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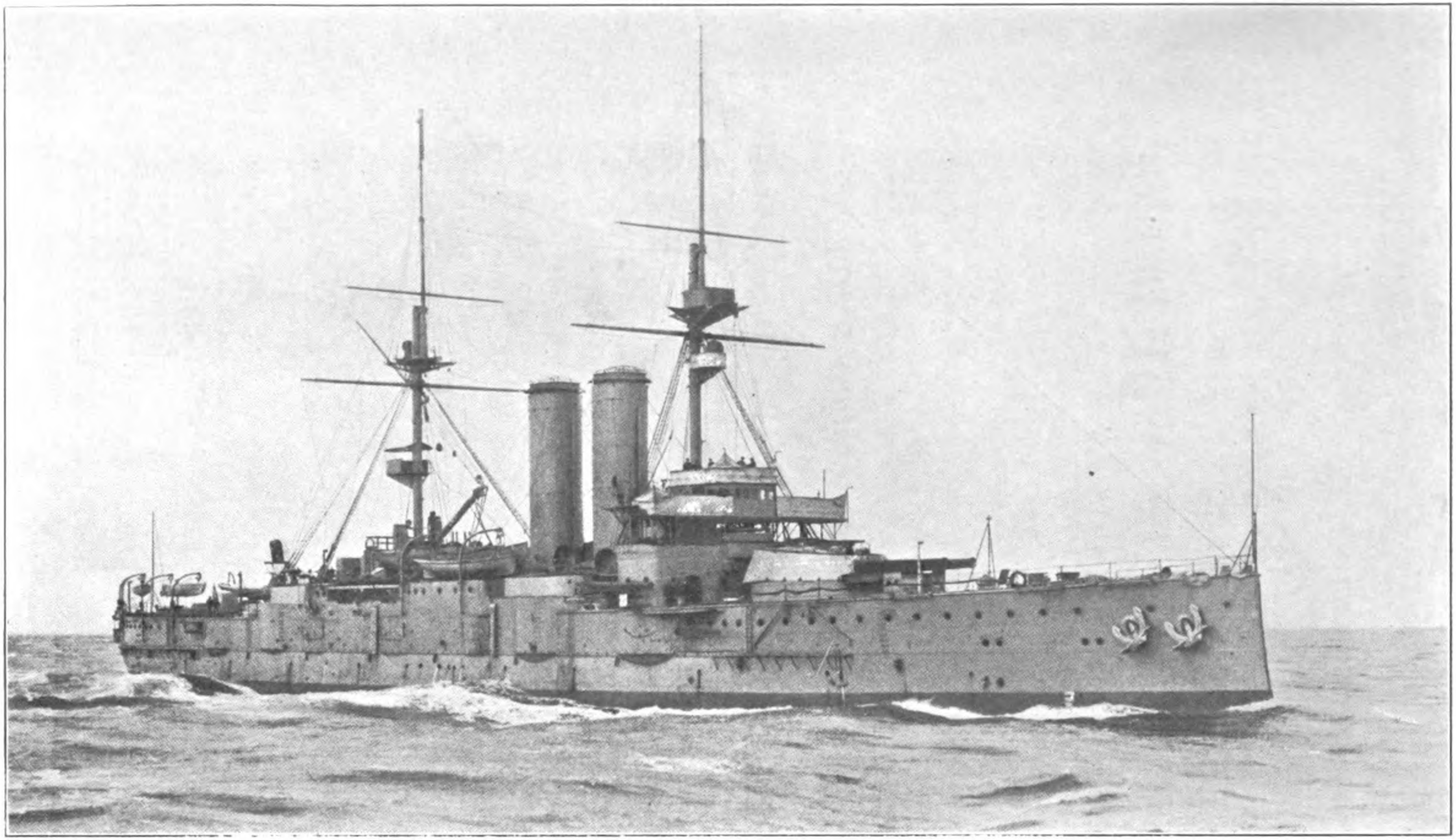

H. M. FIRST-CLASS BATTLESHIP "DOMINION", 16,400 TONS; 18,000-I. H. P.; SPEED 19.5 KNOTS.

ARMOR PROTECTION:—Waterline belt 9-inch K. S. from after armored bulkhead forward to ram, tapering to 2-inch; 5 feet below load-line to 3 feet above it. Side armor, 8-in., 7-inch to upper deck. Barbettes, 12-in. K. S. Turrets, 9.2-in. guns, 7-in. Armored deck 2-in, upper deck 1-in.

ARMAMENT:—Four 12-inch guns; four 9.2-inch; ten 6-inch; fourteen 12-pdrs; fourteen 3-pdrs; two Maxims. Four submerged torpedo tubes.

— *From Engineering.*

JOURNAL

OF THE

UNITED STATES ARTILLERY

"La guerre est un metier pour les ignorans,
et une Science pour les habiles gens."

VOL. 23 No. 1 JANUARY—FEBRUARY, 1905 WHOLE No. 71

SEACOAST GUN-CARRIAGE DESIGN AND CONSTRUCTION.*

BY CAPTAIN EDWARD P. O'HERN, ORDNANCE DEPARTMENT, U. S. A.

SERVICE GUN CARRIAGES.

IT is believed that in no other form of engineering construction has greater progress been made in the United States, in the last decade, than in the design and construction of seacoast gun carriages. This progress has not only met the demands of greatly increased gun-power, but has immensely increased both the rapidity and accuracy of fire, while, at the same time, securing great certainty of successful operation under all conditions of service. While these results have, in general, been obtained only at increased cost for mounts, and, to some extent, at the sacrifice of simplicity of parts, such disadvantages are slight as compared with the large increase thereby secured in the efficiency of the mounts, and in the effectiveness of the guns mounted thereon.

Status in 1894.—Up to the beginning of 1894 no gun carriages for issue to fortifications had been completed, although nine 12-inch mortar carriages had been issued during the preceding year, and a number of others were under manufacture. An 8-inch barbette carriage had been tested with satisfactory

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* Paper read before the International Engineering Congress, St. Louis, Mo., October 3d to 8th, 1904, held under the auspices of the American Society of Civil Engineers. Published by permission of the Secretary.

results during 1893, as had also an 8-inch disappearing carriage of the Buffington-Crozier type. As a result of the above tests, the manufacture had been begun of a few 8-inch barbette, 12-inch barbette and 12-inch gun-lift carriages, and of one 10-inch disappearing carriage of the Buffington-Crozier type. There had also been tested, in 1893, a 10-inch Gordon disappearing carriage, and a 10-inch pneumatic disappearing carriage, with results not entirely satisfactory, but justifying the construction of an additional improved model of each type.

The barbette carriages under construction at that time were of the well known type in which the top carriage recoiled on rollers supported by two chassis, the recoil being checked by the pressure of the liquid in two hydraulic cylinders, forming a part of the top carriage. The gun was returned to the firing position by the action of gravity, the chassis rails being inclined downward to the front for that purpose. With this type of barbette carriage, approximately the following rates of fire were secured:

For 8-inch barbette, one round every 50 seconds.
" 10-inch " " " " 1 minute, 15 seconds.
" 12-inch " " " " 2 " 48 "

That type, with few modifications, continued to be the standard for barbette carriages until about 1898, when it was supplanted by the pedestal type, which had been found to give greatly superior results in rapidity of fire.

The type of gun-lift carriage under manufacture in 1893 was essentially the same as the barbette mount described, but was designed to be secured to a hydraulic lift sufficiently powerful to lower the gun and mount below the parapet, for loading, and to raise it again to the firing position when required. The gun-lift thus fulfilled the functions of a disappearing carriage at a time when it was deemed impracticable to build a successful disappearing carriage of any other type for guns as large as 12-inch caliber. A gun-lift battery containing two 12-inch guns was completed about 1894, at a cost of about $212,000 per gun for emplacement and machinery, not including the cost of the gun or carriage. Its operation was successful, except that the rate of fire was undesirably slow, being only about one round per gun in 6 minutes, or one round every 3 minutes from the battery of two guns.

Later improvements.—The chief aim of an ordnance engineer charged with the designing of guns and carriages has always been to secure the greatest possible rapidity and accuracy of fire, while maintaining reasonable cover for the gun, the mount and the cannoneers. This rapidity of fire has been sought with especial eagerness during the past few years, in an effort to counteract the effect of the great volume of fire that a naval source might reasonably be expected to concentrate upon any land fortification selected for attack.

The effort has resulted in a great increase in the rapidity of fire for guns of all calibers, and has involved rapid changes in types of mountings. The most important steps in this advancement have been made possible by improvements in metal products. While such improvements have, in general, been made through industrial agencies, they have been encouraged by ordnance engineers through their demands for superior products, and have been applied quickly in ordnance constructions.

Probably the greatest advance was made when the improvements in the manufacture of steel springs made possible the substitution of spring power for that of gravity for returning the gun into battery after it had recoiled at firing. This use of springs permits the construction of a mount in which the gun is carried in a cradle and recoils therein in the direction of the line of fire. This feature not only shortens the time occupied by the gun in counter-recoiling, but enables the gunner to maintain his eye constantly at the sight, it being attached to the cradle, a non-recoiling part of the mount.

A second great advance was made when improvements in the soundness of steel castings and in the cheapness and intricacy of steel forgings made possible the general substitution of steel for cast iron in gun-carriage work. This gave the strength necessary to meet the stresses due to increased initial velocities, simplified the mount by shortening to about $2\frac{1}{2}$ calibers the length of recoil for all guns, and decreased the time occupied by recoil and counter-recoil.

The effort to attain increased rapidity of fire has more recently led to the attachment of traversing mechanism and sighting arrangements to both sides of the carriage, thus permitting the employment of two gunners. With this arrangement, one gunner does the necessary traversing to maintain the sights always on the target, and corrects the setting of the sights for errors in deflection, while the other changes the setting of the gun in elevation and operates the firing pistol.

It has also led to the development and adoption of automatic breech-opening and closing mechanisms, whereby the breech block is operated by power, usually obtained from springs compressed during the recoil. Experiments are now in progress to develop a power-rammer for application to disappearing carriages for the large-caliber guns, in order to shorten the time required for ramming the projectile and powder charge. It is even proposed to build up the cartridge of powder in the form of rods, and to ram home the projectile by using the cartridge as a part of the rammer.

Another means of increasing the rapidity of fire has been the application of electric motors to 10-inch and 12-inch disappearing carriages, whereby they can be quickly trained on a target and accurately maintained thereon by the gunner, without removing his eye from the sight. The control is so perfect that the carriage can be traversed at any desired speed from very rapid movement to a movement so slow as to be hardly perceptible to the eye of an observer a few feet away.

Types of carriages.—In any consideration of seacoast guns and carriages, with regard to rapidity of fire, they naturally fall into two classes, one comprising the so-called rapid-fire guns of 6-inch caliber and less, the other, guns of 8-inch caliber and more. The line of demarcation is well marked. It is due primarily to the fact that with the former the charge and projectile may be handled by one man, while with the latter the charge usually comprises more than one section, and mechanical means are required for handling the projectile. Another marked difference is in the time and number of men required for ramming the projectiles.

Again, all gun carriages may be classified under one of the following three sub-divisions, based upon the period of visibility to the enemy:

a. The barbette carriage, in which the gun never disappears from the view of the enemy, but is loaded and aimed while in the firing position. With this type may be included turrets and armored casemates.

b. The disappearing carriage, in which, by the action of the powder gases, the gun is lowered behind a parapet at the instant of discharge, and behind which it is loaded and aimed. With this type the gun is usually permitted to project over the parapet only for the few seconds required to raise it to the firing position, plus a fraction of a second occupied in recoil, since it is usually fired the instant it reaches the firing position. With this type is usually included the gun-lift.

