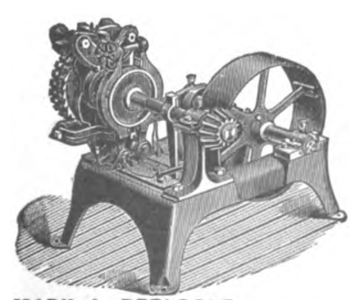

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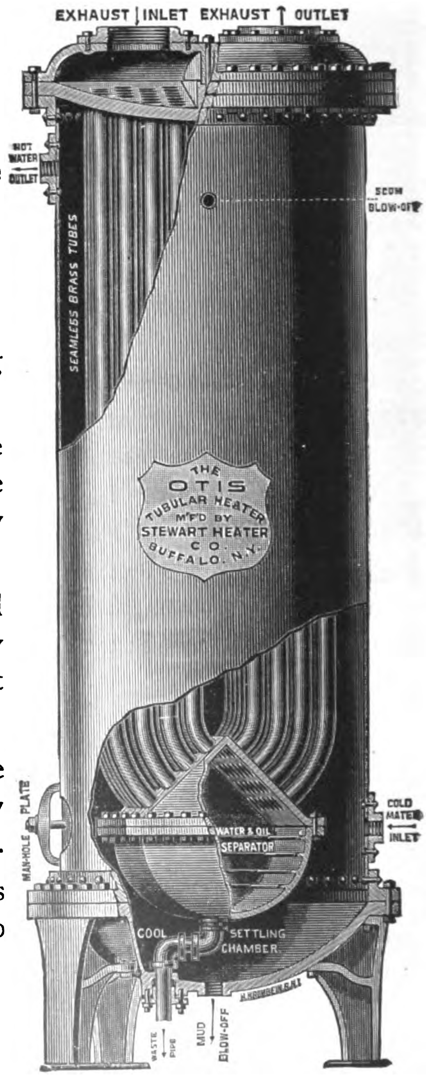

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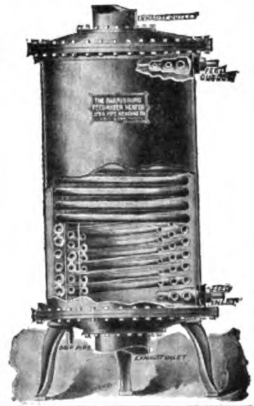

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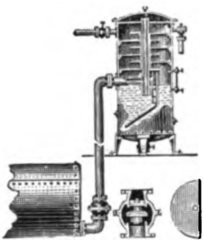

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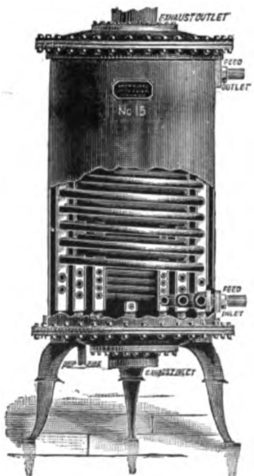

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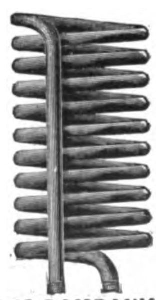

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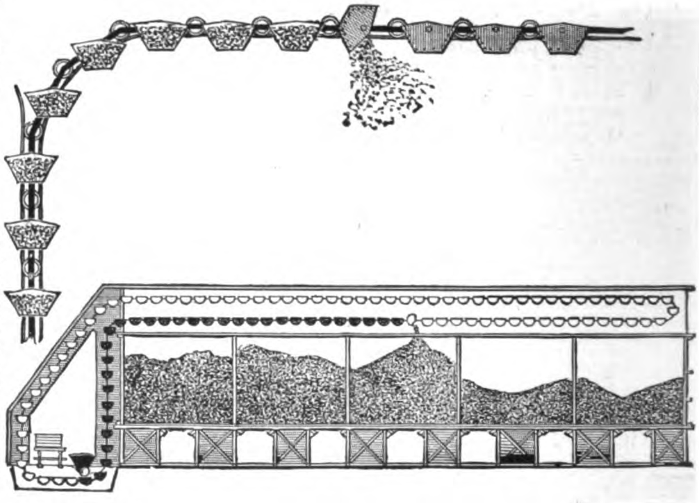

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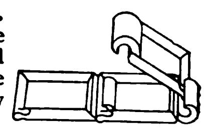

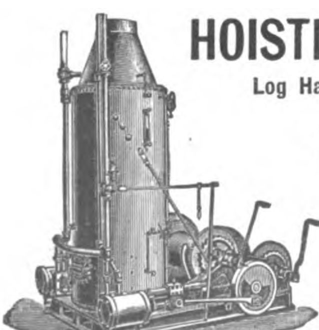

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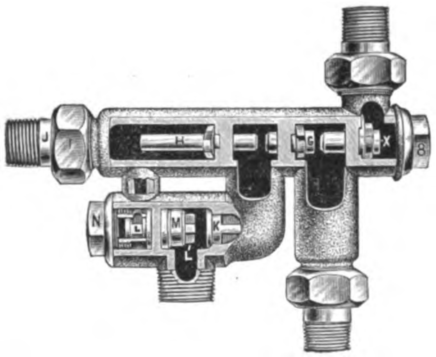

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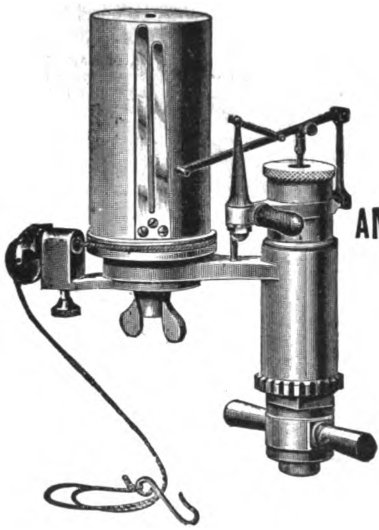

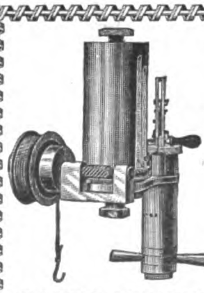

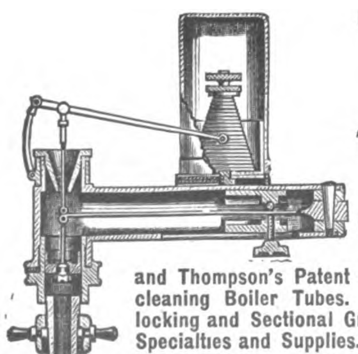

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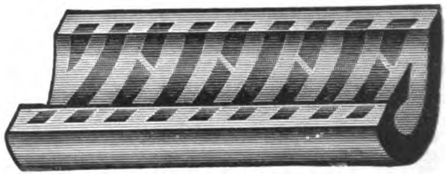

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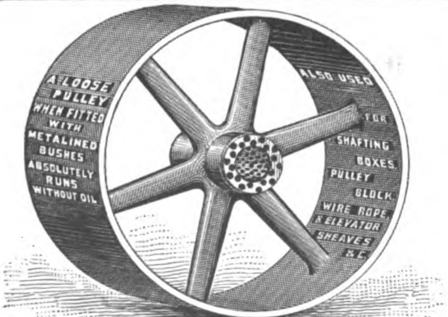