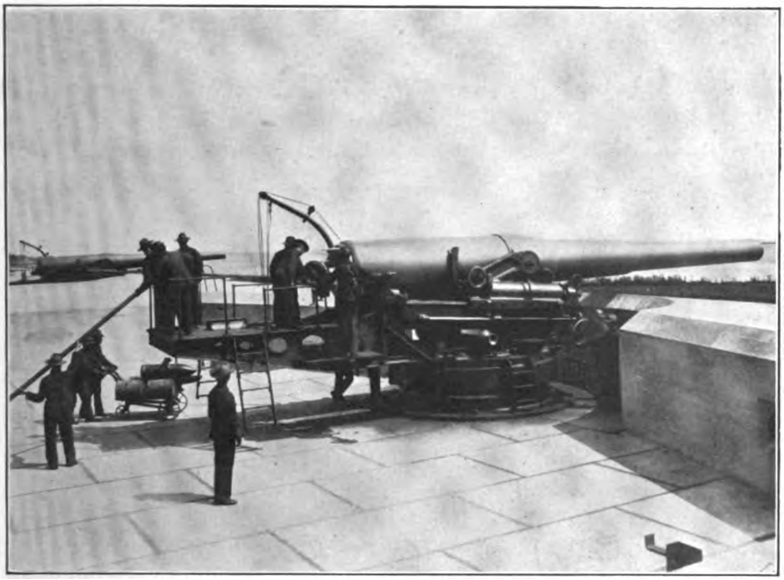


Fig. 1. Loading a Gun Mounted on a 12-inch Barbette Carriage. Showing the exposure of fire of all cannoneers except two.

Fig. 2. Loading a Gun Mounted on a 10-inch Disappearing Carriage, Model 1896.

FIG. 1. Gun Mounted on 10-inch Disappearing Carriage, Model 1896, the Instant before Firing. Gun rises to this position in about six seconds.

FIG. 2. Gun Mounted on 10-inch Disappearing Carriage, Model 1896. (Photograph taken about one second after firing, showing gun below the parapet.

c. The balanced pillar mount, in which the gun may be raised or lowered at will, with respect to the parapet, but in which the time required for such operations is so great as to be inadmissible between consecutive rounds. These mounts are intended to be kept under cover, except when engaged in actual firing and at such time to be used as barbette mounts.

As usually constructed, carriages of the barbette and balanced pillar types are provided with a heavy shield or other protective armor. Carriages of the disappearing type are usually provided with no armor protection, or, at the most, with a light splinter-proof armor for head cover. Their safety is secured by their invisibility, and by the protection of a thick parapet of sand and concrete.

The project for coast defense, as laid down by the Endicott Board in 1886, included a considerable number of armored turrets, armored casemates and gun-lifts, in addition to disappearing and non-disappearing carriages. These were prescribed at a time when no modern type of gun-carriage had been developed for land service, and were selected from a consideration of what seemed to be the tendencies in European countries at that time.

As the service type of disappearing carriage was developed and tested, it became evident that it could accomplish the work of some of the other prescribed types of mounting at a small fraction of the cost of such mountings. It was found that the following was, or would be, the approximate total cost for installing one 12-inch gun in the coast defenses, in accordance with the various methods of mounting indicated:

In armored turret	$600,000
In armored casemate	350,000
On hydraulic lift	312,000
On disappearing carriage of latest type	130,000
On barbette carriage, without shield	103,000

In view of the satisfactory action of the service disappearing carriages for all guns from 6-inch to 12-inch calibers, and their relative economy, no turrets, no armored casemates, and only one gun-lift battery have been constructed or installed in the fortifications. Actual tests have shown moreover, that a 12-inch gun on a service disappearing carriage can fire about seven times as rapidly as one in a gun-lift emplacement.

Advantages and disadvantages of disappearing carriages.— The advantages of a disappearing carriage, as opposed to a pedestal mount or other barbette form of mounting, are believed to be as follows:

a. Superior protection afforded gun, mount and cannoneers, except the one man on the sighting platform. This protection is almost complete against all fire from a ship.

b. Practically no visible target afforded the enemy, since the emplacement may be rendered unrecognizable as such, except during the few seconds at each round while the gun is in the firing position.

c. For indirect fire, the laying of the gun in azimuth and in elevation may be performed under cover, and, hence, may be expected to be accomplished with more coolness and precision than if done while exposed to the enemy's fire.

d. Greater rapidity of fire for guns of 8-inch caliber and above, due to the gun's coming down to a convenient height and angle of inclination for loading.

In considering the disadvantages of the disappearing principle, as opposed to the barbette, the difference in cost must now be eliminated, since the cost of barbette carriages, equipped with the shields now demanded, is fully equal to that of disappearing carriages.

It is believed that the only inherent disadvantage of the disappearing principle, as opposed to the barbette, is that any carriage of the former type must comprise more parts, and to that extent be more complicated, than one of the latter. While this disadvantage is recognized as serious, the advantages of the disappearing principle are so great as to demand its adoption. That such advantages have been fully utilized in the service types of disappearing carriages, and the disadvantages so minimized as to be insignificant, will be evident later from the descriptions of the construction and operation of such carriages.

Development of service disappearing carriages.—It may be assumed that the three most important qualities to be sought in a mounting for heavy guns in seacoast fortifications are: First, the greatest possible offensive efficiency for the gun; second, the greatest possible material protection for the gun, mount and cannoneers; third, the greatest economy of installation. While these conditions are, to some extent, mutually incompatible, it is believed that they are more nearly secured in the United States service disappearing carriage than in any other form of mounting yet devised.

FIG. 1. Six-inch Disappearing Carriage, Model 1898. (Photograph taken during recoil about 1.10 second after firing. The dark cloud is mainly dust from the parapet.)

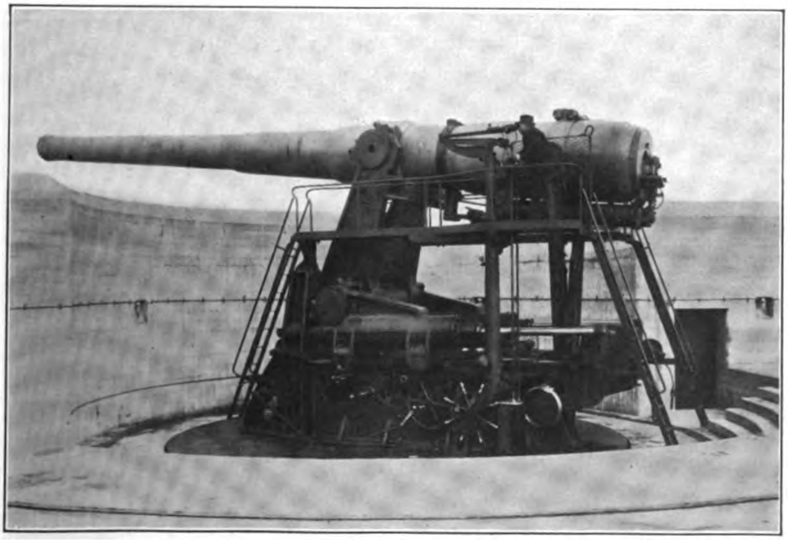


FIG. 2. General View, Left Side, 12-inch Disappearing Carriage, Model 1901. (Taken immediately before firing; gun in firing position.)

The early carriages were of the front pintle type, in which the front part of the carriage was supported by a traversing roller system, while the rear part was supported by an independent traversing arc. The traversing power was applied by means of a chain secured to the traversing arc and passing over a sprocket-wheel attached to the carriage. The recoil rollers, supporting the top carriage, did not move bodily to the rear at recoil, but were supported by axles secured to the chassis. The projectile was hoisted to the breech by a crane, instead of being rammed from a shot-truck.

The designs for the Model 1894 8 and 10-inch carriages were soon superseded by improved designs known as the Model 1896. This model included carriages for 12-inch guns, as well as for those of 8 and 10-inch caliber. The Model 1896 carriages were of the center pintle type, in which the entire weight of the system was carried on a single base-ring and single system of traversing rollers. The traversing power was applied through a pinion attached to the carriage, operating in a rack secured to the base-ring. By this means the ease and speed of traversing were greatly increased. The recoil of the top carriage, except for the 12-inch carriages, took place on a system of live rollers, whereby the friction was reduced, and the certainty of successful operation increased. The retracting gear for hauling down the gun at drill was much improved over that used on the Model 1894, as was likewise the tripping gear and the elevating gear. The height of the chassis was reduced, and the general appearance of the carriage otherwise changed, as shown by the photographs.

The 12-inch disappearing carriage, Model 1896, was followed by the Model of 1897 for that caliber. The latter corresponded in design to the 8-inch and 10-inch carriages, Model 1896, in having the live recoil rollers, the lowered chassis and other improvements.

The first model for a 6-inch disappearing carriage is known as the Model 1898. It differed from the 8-inch and 10-inch carriages, mainly in that it permitted of direct laying by the gunner. Handwheels, located on the sighting platform, enabled the gunner to elevate, depress, or traverse the piece, while the sight was connected to the elevating mechanism so as to change its elevation in exact accordance with changes in the elevation of the gun.

This 6-inch carriage has recently been superseded by the Model 1903. This last model differs from its predecessor in being provided with sighting apparatus on both sides of the carriage, in having an improved form of counter-recoil buffer, and in being equipped with springs to accelerate the starting of the gun into battery.

The double sight-laying apparatus permits the simultaneous employment of two gunners, and the improved counter-recoil buffer permits a very quick return into battery by the use of a large excess in the weight of the counterweight over that of the gun. The springs referred to also tend to shorten the time occupied in counter-recoil. To provide for the greatest probable future increase in gun power, this late model has been designed with sufficient strength to control the recoil from a gun giving an initial velocity of 3600 feet per second.

In recent tests of the first of the 6-inch disappearing carriages, Model 1903, the gun rose into battery in from 2 to 3 seconds. In view of these results, it is expected that this carriage, while giving concealment and protection far superior to that afforded by the pedestal type, will be inferior in its rate of fire by no more than about 2 seconds per round. It is thought that, when firings are being made at angles of elevation greater than about 8°, even this difference will largely disappear, or, perhaps, result in an advantage in favor of the disappearing carriage. It is believed that this change will be due to the difficulty in loading, at high angles of elevation, the gun on the pedestal mount, while the gun on the disappearing carriage will always return to practically the same loading angle, about 4°, no matter at what angle of elevation it may have been fired.

Latest type for 12-inch gun.—The latest models of disappearing carriages for guns of 10-inch and 12-inch calibers are known as the Model of 1901.

As these represent the highest type of gun-carriage development in the United States, and fairly summarize the progress made during the past decade, a more extended description of a 12-inch disappearing carriage of that carriage will be given.

The following are some of its noteworthy features: Electric motors for elevating, depressing, traversing and retracting, with excellent system for control of speed; hand operation for all the above functions, when desired, without interference from the electric equipment; telescopic sight, with 3-inch object glass; sight-laying apparatus, permitting direct aiming by the man on the sighting platform, with all operations under his immediate control, both for laying and for firing the piece; a sighting platform along each side of the carriage, accessible by

Plate IV

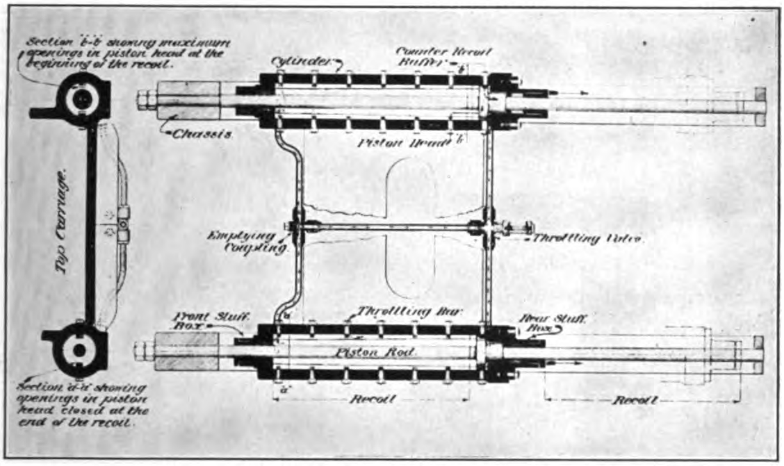


FIG. 1. Hydraulic System for Control of Recoil and Counter-Recoil for all Service Types of Disappearing Carriages.