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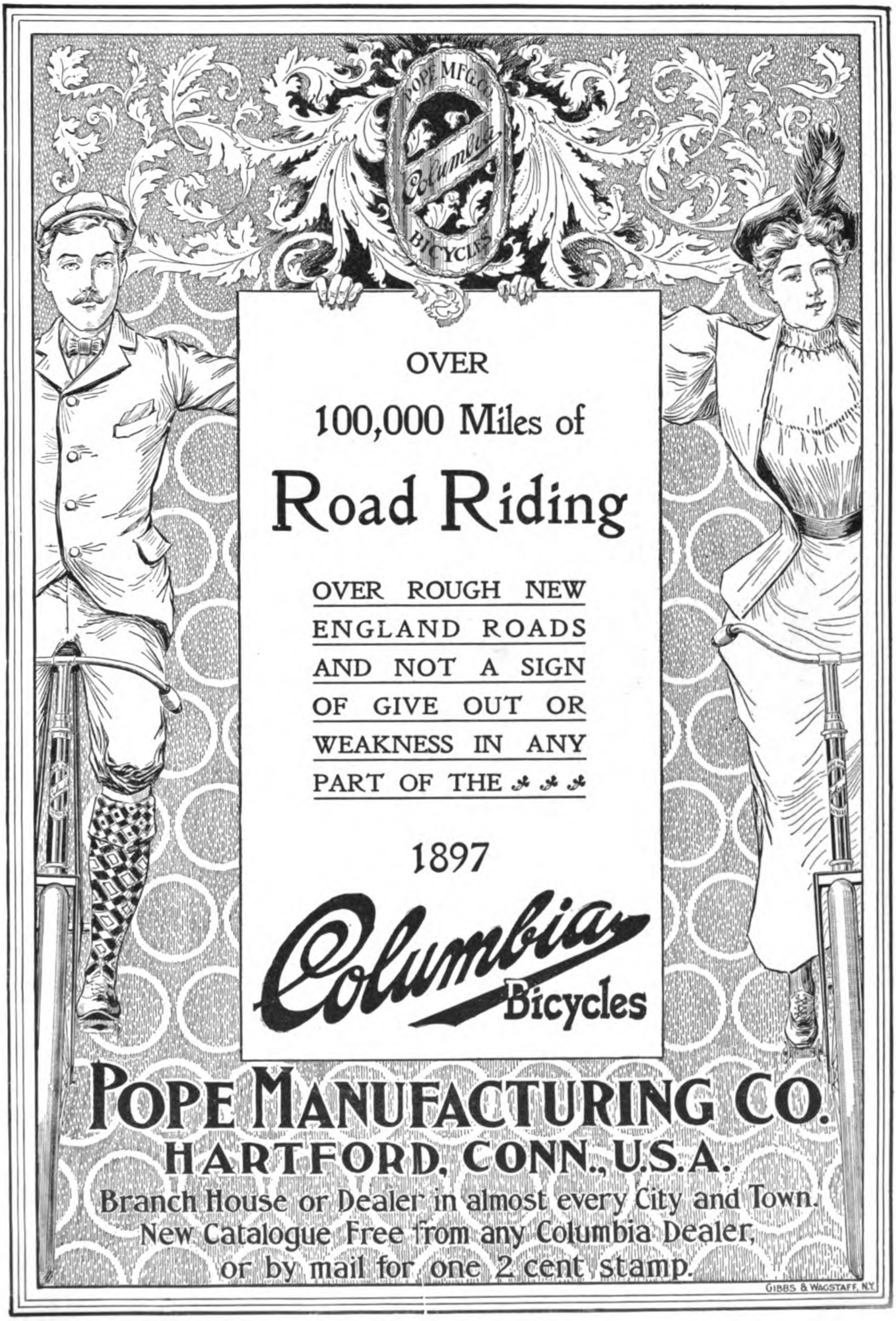
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CONTENTS.

PORTRAIT OF GEORGE WALLACE MELVILLE . . . . Frontispiece
Engineer-in-Chief U. S. Army.

ELECTRIC TRACTION IN CITY STREETS . . Nelson W. Perry, E. M.. 419
With twenty-three illustrations of electric street car lines in different cities.

SHIP BUILDING IN GREAT BRITAIN . . . . Robert MacIntyre 437
With eight illustrations of some recently built vessels.

THE METRIC SYSTEM FROM A MECHANICAL POINT OF VIEW . . . . Samuel Webber 447

AN ARTIFICIAL ICE SKATING RINK . . . . George Hill 450
With seven illustrations representing general views and details of arrangement.

GEORGE WALLACE MELVILLE . . . . . . Wm. Ledyard Cathcart 459
A biographical sketch, with three portraits and several illustrations of Commodore Melville's Arctic experiences.

STEAM ENGINES FOR MODERN POWER HOUSES . Richard McCulloch 481

A TEN-TON PNEUMATIC TRAVELLING CRANE . W. G. Starkweather 483
With two illustrations.

COMMERCE ON THE GREAT AMERICAN LAKES . John Birkinbine 487
With fifteen illustrations of American lake shipping, ore docks, Soo canal views, etc.

THE IDEAL ENGINE LATHE . . . . W. D. Forbes 502
With an illustration of a lathe 700 years old.

MODERN METHODS OF ELECTRIC ENERGY TRANSMISSION . . . . Dr. Louis Duncan 505

CURRENT TOPICS 507
Independent Driving of Machines—An Oddity in Steam Engine Design—Bicycle Inventions—A Railroad Without Cars. Illustrated—The First Armour Plates—Self-Propelling Fire Engines—Shooting Under Water—Explosion of an Induction Coil—Coal for Steamship Propulsion—Power for Horseless Carriages.

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Alphabetical Index to Advertisers.

	PAGE
Aitchison, Robert, Perforated Metal Co	57
Allis, The Edward P. Co	25
American Engine Co	33
American Steam Gauge Co	54
Armstrong Bros. Tool Co	13
Armstrong Manufacturing Co	14
Ashcroft Mfg. Co	54
Atlas Engine Works	26
Ball Engine Co	32
Barnett, G. & H. Co	2
Bates Machine Co	31
Becker, The John Mfg. Co	12
Bickford, H	back cover
Berlin Iron Bridge Co	64
Bernard Co., E. G	6
Besly, Chas. H. & Co.	back cover
Boyer's Sons, L.	39
Bradford Mill Co	12
Bristol Co., The	back cover
Brixey, W. R	1
Brown & Co., C. H	33
Buffalo Forge Co	back cover
Bullard Machine Tool Co	11
Bullock Mfg. Co	30
Cahall Sales Department	inside front cover
Cameron Steam Pump Works	45
Carborundum Co	12
Castle Line	55
Century Co	5
Clonbrock Steam Boiler Works	38
Colorado Iron Works	57
Consolidated Safety Valve Co	56
Crane Co., The	51
Crook, W. A. & Bros. Co	50
Currie Co., Donald	63
D'Este & Seeley Co	55
Deming Co., The	inside front cover
Dixon Crucible Co	58
Eastman Kodak Co	40
Erie Engine Works	34
Filer & Stowell Co	25
Fisher Governor Co	44
Fishkill Landing Machine Co	32
Frick Co	31
Fuel Economizer Co	inside back cover
Gates Iron Works	18
General Electric Co	8
Gould Packing Co	55
Guild & Garrison	44
Greenfield, W. G. & G	34
Graphite Lubricating Co	58
Hammond Typewriter Co	34
Harrisburg Pipe Bending Co	49
Hascall Steam Generator Co	36
Hartford Steam Boiler Insp. & Ins. Co.	inside back cover
Hayden & Derby Manufacturing Co	53
Heine Safety Boiler Co	37
Hooven, Owens & Rentschler Co	28
Hunt Co., C. W	50
Ide, A. L. & Son	32
Interior Conduit and Insulating Co	6
Jeffrey Manufacturing Co	inside front cover
Jenkins Bros	51
Johns Mfg. Co., The H. W	57
Jones & Lamson Machine Co	12
Keuffel & Esser Co	1
Laidlaw-Dunn-Gordon Co	48
Lane & Bodley Co	27
Learmonth, Robert	49
Leffel, James & Co	46
Lehigh Valley R. R. Co	62
Link Belt Co	50
Lombard Water Wheel Governor Co	47
Lunkenheimer Co., The	51
Magnolia Metal Co	58 and back cover
McGowan, J. H. Co	41
McIntosh, Seymour & Co	28
Miami Cycle and Manufacturing Company	
Michigan Brass and Iron Works	51
Michigan Central R. R. Co	60
Michigan Mining School	
Morse Twist Drill and Machine Co	14
Mosher, Charles D	41
Munn & Co	57
Mutual Life Insurance Co	16
National Pipe Bending Co	49
New Era Iron Works	34
New York Air Brake Co	47
Nicholson, The Jos. C., Tool Co	13 and 15
Niles Tool Works	10
North American Metaline Co	58
Office Specialty Manufacturing Co	34
Ocean Steamship Company	6
Pelton Water Wheel Co	46
Penberthy Injector Co	52
Phœnix Iron Works Co	31 and 38
Pond Machine Tool Co	14
Pope Manufacturing Co	61
Pratt & Whitney Co	8 and 11
Professional Cards	3
Pulsometer Steam Pump Co	44
Pulsifer, N. T	6
Q. & C. Company	13
Quimby & Co	42
Replogle Governor Works	46
Reilly Repair and Supply Co., The James	59
Riter & Conley	40
Rochester Machine Tools Works	37
Roelker, H. B	42
Schaffer & Budenberg	53
Scientific American	57
See, Horace	40
Seibert Cylinder Oil Cup Co	56
Sharon Boiler Works	39
Shaw, Willis	49
Sherwood Manufacturing Co	53
Southwark Foundry and Machine Company	
Southern Pacific Company	63
Standard Tool Co	14
Stanley Electric Co	7
Stearns Mfg. Co	29
Sterling Emery Wheel Co	11
Stewart Heater Co	48
Stillwell-Bierce & Smith-Vaile Co	45
Struthers, Wells & Co	39
Sturtevant, B. F., Co	27
Sullivan Machinery Co	back cover
Thompson & Bushnell Co	54
Tinkers Co., Ltd	35
U. S. Mineral Wool Co	back cover
Union Electric Co	49
Van Wie, Irvin	48
Washington Carbon Co	8
Watson-Stillman Co	10
Westinghouse Machine Co	
Weston Electrical Instrument Co	8
Wetherill, Robert & Co	40
Wood & Co., R. D	2
Worthington, H. R	44
Wrought Iron Bridge Co	56