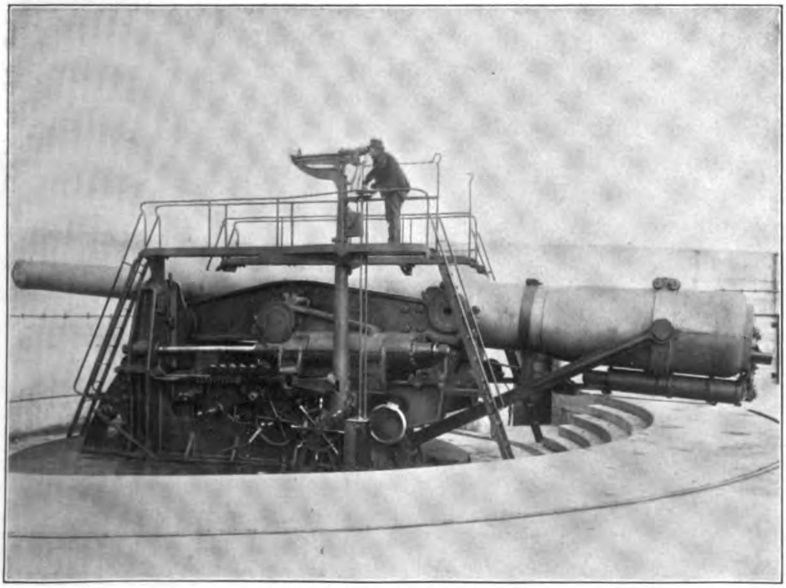
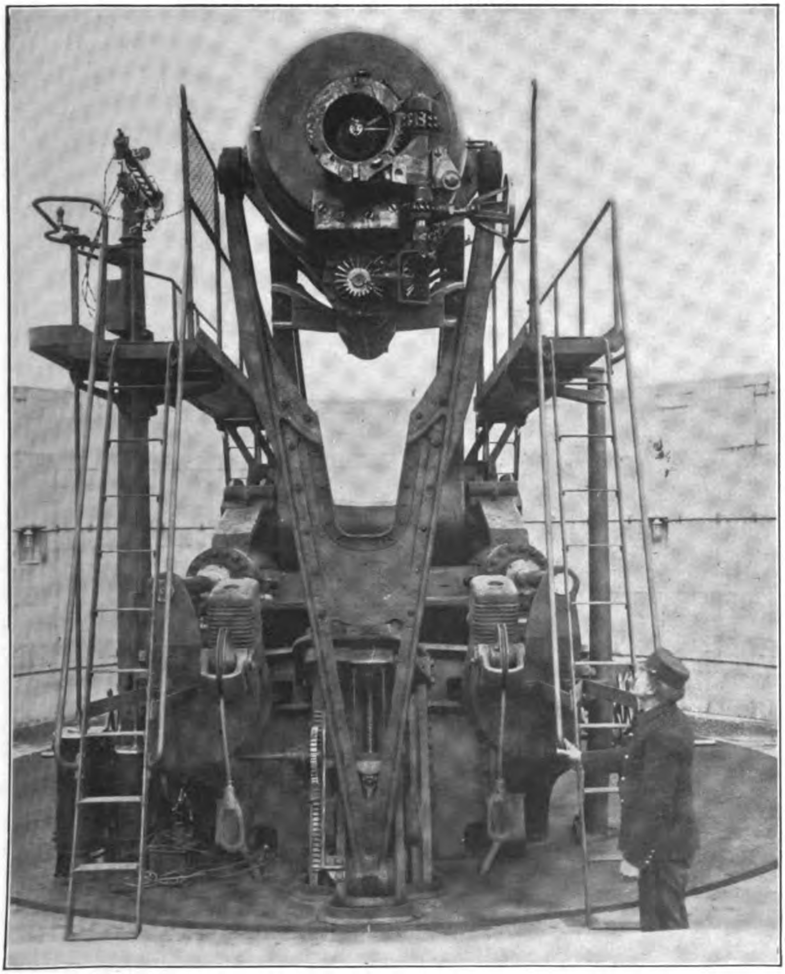


FIG. 2. General View, Left Side, 12-inch Disappearing Carriage, Model 1901. (Taken about one second after firing; gun in loading position.)

Plate V



Rear View of 12-inch Disappearing Carriage, Model 1901.
Gun in firing position.

ladders both from the front and from the rear; arrangements for electric firing by the man on the sighting platform; safety-firing devices to prevent all possibility of firing either electrically or by lanyard while the gun is out of battery; compression grease-cups on all important bearings; extra long counter-recoil buffers which permit the use of sufficient counterweight to bring the gun into battery in from 4.8 to 6 seconds; great strength and stiffness in all parts.

The carriage comprises the following principal parts: Base-ring, traversing system, racer, chassis, top carriage, recoil and counter-recoil systems, gun levers, cross-head, counterweight, elevating system, traversing system, retracting system, sight-laying mechanism, safety-firing attachments, electrical equipment for power operation, ammunition trucks.

The base-ring is bolted to the emplacement, and supports the remainder of the carriage. It is noteworthy on account of its great stiffness, and for the fact that it is constructed so that the traversing rollers may be run partly immersed in oil, if so desired.

The traversing system is designed to secure the movement of the gun in azimuth, with the least possible friction from the great weight of gun and carriage. The system comprises 24 conical rollers of forged steel, held in alignment by cast-steel distance rings. The system works so admirably that, in most cases, two men can readily traverse, by hand, a 12-inch disappearing carriage, where the weight traversed amounts to about 494,000 pounds, an amount greater than the combined weight of two modern passenger locomotives of the heaviest type.

The racer rests on the traversing rollers and supports the chassis. The pintle surface between the racer and the base-ring is lined with bronze, and is well lubricated, in order to minimize the effect of any possible rubbing.

The two parts of the chassis are secured to the racer and support the recoil rollers, which carry the weight of the top carriage, gun and counterweight. The path, machined on its upper surface for the recoil rollers, is inclined downward to the front 1° 20′, to facilitate the return of the gun to the firing position.

The top carriage rests upon the recoil rollers and supports the gun lever arms. It contains two hydraulic cylinders, in which operate pistons secured to the chassis. The greater part of the energy imparted to the gun at firing is absorbed in forcing the liquid in these cylinders to pass from one side of the pistons to the other during the second occupied by the top carriage in recoil.

A sketch, showing the principles of operation of the hydraulic system for controlling the recoil and counter-recoil is given in Fig. 1, Plate IV. A pipe joins the front ends of the two cylinders, in order to equalize the pressure in the two parts of the system, and prevent any tendency for one side to recoil faster than the other. Additional piping, containing an adjustable valve, provides a channel for the passage of oil around the piston heads, in addition to the channels provided inside the cylinders. By means of this adjustable throttling valve, the length of recoil can be increased or shortened at will, between successive rounds, within reasonable limits.

Upon counter-recoil, the movement of the top carriage, over the last few inches, is checked by the pressure generated in the counter-recoil buffer, at the rear end of each cylinder. This pressure is caused by forcing the oil caught in the cup-shaped part of the buffer to escape through a very small opening.

The gun levers carry the gun at their upper ends, and the counterweight at their lower ends, and by their rotation serve to lower the one and raise the other. Each of the six large bearings relating to these parts is provided with a compression grease-cup, which maintains a lubricant under pressure in H-shaped grooves at the under part of the bearing. The lubricating material used in these bearings is a petroleum product known as No. 4½ lubricant, which has been found excellent for the purpose.

The cross-head serves to unite the gun levers to the counterweight, and, by engaging with guides on the chassis, constrains the lower end of the gun levers to move only in a vertical direction. The counterweight is made up of lead discs, strung on four suspension rods secured to the cross-head. The total weight thus suspended from the lower end of the gun levers is about 183,000 pounds. This is approximately 67,000 pounds more than the weight of the gun, which great excess serves to quicken the return of the gun to the firing position.

The elevating arms unite the breech of the gun to an elevating slide, capable of being moved up or down, in order to change the elevation of the gun. A graduated disc, geared to the slide, serves to indicate the exact elevation at any time. A counterweight, attached to the elevating slide, maintains the system in balance for elevating or depressing, whether the gun be in the firing position or in the loading position.

The traversing is accomplished by a train of gearing which actuates a pinion engaging a rack secured to the base-ring. To prevent excessive shocks to the traversing system, one of the gears is secured to its shaft by an adjustable friction device, which permits a slip to take place when too large a strain would otherwise be brought upon the traversing system.

Two wire ropes, arranged to be wound upon drums, are provided for retracting the gun to the loading position, when desired at drill. The drums are actuated by a system of gears, carried upon two parallel shafts supported by the chassis. The various bearings of this system are equipped with roller bearings, in order to reduce as much as possible the work absorbed by friction. An actual test of a 12-inch disappearing carriage, Model 1897, showed that 50.77% of the work of retracting was saved by substituting roller bearings for plain ones, bronze bushed.

The telescopic sight is connected by gearing to the elevating mechanism in such a way that it changes its elevation in exact accordance with changes in the elevation of the gun. It is secured to the carriage in such a way that the vertical plane containing the axis of the sight remains always parallel to the one containing the axis of the gun. The sight is provided with a shank, graduated in degrees, and a range drum, graduated in yards. In direct laying, the gun is given any desired elevation in degrees and minutes, or the elevation required to secure any assumed range, merely by setting the sight shank or the range drum at the desired value, then bringing the cross-hairs of the telescope on the target. This can be accomplished by the electrical traversing and elevating mechanisms, operated by the controller handles, conveniently located near the sight.

The firing arrangements permit of firing the gun either electrically or by friction, as may be desired, the same primer being capable of being fired either way.

In order to avoid all possibility of firing electrically when the gun is out of battery, a switch is provided which maintains a double break in the firing circuit, except when the gun has risen to a safe firing position. This break is secured by the separation of two parts of the switch at recoil, one part being secured to the chassis and the other being secured to the top carriage.

The lanyard safety device is a fixture secured to the gun. It is designed so as to make impossible the firing of the primer by the lanyard, until the approach of the gun to its firing position has released the securing mechanism.

For electrical operation, the carriage is equipped with two motors, each of 4 h.p. capacity. One serves for traversing, the other serves both for elevating and for retracting, since the two latter operations are not required simultaneously. All the operations may be controlled either from the sighting platform or from the general working platform of the carriage.

The speed control of the traversing motor is obtained by varying the voltage impressed upon its armature, while its fields remain constant by independent excitation. This is accomplished by the use of a motor-generator set, the generator of which supplies the current for the armature. The voltage delivered by the generator is regulated by the operator through a controller, which varies the resistance in its field circuit. By this system a minimum of power is wasted in the resistances, while the speed of the traversing motor is made independent of the torque, but dependent only upon the voltage supplied to its armature, as determined by any particular setting of the controller handle. As there are sixty sections of resistance in the controller, that number of possible traversing speeds may be secured. The time required for traversing 360° is about 1 minute and 14 seconds at the fastest speed, and about 50 minutes at the slowest.

The speed control for the elevating and the retracting motor is secured by varying a resistance in series with its armature circuit. When the controller handle is moved to the "off" position, the armature becomes short-circuited on itself, while the field remains in full force. This causes the motor to become a short-circuited generator, whereby it automatically brings the system to a very sudden stop. This enables an operator to make quick, accurate setting in elevation. The control is so excellent that the elevation of the gun can be readily changed by as small an amount as $\frac{1}{8}$ of a minute.

The ammunition is brought to the gun on trucks, which receive it from electric hoists at the side of the emplacement. Each truck carries one projectile and one powder charge. Three trucks are furnished with each carriage.

Electric lights are provided for illuminating the cross-hairs of the telescopic sight and for illuminating all scales and pointers, so that the carriage may be operated by night almost as well as by day.