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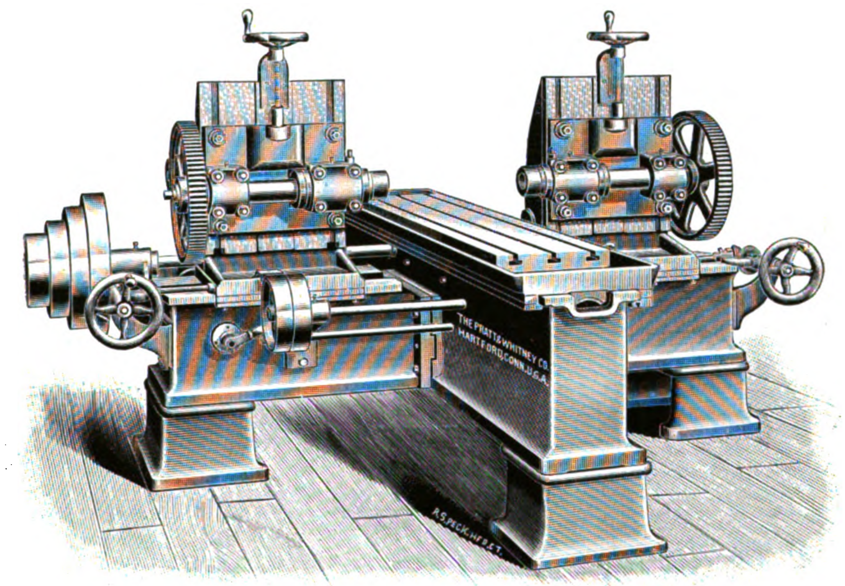

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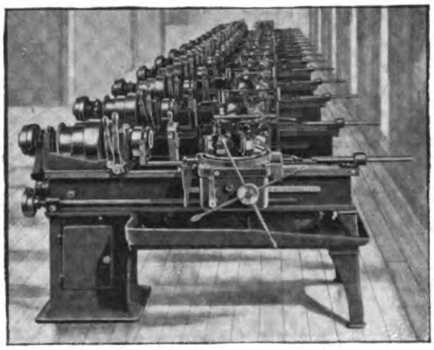

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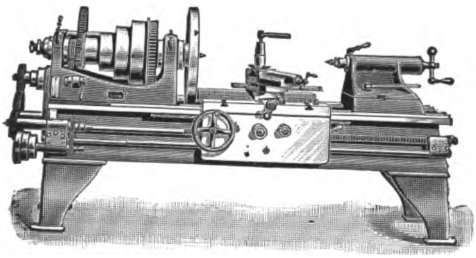

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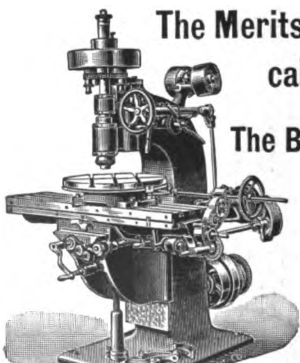

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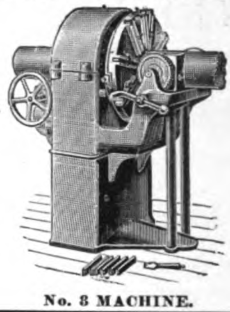

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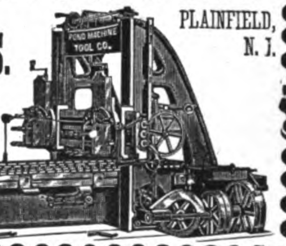

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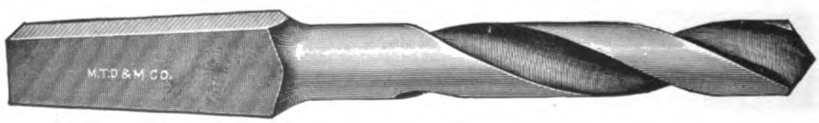

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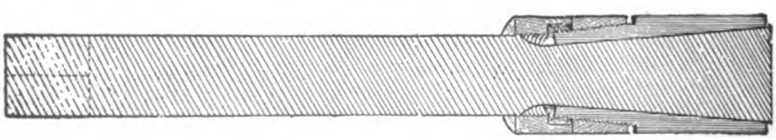

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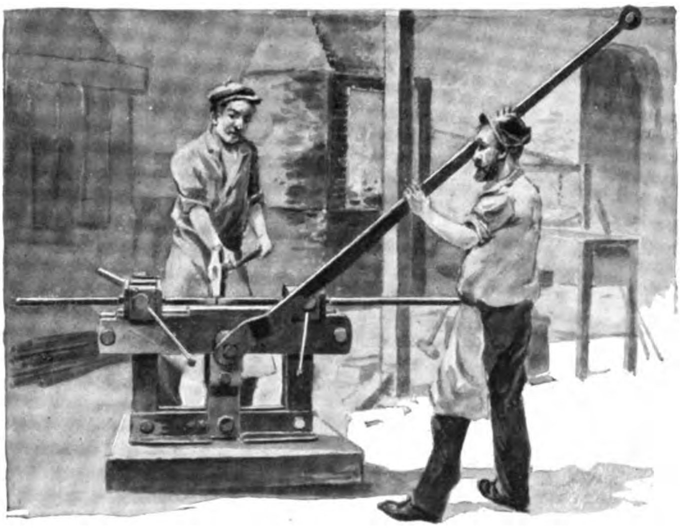

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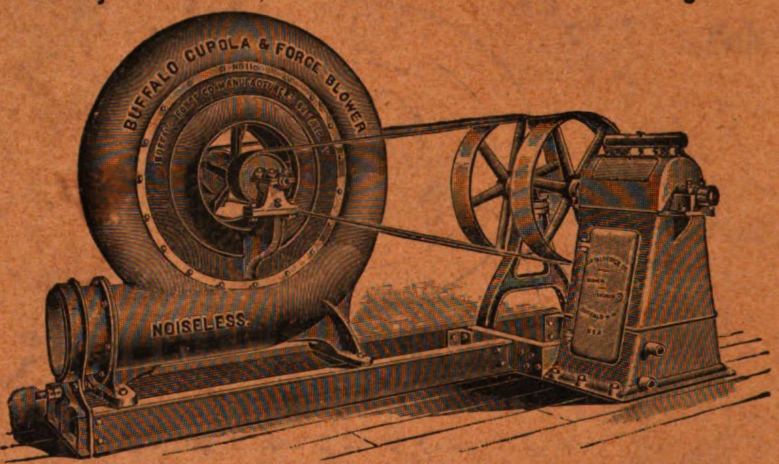

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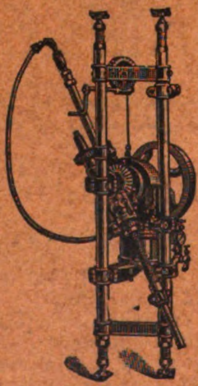

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