The cost of one of these carriages is about $40,000, which is almost the exact cost of the gun to be mounted thereon, and about 25% less than the cost of the emplacement.

A 12-inch rifle, Model 1900, mounted on one of these disappearing carriages, has fired a 1000-pound projectile with an initial velocity of 2602 feet per second, giving a muzzle energy of 52,560 ft-tons. A capped armor-piercing projectile, fired with this velocity, is capable of penetrating the heaviest and best armor afloat at practically all fighting ranges. One of these projectiles can be fired about every 52 seconds with an accuracy believed to be capable of hitting a battleship every two rounds out of three, at fighting ranges up to 5 miles. The maximum range for a gun mounted on one of these carriages is slightly less than 8 miles. Even near that range, a fair degree of accuracy can be secured.

SERVICE MORTAR CARRIAGES.

Carriages of a very satisfactory type, known as the Model 1896, for mounting 12-inch mortars, have been manufactured in considerable numbers, and installed in the seacoast defenses. They are simple and inexpensive in construction, and quick and reliable in operation. The mortar is checked in recoil by pistons operating in two hydraulic cylinders, and is returned to the firing position by springs which bear against the top carriage between its pivot and the points of support for the gun. Traversing and elevating mechanisms are provided by means of which the mortar may be set quickly at any desired azimuth or elevation.

Four mortars in a group, mounted upon these carriages, have been loaded, aimed and fired once about every $1\frac{1}{3}$ minutes, and have secured gratifying accuracy. They attack the deck of a ship, its most vulnerable part, while they themselves are usually mounted in deep pits, where practically no fire from a ship can reach them.

SIGHTS.

The question of proper sights for seacoast guns and carriages has always been a very important one. The tendency for some years has been to rely more and more upon the telescopic sight, and to increase largely its efficiency, without regard to expense of construction. At present all the latest types of carriages are being equipped with two of these sights. The telescopes have a 3-inch triple objective, a 15-inch focal length, and Porro erecting prisms. Each telescope is provided with two eyepieces, with a power of 20 and 12, respectively, giving the telescope a field of 3 or 4°, depending upon which eyepiece is used. The eyepiece with the power of 12 serves to make the telescope particularly valuable in hazy weather, or when the light is poor from any other cause.

They are mounted on a bar sight, which furnishes both an open sight and a peep sight, in addition to the telescopic sight.

SHIELDS.

The proper size and thickness of shields for pedestal and other forms of barbette mounts has been the subject of no little discussion.

The advantage of a shield is the protection it affords the gun, mount and cannoneers. The value of this protection is determined by the ability of the shield to keep out the projectiles fired against it, and by the extent of the cover it affords, as regulated by its size. A shield is undoubtedly of most benefit as a protection against small arms and machine guns at short ranges.

Its disadvantages are as follows:

a. Likelihood of exploding a large projectile without stopping it, thus destroying mount and detachment, whereas the projectile might have harmlessly passed by, except for the larger target afforded by the shield.

b. Ease and speed of traversing injuriously affected by weight of shield and necessary additional weight of mount to give strength to support same. It has been found necessary to secure the shield to the mount by spring supports, but the shock to the mount is still very great when the shield is struck by a projectile as large as a 6-inch.

c. Great cost for shields of any considerable thickness. Five 4.5-inch Harveyized shields, purchased about one year ago for 6-inch pedestal mounts, cost about 80% as much as the combined cost of the guns and mounts proper. It has been reported that an order has been placed recently for similar shields at little more than one-half the former price. These new shields will cost about 45% of that of the gun and mount proper. While some consider that the protection afforded by a shield is insufficient to justify its cost, and that the money might better be expended in installing additional guns and mounts, yet the consensus of opinion among artillerymen at present demands shields, and they will undoubtedly continue to be supplied.

The shields now prescribed for the service pedestal and barbette carriages are 1½-inch thick for 6-pounders, 2-inch thick for 15-pounders, and 4½-inch thick for all barbette carriages mounting guns of 5-inch and larger calibers. They are to be made of the best quality of Harveyized or Kruppized armor.

Figure 1, Plate VI., shows one of the 4.5-inch shields referred to mounted on a 6-inch pedestal mount after attack by 5 and 6-inch armor-piercing shot, with striking velocities corresponding to a battle range of about 3000 yards. The shield proved capable of keeping out 5-inch, but could not keep out 6-inch projectiles. The mount was not seriously damaged by the firings, but could be operated after the impact of one 3.2-inch, five 5-inch, and three 6-inch projectiles. Under the conditions of this test, the shield undoubtedly gave good protection to the gun, mount and dummy figures representing cannoneers. Several of the projectiles would probably have disabled the gun or mount had it not been for the presence of the shield.

The photograph was taken with the gun pointing 60° from the line of observation, so that it does not indicate the full amount of protection that is usually afforded the cannoneers by the shield.

The 6-inch Armstrong gun shown by Fig. 2, Plate VI., is one of those in the Taku Forts, China, and was provided with a shield 4.5-inch thick at the front, but tapering to about 2 inches thickness at the rear. Thirty-five dead Chinamen were found about this gun.

DESIGNING OF GUN CARRIAGES.

While almost every other field of mechanical engineering has been covered by books which are accessible to a designer, there is practically no such literature covering the methods of computing the firing stresses on a gun-carriage. Whatever information and experience has existed on that subject has been confined to a limited number of persons and has been handed down by them to their assistants without publication.

A brief outline will be given of the steps involved in computing the stresses on the parts, and in computing the throttling orifices for a disappearing carriage of the service type.

The actual computations are long and intricate, and occupy the services of an expert for many months. They involve the establishment and solution of twenty-five equations of condition containing the same number of unknown quantities, and twenty-seven auxiliary equations based upon geometrical relations between the parts of the system.

The known data usually comprise the weight of the gun, its length of bore, the weight of the projectile, the weight of the powder charge and the initial velocity. The required length for the gun lever arms, and thus the length of recoil for the top carriage, are determined from a consideration of the amount by which the gun must be lowered from the firing to the loading position in order to secure an assumed degree of cover.

The amount of counterweight is determined from a consideration of the forces acting to return the gun into the firing position, and of the work to be done, including that caused by the various frictional resistances. The time to be occupied in counter-recoiling is assumed in this connection.

Having secured these data, the procedure is as follows:

a. Plot the curve showing the velocity of a projectile along the bore as a function of the distance travelled as determined by Ingalls' or other satisfactory formulas.

b. Compute the reciprocals of the above velocities of free recoil, and plot them as a function of space.

c. Measure the areas under the resulting curve from the origin to various ordinates, and plot the velocity, as represented by such ordinates, as a function of the time of travel, as determined by the measured areas. The resulting curve shows the velocity of free recoil as a function of time, since the measured areas represent the time occupied in recoiling to the corresponding points, as is evident from the following equation:

$$\int \frac{1}{v} d\,u = \int \frac{d\,t}{d\,u} d\,u = \int d\,t = t.$$

The total time during which the powder gases act upon the gun is usually designated by τ, and the total theoretical distance moved by the gun in free recoil during that time by ξ. The latter symbol is also used herein to designate movements less than the total.

d. Make such change in the scale of its ordinates that they will represent the velocities of free recoil of the gun. The change of scale is made in accordance with the formula:

$$\frac{v_g}{v} = \frac{W + \frac{c}{2}}{W_g}$$

in which

v_g = velocity of free recoil of the gun during the time the projectile is in the bore;

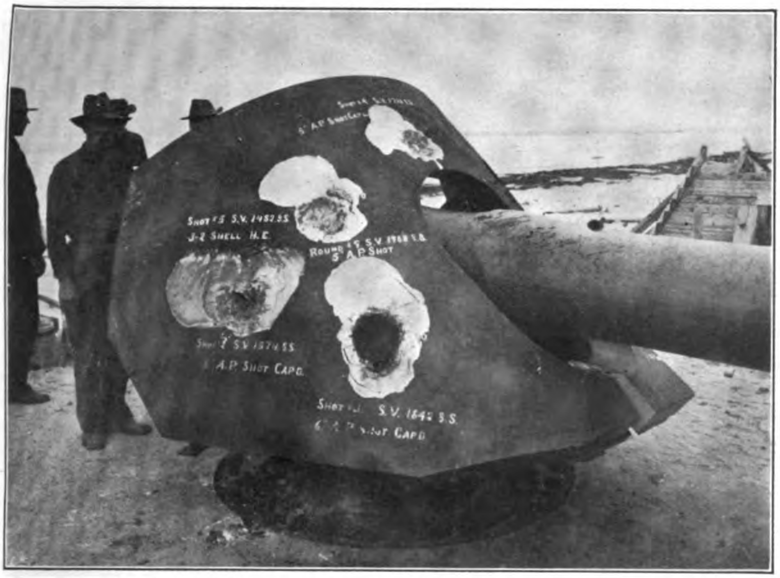


FIG. 1. Harveyized Shield, 4.5 Inches Thick, on 6-inch Pedestal Mount, After Attack by 5-inch and 6-inch Armor-piercing Shot.

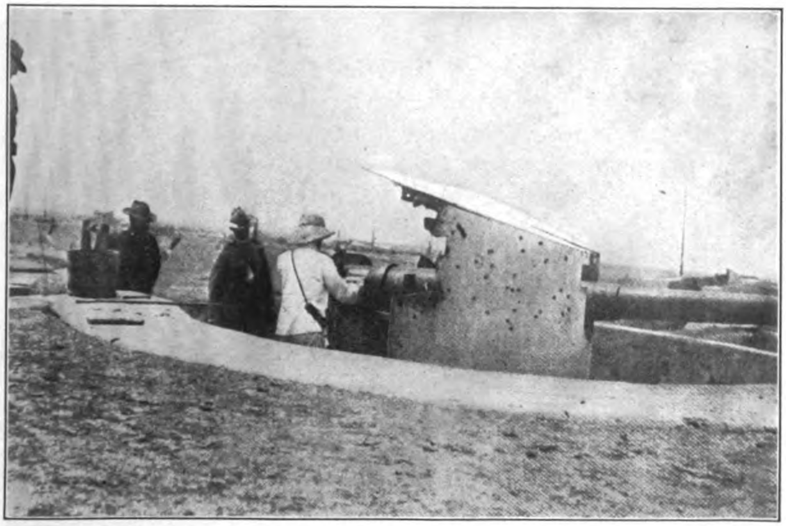


FIG. 2. Six-inch Armstrong Gun and Pedestal Mount in Taku Forts, China, After Attack by Gunboats.

v = corresponding velocity of the projectile, as already computed;
W = weight of the projectile;
w_g = " " " gun;
c = " " " powder charge.

e. Determine the maximum velocity of free recoil of the gun by the equation:

$$V_g = \frac{W V + 4\,700 \times c}{w_g}.$$

The value of the above coefficient of c has been determined experimentally to be the proper one for a smokeless powder charge.

f. Determine the effect of the powder gases upon the gun after the projectile has left the bore, by continuing the curve of velocity of free recoil until it becomes tangent to a line representing the above maximum velocity. The completed curve gives the theoretical velocity of free recoil of the gun as a function of time from the beginning of recoil up to the point where the gases cease to act.

We now form equations of equilibrium for the forces acting upon the gun, the gun levers, the top carriage and the elevating arms, each part being considered separately as a free mass acted upon by forces.

The forces acting upon the gun are its weight; the powder pressure (during the period while t is less than τ); the force applied by the gun levers, including friction; that applied by the elevating arms, including friction; the product of the mass of the gun times its acceleration of translation; and the product of the mass of the gun, the square of its radius of gyration, times its angular acceleration of rotation about the axis of its trunnions. Three equations are formed expressing the equilibrium of these forces with respect to each of two rectangular axes and with respect to rotation about the center of mass. (Equations *A*.)

In order to eliminate the powder-pressure factor and introduce that of velocity of free recoil, each equation is multiplied by $d\,t$ and integrated. The resulting equations express the equilibrium of the momentums of the system. (Equations *B*.)

These are again multiplied by $d\,t$ and integrated, whereby three additional equations are secured, one of which contains the factor, τ, (Equations *C*.) Equations *B* and *C* constitute six of the required equations of condition.

By an entirely similar method of procedure, including the two integrations in each case, six equations of condition are formed for the gun levers, six for the top carriage, and six for the elevating arms. In each case the applied forces include some of those previously considered, together with others not thus considered.

An equation is next formed expressing the fact that the work done by the system after the powder gases have ceased to act is equal to the kinetic energy of the system at the time when $t = \tau$. (Equation *D*.)

Twenty-seven auxiliary equations are formed from geometrical relations between the various angular movements of the parts of the system.

Equations *B* are combined among themselves, and a value obtained for $\frac{d\psi}{dt}$, the angular velocity of rotation of the gun levers about the pivot at their lower ends, in terms of ψ, the angle made by their longitudinal axes with the vertical; of R, the resistance developed in the hydraulic cylinders of the top carriage; of v_g, the velocity of free recoil of the gun, and of τ, the time from the origin. This value for $\frac{d\psi}{dt}$ is true only for values of t less than τ. (Equation *E*.)

The above value for $\frac{d\psi}{dt}$ is equated with that obtained from the work equation, which latter is true only from the time $t = \tau$, thereby securing an equation containing R, v_g, t, and ψ, true only for the instant $t = \tau$. (Equation *F*.)

The remaining twelve equations of condition are combined until one is obtained containing R, ξ, t, and ψ. This equation is true for all values of t up to and including $t = \tau$. (Equation *G*.)

Since Equations *F* and *G* are too complex to combine and eliminate ψ and thus to solve directly for R, various values of ψ are substituted in them, together with the corresponding values for v_g, t, and ξ. The values for R, resulting from each equation, are then plotted as a function of ψ. The point where the two curves intersect indicates the value of ψ for the instant when $t = \tau$, while the corresponding value for R is the required cylinder resistance.

The value of $\frac{d\psi}{dt}$ and thence the actual velocity of the top carriage at later points in the recoil, are determined by substituting in the work equation the value of R already determined and various assumed values of ψ.

To determine the velocity of the top carriage for points, while t is less than τ, a value of t less than τ is assumed, and the corresponding values for ξ and v_g obtained from the curves constructed previously.

Various assumed values for ψ are then substituted in Equation G, together with the known value of R and ξ. Disregarding its assumed value, the equation is solved for t and the results plotted as a function of ψ.

The value for ψ, corresponding to the assumed time, is indicated by that point on the curve where the plotted value for t corresponds to the assumed value. This value for ψ is then substituted in Equations E, together with the corresponding values for R, v_g and t, and the value for $\frac{d\psi}{dt}$ thus determined. From this angular velocity, a point on the curve of linear velocity of recoil is readily obtained.

The magnitude of the other forces acting on the system may now be determined by substituting in the various equations of condition the values of the quantities already determined, and solving for the others. The forces having been completely determined, both in direction and amount, the various parts of the gun carriage system are proportioned so as to have, in general, a factor of safety of two on the elastic limit. Piston rods and a few other parts are usually given a somewhat greater factor of safety.

The pressure in the recoil cylinders, and a curve showing the velocity of recoil of the top carriage, having been determined, the next step is to compute the throttling-bar openings so as to secure the desired constant pressure throughout the recoil.

Neglecting the contraction of the liquid vein and the friction of the liquid against the sides of the orifice, the required area of orifice for any point of recoil is represented by the equation:

$$a = V\sqrt{\frac{\delta A^3}{288 \times g \times R}} \quad \text{.................. (Equation } H.)$$

in which

a = area of orifice, in square inches;
A = effective area of piston, in square inches;
V = velocity of recoil of top carriage, in feet per second;
δ = weight, in pounds, of 1 cubic foot of liquid used in the cylinders;

g = 32.2 ft. per second;
R = resistance, in pounds, developed in the cylinders.

Equation H is deduced from the following equations, in which v = the actual velocity of flow of the liquid through the orifice:

$$v\,a = V\,A \quad \text{..........(Equation } I.\text{)}$$

$$v = \sqrt{2\,g\,h} = \sqrt{\frac{2\,g\,p}{\delta}} = \sqrt{\frac{2 \times 144 \times g \times R}{\delta\,A}} \quad \text{..........(Equation } J.\text{)}$$

Equation I expresses the fact that the volume of liquid passing through the orifice at any time is equal to the volume being displaced by the piston. Equation J is obtained from Torricelli's formula for the flow of liquid through an orifice.

Until recently, all hydraulic brakes in service were designed in accordance with the foregoing formulas, since there were no data available to show the effect of the contraction of the liquid vein under the conditions of small openings and high pressures existing in recoil cylinders. Recent actual measurements of the velocities of recoil and of the pressures in such cylinders have shown that, while the actual maximum velocities of recoil varied but little from the computed ones, the maximum pressures were nearly double the mean values. From a consideration of the actual velocities and pressures, it has been determined that a value larger than its actual value must be substituted for v in Equation J, in order that it may express the true relation between areas, velocities and resistances. This theoretical value designated v_o, is a function of the actual value.

For the 12-inch disappearing carriage. Model 1901, this function has been determined to be:

$$v_o = 1.3\,v + 122 \quad \text{..........(Equation } L.\text{)}$$

Equation J becomes, in this case:

$$v_o = \sqrt{\frac{2 \times 144 \times g \times R}{\delta \times A}} \quad \text{..........(Equation } M.\text{)}$$

Equation I remains, as before:

$$v\,a = V\,A.$$

By combining the last three equations, the following has been determined to be the expression for the areas of orifice for that carriage, in square inches:

$$a = \frac{1.3 \times V\,A}{\sqrt{\frac{2 \times 144 \times g \times R}{\delta\,A}} - 122} \quad \text{..........(Equation } N.\text{)}$$

With throttling orifices computed in accordance with this formula a practically constant cylinder pressure has been obtained.

The value of v_o for the 12-inch barbette carriage has been determined to be

$$v_o = 1.63v + 67.$$

Experiments have shown that the value of v_o in terms of v is determined chiefly by the area and length of orifice and the velocity of the liquid, but that it is affected materially by rounding the outer edges of the orifice and by other changes which tend to vary the contraction of the liquid vein.

AIMING BY TELESCOPIC SIGHT

COMPARED WITH AIMING BY OPEN SIGHTS

A Physico-physiological Study by Dr. S. Czapski, Jena, Germany

Translated by Captain A. E. PIORKOWSKI, I. G. A.

THE advantages gained by the use of telescopes in aiming and laying guns have recently and repeatedly been the object of discussion, even before the general public.

P. R. Alger, Professor of Mathematics, United States Navy, strongly urges their application to Naval Ordnance, in in a lecture[*] before the U. S. Naval College, Newport, R. I., which contains a wealth of interesting remarks. In accordance with this the American *Handbook of Telescopic Sights* (Washington, 1899) expresses itself decidedly in favor of advantages reached by the adoption of telescopes and so does the English *Handbook for Telescopic Sights, Land Service* (London, 1901). More recently E. von Kodar, 2d Class Naval Engineer, Austrian Navy, gave a lecture[†] on this subject in the *Marine-wissenschaftlichen Verein* at Pola, in which the characteristic peculiarities of construction and efficacy of telescopic sights are clearly and accurately shown, with the exception of some inaccuracies which shall be mentioned later. This work also is highly in favor of the telescope. Anton Korzen, engineer of artillery, Austrian Army, and instructor in the War College, in his valuable memoir on *Die Richtmittel der Geschütze*,[‡] pronounces his opinion in a similar way in the chapter on telescopic sights.

After reading Korzen, however, it might be believed that the specific advantage in using telescopic sights was the magnifying effect, as if the aiming by telescope could only be improved in proportion to its magnifying power. This is a very general mistake—may it be stated right here—the correction of which is the chief object of the following pages. The SPECIFIC

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[*] Published in the *Proceedings of U. S. Naval Institute*, 1897, XXIII, pages 125 to 140.

[†] Published in *Mitteilungen aus dem Gebiete des Seewesens*, Vol. XXXI, No. IX, August 15, 1903, pages 713 to 734.

[‡] *Mitteilungen uber Gegenstande des Artillerie-und Geniewesens*, Nos. 5, 6 and 11, 1903.

advantage in using telescopic sights is quite a different one, and is gained even if there is no magnification at all. It is, indeed, a matter of free choice, viz., to be decided on the ground of special argument, if a telescope for sighting shall have magnifying effect, and how much of it. With geodetic work, for example, non-magnifying telescopes are much in use and are very satisfactory.

In Alger's and von Kodar's publications this specific argument is also more or less clearly given (indirectly also in the handbooks mentioned). Thus Alger says (page 125):

"It has long been recognized by those who have investigated the subject that it is physically impossible for the human eye to judge when three points at widely different distances are in one straight line" and von Kodar (page 715) states even more pointedly: "There is no doubt, that this method of aiming (i. e., with open sights) would be very perfect, if the qualities of our eye would not make it impossible to align simultaneously three points situated at different distances. Everybody knows that in looking at a distant object our eye automatically accommodates itself to the long distance, and then objects nearer us are only dimly visible, and vice versa. *Therefore it is quite out of question for the eye to perceive simultaneously and distinctly the rear sight, quite near the eye, the front sight, a small distance off, and the far away target.*"

This is the one argument clearly put against aiming with open sights, and further on it is also explained how by using telescopes (or the Grubb sight) the said errors are avoided.

But von Kodar does not enter into discussing the *amount of error* to be expected in aiming with open sights. He is satisfied by characterizing the *quality* without determining the *quantity* of the error. In all the publications on the subject, known to the author, the only computation of an error in aiming is that of the difference in elevation by aiming with "fine sight" or "full sight," or "half sight," in the monograph by Colonel von Kretschmar on his level sight, July, 1890. A very abridged extract of this came out first in General R. Wille's book "Das Feldgeschütz der Zukunft," Berlin, 1891, pages 253 to 256, and was later, repeated in part, unfortunately not textually, in the same author's book "Fried. Krupp's Schnellfeuerkanone C/99," Berlin 1900, pages 68 to 71. (From there it was taken into the discussion of Korzon's article, by Captain Wangemann, quite recently in *Kriegstechnische Zeitschrift*, VIIth year, 1904, pages 158 to 160).

In von Kretschmar's monograph, the original text of which he kindly lent the author, there are remarks which though short seem to strike the true core of the matter. These remarks, according to von Kretschmar, are founded on "observations made in actual shooting of four batteries in two years' courses and verified by the target reports." Von Kretschmar says (page 1 of his monograph): "Uniform and satisfactory aiming can only be obtained when the apparatus for aiming attached to the gun furnishes the requirements and will not itself cause inaccurate and uneven aiming. The latter will and must be the case with all sighting apparatus that allows to the individuality and unreliability of the gunner a certain influence on the accuracy of every single aiming." Probably the authors of the American and the English Handbook had something similar in mind, when they described "the *diminution or elimination* of the personal error" as one of the advantages of telescopic sights.

Looking at these conditions somewhat closer shows that the problem consists in the discussion of and answer to two questions of widely different character but of equal importance in practice, viz.:

1st. What *uncertainty* (inaccuracy) results with open sights from the fact that the human eye is unable to perceive at the same moment distinctly the sights and the target? And

2d. Are there factors in the human eye which, in aiming with open sights, i. e., looking simultaneously at objects at different distances, will produce a *regular one-sided error* as to *direction of vision*?

The difference in meaning of these questions is evident, considering that *uncertainty* may to a certain degree diminish through practice; but one-sided error in the eye will, through such practice, be recognized only more clearly, as is well known from the practice of astronomical and other art of measuring.

In the present case—not by far in all cases—it is very fortunate that the same means which relieves the *uncertainty* also eliminates the *personal one-sided error*.

I. UNCERTAINTY IN AIMING AS A CONSEQUENCE OF THE DIFFERENCE IN DISTANCE OF REAR SIGHT, FRONT SIGHT AND TARGET FROM THE EYE.

It is easy to calculate the amount of this uncertainty.

A is a section through the middle *P* of the pupil *P' P''* of the human eye focussed and aiming at the target *Z.* Distinct images on the retina will then appear only of objects near the target, i. e., relatively very distant objects. Points at closer range, for example the top of the front sight will give indistinct images. Instead of calculating how these are shaped on the retina it is simpler and more practical to find out how such indistinct images *appear to the observer*. Of course he perceives them as *projected on* the the plane on which his eye is focussed, and every point of the objects in the "extrafocal" plane as a "dispersion circle," a dim small disc whose centre is in the connecting line of the object point and the middle of the pupil, or its prolongation, and whose circumference is determined by the *geometrical projection of the pupil on the focussed plane, the object point as centre of projection*. So, if the top of the front sight *K* be connected with the rim of the pupil by lines *KP′* and *KP″* and these lines be prolonged beyond *K* to the distant plane of the target, their dispersion there will show the size of the little disc representing the top end of *K* as it appears in an eye focussed on the target.

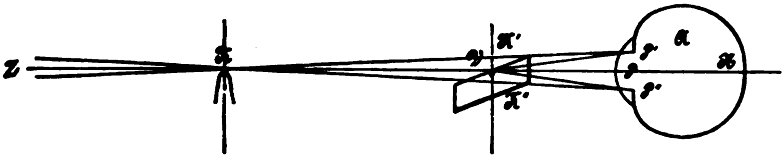

Fig. 1

This determination holds good in every case. It gives in exactly the same manner the dispersion circle (disc) for every point of the rear sight as it appears in the plane of the target; also the dispersion images of the target and rear sight in an eye focussed on the front sight, and those of the target and front sight in an eye focussed on the rear sight. In the following the three cases in which the eye is focussed on the target, front sight or rear sight, will be called (a), (b), (c), respectively.

For instance, the same drawing which in case (a) gives the dispersion figure of *K* in the plane of the target, serves in case (a) to give the dispersion figure of *K* in the plane of the rear sight *V*. The intersection of the lines *KP′* and *KP″* with the vertical plane through *V* outlines the dispersion image of *K* when the eye is focussed on *V*.

Size and shape of the dispersion images is then easily computed. In the similar triangles *KP′P″* and *KK′K″*

$$K'K'' : P'P'' = KV : KP$$

therefore
$$K'K'' = P'P''\frac{KV}{KP}. \qquad (1)$$

The diameter $K'K''$ of the dispersion figure $= Z$, (if the figure is not circular, Z means its dimensions in the particular meridian), the diameter of the opening of the pupil $P'P'' = p$, the distance between the eye and the distinctly seen object $VP = d$, the distance of the dimly seen object, whose dispersion figure is in question, from the other $KV = a$; the last equation can then be written.

$$Z = p\frac{a}{a + d} \qquad (1a)$$

or in case the distance of the dimly seen object from the eye $KP = e$

$$Z = p\frac{a}{e} \qquad (1b)$$

This equation means, what is evident, that the dispersion image of a dimly seen point in the plane of distinct vision increases in direct proportion with the diameter of the pupil of the observer's eye, and the distance between the dimly seen and clearly seen object, and in inverse proportion with the distance of the dimly seen object from the eye.

Assuming, for instance, an opening of 3 mm. of the pupil—as normal when looking at a landscape of average brightness—assuming further that the eye is focussed on the point of the front sight, that the length of the sight line is 1000 mm. and the distance between the rear sight and eye, 200 mm., then the dispersion circle of every point of the rear sight will have a diameter in the plane of the front sight

$$Z_{200} = 3\frac{1000}{200} = 15 \text{ mm.}$$

Moving the eye to 300 mm. from the rear sight, makes

$$Z_{300} = 10 \text{ mm.}$$

or to 500 mm.

$$Z_{500} = 6 \text{ mm.}$$

Z even then remaining considerable.

It may justly be objected that the parts of the sighting apparatus do not consist of separate points, being solid objects and those dispersion circles, covering each other to a great extent, will make a relatively clear impression on the eye with only indistinct outlines. This is correct and is easily proved by using the above equation for points in succession. It is preferable instead of such calculation to show to the reader its visible result by *photographic* representation.

For this purpose an artificial eye has been used, whose pupil opening could be adjusted to an accurately defined size, whose retina is replaced by photographic plates; in other words, instead of the eye a *camera** was used. With this artificial eye photographs were taken of a sighting apparatus, which the Krupp Company in Essen through Colonel von Kretschmar lent the author and in which an open sight with cross-wires and another with a notch could alternately be put at exactly 1 m. distance from the point of the front sight.

This instrument was aimed at an object about 1000 meters away (spire of the "Landgrave House" near Jena) and photographs were taken with different focussing of the artificial eye—on the objective, the front sight and the rear sight—and with different pupil openings—2, 3, 4 mm. The photographs were made under a covered sky to avoid a one-sided illumination of the sights, and they have been reproduced in the following illustrations to such size that seen from a distance of 220 mm. they will give *the same impression* regarding the relative size of the objects represented, *as when observed by the eye of the pointer*. The illustrations show only the pictures obtained with 3 mm. pupil opening focussed on the target, front sight and rear sight, for a notch sight and for a cross-wires sight. For comparison the drawing has been added by which usually aiming with an open sight is demonstrated (Fig. 2 and 3). These illustrations, whose truth to nature is guaranteed speak a language more eloquent than words.

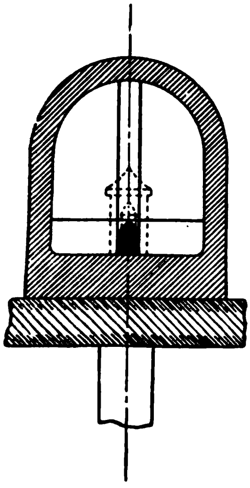
Fig. 2.

Involuntarily the question arises, how it is possible to produce from such images, such visions, a direction of sight as distinct and accurate as actually obtained.

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* As our eye focusses itself for different ranges by means of a change in the refracting mediums, without changing the distance of the retina, so in the camera photographic lenses of suitably different focal distance were used to obtain always the same size of the image. These pictures were made under the author's direction in the photographic laboratory of the firm of Carl Zeiss at Jena by the superintendent of that laboratory, Herr R. Schuttauf, with greatest care and ingenuity.

The printed reproductions do not show the difference in distinctness as clearly as the original photographs, but they show enough of it to demonstrate the conditions.

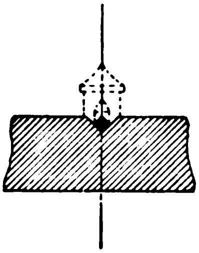


Fig. 3.

Two possibilities seem plausible. Either our eye focusses itself in rapid *succession* on the target, front sight and rear sight and by comparing the *remembered* perception forms a judgment as to the direction; or our eye in aiming uses none of the pictures here shown, but unconsciously focusses itself on a *mean distance* between target and front sight, at which the inaccuracies of all three of them is best equalized. It would be hard to find out which of these possibilities is the true cause.

In a correctly focussed telescopic aim, front sight and rear sight are projected in the same plane. In the focus plane of the objective glass appears a sharp image of the target and it is seen there together with the sharp image of the cross-wires through the magnifying ocular lens. Fig. (d) on the plate shows a photograph of these images as seen in a Krupp-Zeiss telescopic sight enlarged three times. Fig. (d′) is a picture of the same target as it appears in a telescope without enlargement.

In Grubb's sighting apparatus not the real image of the target is projected on a real cross, but on the contrary the virtual image of a real cross is projected on the target remaining in the distance, and through a semi-transparent, semi-reflectant glass plate they are simultaneously presented to the pointer's naked eye or eye assisted by glasses. The appearance as to distinctness is the same as in a telescope, only the cross is bright, and there is no enlargement for the naked eye. The above leaves no doubt any longer that aiming with either of these sighting apparatus is far superior to aiming with open sights. (The relative advantages and disadvantages of the Grubb apparatus, and the Krupp-Zeiss telescopic sight do not enter the subject of the present article.)

II. THE ERROR IN THE DIRECTION OF AIMING CAUSED BY THE PECULIARITIES OF THE HUMAN EYE.

The peculiarities of the human eye as an organic apparatus have been ignored until now. In this theoretical deduction of the relative measures it has been assumed that our eye is a perfect optical instrument, and accordingly optical instruments as perfect as at present obtainable have been used for graphic demonstration. In this way have been found the *typical* and general qualities of the phenomena under discussion, but not

The following photographs show a cross-wire sight and a notch sight, as it appears to the human eye, when focussed (a) on the target, (b) on the front sight, (c) on the wires of the notch.

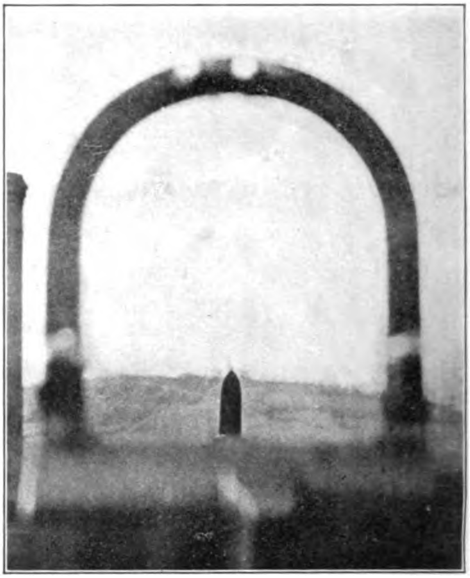
When the photographs were taken the distances of the notch or wires were

from the (artificial eye)	220 mm.
" " front sight	1000 mm.
" " target	925 m.

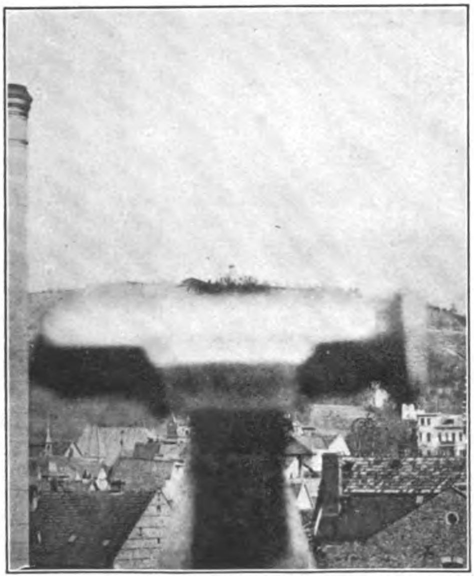
Next to these the image appearing in a telescopic sight is shown, in the upper picture (d) with an enlargement = 3, in the lower (d^1) with an enlargement = 1.

The opening of the pupil of the artificial eye was 3 mm.

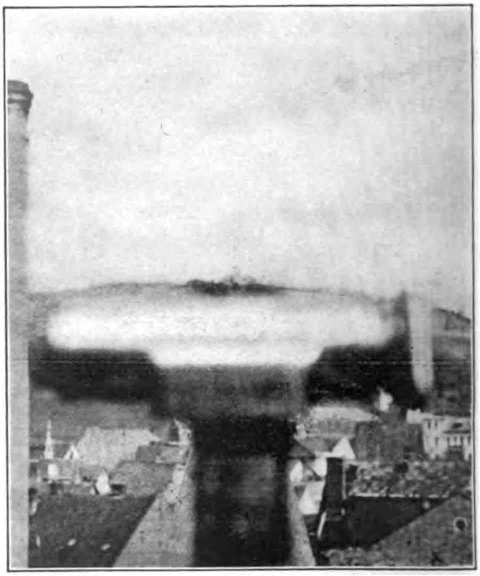
a



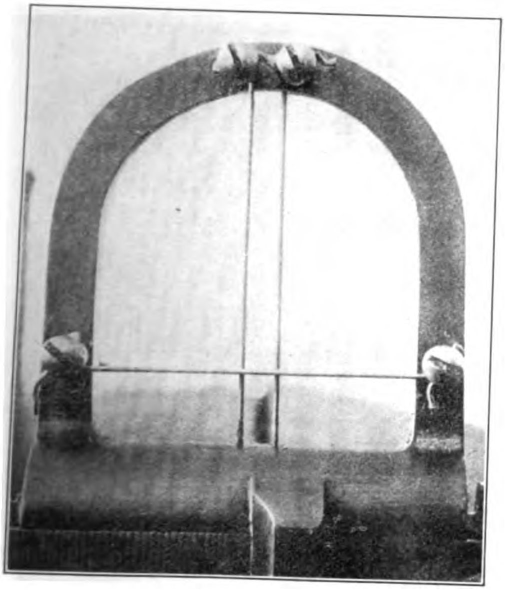
b



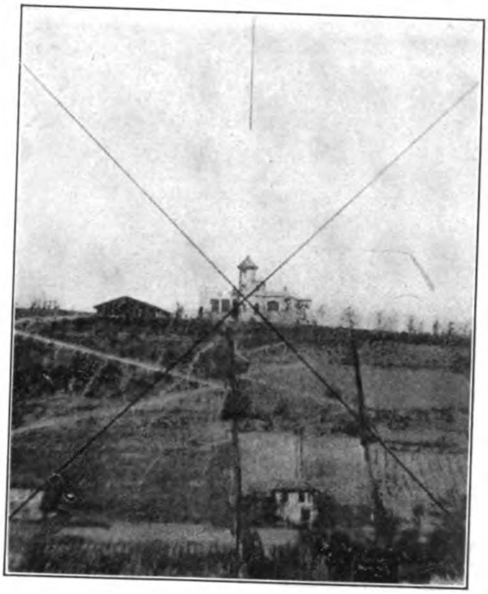
a^{1}



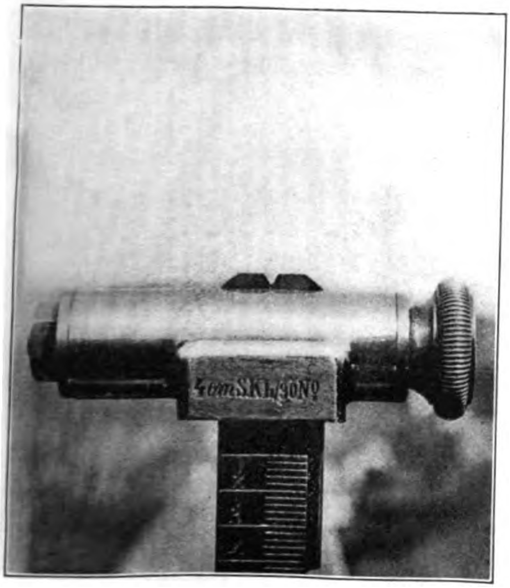
b^{1}



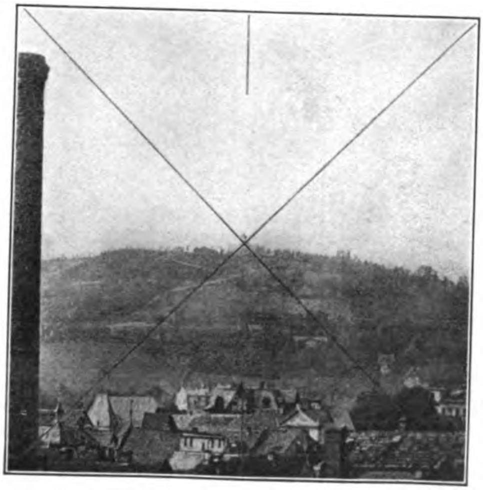
c



d



c^1



d^1

yet the particulars depending on the *peculiarities* of that special instrument, which has to be used, the *human eye.*

It may perhaps be claimed as the most general peculiarity of all human organs, or all organic apparatus, that though their special object is often reached in an admirable and marvellous way, they are suited for this only and no more. Their structure and functions, fit for their special purpose and just sufficient for it, do rarely satisfy further claims lying beyond their task.

Now the human eye is justly lauded and admired for its marvellous aptitude for the perception of visible phenomena. Taking this ability in its totality, nobody could think of artificially producing such an organ. But in its particulars are certain defects discovered which are avoided, even easily avoided, in an artificial apparatus. Helmholtz, on the basis of his own subtle investigations and those of earlier scholars has stated that the refracting surfaces of the optical apparatus in our eye are not perfectly spherical, not even parts of accurate rotation surfaces, that their axes do not coincide among themselves and with those of the diaphragms or with the line of vision, that the entire composition of this optical apparatus does not satisfy those fundamental requirements as to the production of the image, which are fulfilled by every artificial instrument, (compensation of the chromatic and spherical inaccuracies of the image, and so forth).

Generally, i. e., with sound normal eyes, these deviations remain within such limits, or compensate each other so favorably, that the task of our eye, viz., the perception of material objects as visible phenomena, is reached in the satisfactory manner known to everybody. But *the simultaneous perception of objects placed one behind the other in different ranges from the eye, as demanded in aiming, is beyond that task.* Our eye is "not suited" for this purpose. Only by successive accommodation (focussing) on the several objects does our optic furnish us images of satisfactory sharpness without exertion and in rapid succession. Inaccurate pictures, consisting of dispersion circles, of objects on which our eye is not focussed, aside from that inaccuracy, are possessed of certain *specific defects* which will occasionally be fatal to correct aiming, by one-sided errors in direction.

Before discussing the cause of this phenomenon, some facts must be stated which in part are known to everybody and in part can easily be experienced. As a most important fact, directly concerning our theme, is to be mentioned what Colonel von Kretschmar states as a result of his observations on the shooting range, viz., that there are pointers who always, i. e., with every gun, whatever its aiming apparatus and its eventual inaccuracies may be, make an error in direction to one side. (An individual error in elevation can not, of course, be verified because of the possibility in using an open sight with a notch, at "full sight" or "fine sight" instead of "half sight".)

Furthermore, every nearsighted or very farsighted person knows that the moon's crescent, which ought theoretically to appear as *one* indistinct semi-circle, is seen instead as an aggregation of several relatively clear semi-circles displaced to the right and left.

Simpler still and therefore more convincing is the result of a test which Helmholtz describes in his "Physiological Optics"* which everybody may easily repeat: Make a pinhole in a black cardboard and in a dark room hold it against a bright light at such distance from your eye that it cannot be seen distinctly; if nearsighted hold the card further away than your range of clear seeing; if farsighted approach it below that range; if normal make your eye artificially nearsighted by using a convex lens of several dioptrics ($f = 200$ to 400 mm.) (objectives of opera glasses usually have a convexity of 5 to 7 dioptrics) and proceed as if nearsighted.

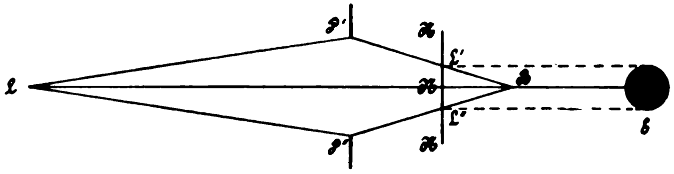


Fig. 4

The theory of this experiment for a perfect optical instrument (photographic camera) is very simple; instead of the pinhole there ought to appear a smaller or larger disc of even brightness. In fact, as the picture *B* (figure 4) of a luminous point *L* appears before or beyond the sensitive plane *N N* (retina, dulled glass, photographic plate) a dispersion figure *L' L''* will appear on it, resembling in all parts the opening in the screen, (pupil, diaphragm), and whose dimensions are in direct proportion to the focal difference *N B* and the size of the opening *P' P''*, in just the same way as shown above for the appearance of the front and rear sights. As our pupil is approximately circular, we would be justified in expecting to perceive a small

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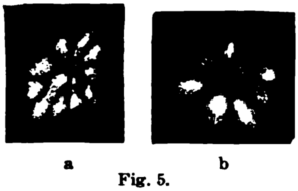
* 2nd edition, Hamburg & Leipzig, 1885 to 96, page 170.

equally bright disc *E*. We see this whenever we take a photographic camera with a *reasonably* good objective in place of the eye. Our eye itself, however, shows something different, varying from one individual to another and also from one eye to the other in the same individual. Helmholtz draws it for his left eye, as in fig. 5, fig. 5a being the appearance with eye focussed on a near object, fig. 5b, with eye focussed on a more distant one. Instead of the little disc of even brightness there appear several (usually 4 to 8) smaller ones grouped more or less symmetrically round a central one. The axes of symmetry of the figure differ with different persons, and are at different angles with the horizontal and vertical. The several luminous discs or specks show more or less of a tail. "As long as the light is faint, we see only the brightest parts of the phenomenon, and several images of the brightest point, one of them appearing brighter than the others. On the other hand, in case the light is very strong, for example, where direct sunlight falls through the pinhole, the rays of the star will flow together, and all around will appear a crown, much larger, of countless very fine lines in all colors," (Helmholtz). (Anybody who should find it difficult to observe this phenomenon, which is beyond his range of accurate sight, ought to "glare" or look at it half dreamily. Otherwise desperate attempts of the optics will ensue to see the cardboard clearly, often causing pain and in all cases failing).


a Fig. 5. b

The experiment which W. C. Roentgen described in 1894*, will serve as a third demonstration. Take an angular mirror of exactly 90 degrees with faces well meeting, i. e., with a very narrow, yet not quite disappearing edge *K*, (fig. 6). It will be best to use a good right-angled glass prism, through whose hypotenuse surface *H*, one looks towards its side surfaces *W' W''* which act as mirrors with total reflection. The observer then sees his own eye and at first thinks it is a simple reflection,

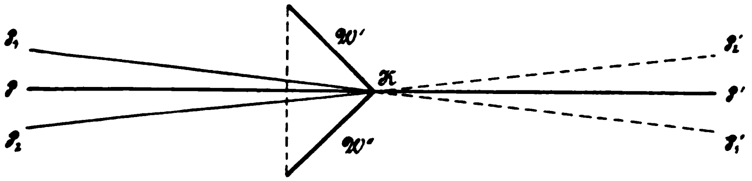


Fig. 6

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* Wiedemann's "Ann. der Physik und Chemie," N.S. Vol. 52, pages 589-92.

but on closer examination he finds that right and left are not reversed, as in a mirror, but that he sees its *correct* image only turned round *K* by 180 degrees. It is easily understood that every point of the image is obtained by drawing a line from the object point perpendicular to the edge *K* and doubling its length; in this way points P_1 PP_2 of the pupil are pictured in P'_1 P' P'_2.

The edge *K* of the angular mirror remains as a real object steady between the pupil and its image, independent of eventual movements of the eye sideways or forward and back, always exactly in the middle between pupil and image, and also exactly in the plane through both—the horizontal middle plane when the edge is held horizontal, the vertical, when vertical.

These peculiar relations, absolutely accurate, make this experiment well suited to explain the theory of aiming. The analogy is apparent; the edge represents the front sight which, from a fixed position of the eye, is projected on the reflected picture of the eye representing the target. Again, it is easily computed how the edge *ought* to appear, were the image of the eye seen distinctly, and how the image is seen in fact, when in place of the human eye a camera is used in the experiment: Instead of a sharp edge (supposing it is bright) a diffused broad band would spread over the picture of the pupil, of uniformly dim brightness and just as wide as the picture, exactly covering it.

Figure 7 is the reproduction of such a picture as produced on the sensitive plate by a photographic objective. Again the appearance in the eye is quite different, instead of one *band* of diffused brightness several more or less clear *lines* parallel to each other are seen, one of them, brighter than the others, absorbing usually the observer's attention, who neglecting the others takes this one for the only picture of the mirror's edge.

Fig. 7.

Now it ought to be expected from theoretical reasons that this prominent picture of the edge would *exactly halve* the picture of the pupil, horizontally or vertically, as the angular mirror may be held. This is, however, as Roentgen states, *generally not so*. With some persons the vertical line is nearer the nose, with others nearer the temples; the horizontal with some persons is too high up, with others too low down. This deviation is stated as of different size by different persons, and undoubtedly perceived so. With some persons the anomaly is nil. This test by Roentgen furnishes an excellent explanation of the theory of aiming by front and rear sights; the conditions of the test being especially simple, they can be determined with absolute accuracy and are invariable. No kind of carelessness or lack of attention can influence the accuracy of the test; the angular mirror automatically corrects the conditions and even an inaccuracy of its angle (more or less than 90 degrees) will only make the *observation* slightly *more difficult*, but will not diminish its *accuracy*.

The *explanation* of *Roentgen's experiment*—which its originator sought in vain*—is, the author thinks, to be derived without strain and perfectly consistently, as in the case of Helmholtz's experiment, from the so-called "*irregular astigmatism*" of the eye. The edge of the angular mirror is nothing but a linear repetition of Helmholtz's pinhole, the phenomenon in the one case only an integration of the one in the other.

The phenomena of "regular astigmatism" or simply "astigmatism," of the eye as well as of artificial optical apparatus, are well known. With our eye they show most conspicuously in that the rays of a star-shaped figure ✳ do not appear equally sharp; one direction is specially favored, the one at right angles to it specially neglected. A change of the state of focussing of the eye makes these main directions or "meridians of astigmatism" reverse their parts: the meridian dimmest before changes into the clearest, and vice versa. The cause for this is that the refracting surfaces of the eye, especially the cornea, are not regular rotation surfaces around the axis of the eye as axis of rotation, but in one meridian have a greatest and normal to it a smallest curvature, like a rotation surface, say an egg of plastic material, which has been slightly deformed by one-sided pressure. Consequently the rays will meet sooner in the meridian of greatest curvature than in that of the smallest. Such an eye strictly speaking receives two images of every point (which explains the term "astigmatism," from *α* and *στιγμα*, literally "pointlessness"). Practically every eye is astig-

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* Roentgen explains the phenomenon by what Helmholtz states as a deviation of the "line of vision" from the axis of the eye. This explanation, however, seems to differ from Helmholtz's own theory of aiming, the resume of which reads: (Helmholtz, page 127), "The ray which touches the center of the dispersion circle runs in the anterior chamber in fact through the center of the pupil, and *prolonged in the air through the center of the image of the cornea of the pupil.*" But that image of the pupil is just the one we see from outside so we must see it divided into equal halves, in spite of the deviation of the "line of sight." Roentgen's experiment is identical with that which Helmholtz himself described in connection with the one mentioned above, where he uses a narrow slit instead of the pinhole for his object.

matic in a small degree, because the refracting surfaces are in no eye perfect rotation surfaces. But astigmatism of less than $\frac{1}{2}$ dioptric is hardly perceptible and occulists do not consider it as pathological.

Irregular astigmatism does not consist of a regular systematic deformation of the refracting surfaces in the eye, like an egg under one-sided pressure—mathematically speaking a three-axed ellipsoid—but of a relatively irregular one, producing accordingly a "scattering" of the rays which form the image into several bunches more or less separate from each other. On close examination the crystal lens of the human eye shows a peculiar texture and condition of its surface (Fig. 8). While the cause for regular astigmatism is found nearly exclusively in the cornea, the texture of the crystal lens causes the irregular astigmatism.

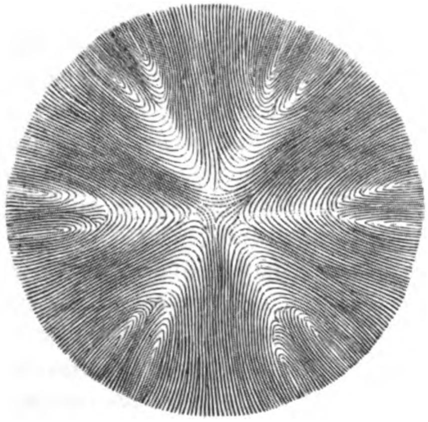

Fig. 8.

The crystal lens does not descend uniformly from its center but there are so to speak, hill ranges, six in number, separated by as many valleys—very shallow ones of course—running radially from it. These hills and valleys are not even quite smooth like well polished glass lenses, but show fine grooves, the lens consisting of fine fibres. It is evident that every lack of uniformity in the shape or texture must result in adequate irregularity of the image. And so even an excellent eye will not perceive a bright star as one point of light, but with "tails," as a center of nimbus of rays, wherefrom we derive our definition of the words "star" and "star-shaped." With regard to these conditions, Helmholtz whose thoughtfulness in judgment is as much beyond suspicion as his authority, made the statement, grown famous since and often quoted*: "Now it is not saying too much, that dealing with an optician who would try to sell me an instrument having the last named imperfections, I should believe myself perfectly justified in using the strongest words as to the negligence of his work and in refusing to accept his work."

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* Cfr. "Die neueren Fortschritte in der Theorie des Sehens." Preuss. Jahrb. 1868, reprinted in "Vortrage und Reden von H. Helmholtz."

Helmholtz adds prudently: "Concerning my own eyes, of course, I should not act that way, but on the contrary be glad to keep them with all their shortcomings as long as possible. But the fact that though defective they cannot be exchanged for better ones, evidently does not diminish the amount of what we must call their defects, considered from the one-sided but justifiable point of view of the optician."

With less marked objects, not standing out as bright and and isolated on a dark background as the stars, the irregular astigmatism does not interfere with distinct perception and localisation, i. e., with the task of the eye, *as long as it is well focussed on these objects*—either by this accomodation of the eye, or by the assistance of spectacles. However, in such cases where an object, on which the eye has not been focussed, must still be observed, as in the above experiments of Helmholtz and Roentgen, and especially the "experiment" of *aiming with front and rear sights*, the effect of irregular astigmatism is fully recognized and changes the normal character of the result. A bundle of rays emanating from a luminous point, in the shape of a cone, because entering the eye through the circular pupil, will if "stigmatic" (or as called in opto-technics "anastigmatic") unite after refraction in one point, the focus. When caught upon a screen before its union, wherever the screen is placed, it will mark a regular, uniformly illuminated circle. The same bundle deformed by *irregular* astigmatism (as long as not at the same time influenced by regular astigmatism) will in general also unite in *one* image-point, the focus *F*. But caught before or beyond the focus it shows an irregularly shaped and unequally illuminated figure. This dispersion not being regular and uniform around the center, produces an irregular effect varying from person to person. Sometimes it is one part of the bundle, sometimes another, which prevails in the final effect, often none of them, so that the strongest illumination will remain in the center.

The perception of objects on which the eye is not focussed is often facilitated by irregular astigmatism. If the object consists of lines, wires, etc., the effect of the single secondary images of each point will accumulate so that several full images will appear—the moon's crescent, the mirror edge with Roentgen's experiment—and if one is found among these predominating in brightness and clearness, *that* one will be perceived as *the* image of the insufficiently focussed object, and all the others ignored. In this way a much more distinct and clearer impression is obtained than from an image consisting of equally dim dispersion circles. Perhaps this might be considered by some as a "useful defect" of our optic. But the reverse of this usefulness lying too near, the distinctness of perception is to be paid for by more or less of an *error in localisation*, unless, as it were by accident, the prevailing picture lies in the "optical center of gravity" of the bundle of rays. Such is undeniably proved by the Roentgen experiment.

The mere fact that dimly seen points will not appear in the center of their geometrical dispersion circle does not yet constitute an error in the direction of aiming. For, if a lateral movement would affect all objects in the line of vision uniformly (i. e., by an equal value of angle), the foundation of the usual theory of aiming would remain, viz., that 3 points lying actually in the same line would so appear to an eye in the prolongation of that line. The direction of vision only would be slightly altered.

But unfortunately the lateral movement is *not* uniform. Helmholtz's dispersion images of a point in and outside the focus show that the distribution of light in the dispersion image is considerably altered. The texture of the bundle of rays between the lens of the eye and the retina is by no means regular; or, to word it more accurately, the deviations from the fundamental cone are so irregular that the rays group themselves in a steadily changing manner into a number of partial bundles. In consequence, in one cross section of the bundle—corresponding to *one* distance of the object—one partial image prevails, in others—corresponding to another distance—another will prevail; and these partial images which, as said above, are perceived as *the* images, are perceptibly deviated from each other in direction as well as in elevation. The amount of the error in direction of vision certainly depends on the shape of the sights. With massive objects the one-sidedness in general will appear less distinctly than in the alleged tests with mere points and lines. Strictly speaking, for every separate shape of the sights an integration of all the points of the image ought to be made to get at the whole. But in practice the conditions of illumination will have very great influence. In an open notch sight the horizontal upper edge and one of the oblique edges of the notch will be brightest and therefore of more influence on the total appearance. The reflection of the sky from the front sight will make one side of it appear brighter. (The fact that this uneven illumination of parts of the aiming apparatus is an additional source of error will not be further discussed here; it has often been justly pointed out by others.) With a cross-wire sight, even under diffused light, the individual lateral error of the eye will also fully influence the result.

Vision under conditions such as obtain in aiming with rear and front sights is so to speak *against nature.* Our eye is only made, only fit to see objects *clearly* and at the same time *in their correct place* at *one* distance; those at perceptibly different distances will be seen either *dimly, inaccurately,* or less dimly *in a wrong place, in a wrong direction.* The telescopic sights (and the Grubb sight) avoid this defect in principle by placing the target and the parts of the sighting apparatus (reduced to cross-wires or similar marks) in the *same plane,* the *same distance from the eye.* The natural defects of the eye are thus eliminated, its ability to see and aim are used rationally. Therefore these instruments are preferable to the open sights even if, as in Grubb's instruments, there is no enlargement of the image. For opto-technical reasons essentially, an enlargement of more than 1 has been chosen; it seemed, so to say, unnatural to make telescopes without enlargement.

As to the advantges of telescopic sights, probably all experts agree that the suspicions which were formerly expressed against too great weight, great length, and particularly too small *field,* are void since prismatic telescopes were introduced.

"It must not be supposed, however," says Alger "that all these great advantages can be attained at once and without accompanying disadvantages and sometimes mistakes. In the first place it was very difficult to obtain a telescope of large field and yet otherwise satisfactory, and those first issued had a field of only 4°, which is entirely inadequate. With such telescopes, the ordinary rolling and pitching of a ship throw the target completely out of the field of view, as does also a relatively small lateral motion, and this made it extremely difficult to get the image of the target at the cross-wires. The telescopes now issued, however, have a field of 17°, which makes pointing easy, since the target remains in the field of view when the rolling is very heavy." Von Kodar, page 718 expresses himself similarly: "The field of a telescope ought to be at least large enough to prevent the gunner from losing the target from his field of view while the ship is rolling, as long as in the mean position of the ship the optical axis meets the target. The limits of rolling within which artillery can be used to advantage are not very wide; 6° to each side may be considered the extreme. An instrument with from 12 to 14° field therefore will be sufficient, although with modern arrangements angles of view up to 20° and more can be obtained. Besides the chief advantage of a large field, that the target may always be kept in view, there is the further important advantage that the gunner can observe the hits of projectiles through the telescope, enabling him to judge of the place and effect of the hits, etc., better than with his naked eye." Also page 724, he says: "The field of view of the ordinary terrestrial telescope is very small, considering its great length and small ocular glass. The latest designs, however, show astonishing improvement in this respect." And pages 733 to 734: "The adoption of telescopic sights means an essential progress in ordnance, because by this means only, full use of modern guns regarding precision, efficiency and rapidity of fire can be obtained. Aiming in itself will be facilitated, therefore correct aiming will be easier, and the results of firing increased in consequence."

"It is probable that on the strength of such experience the ranges for firing will increase, yet with guns provided with telescopic sights, a range of say 6000 m. will not mean more than does now a range of from 2000 to 3000 m. A new era confronts us, in which sea fights instead of being decided at close range, will be fought, if not decided, at ranges hitherto not thought of."

Even the perfectly free field, with only its cross-wires, has indisputable advantages over the use of the open sight where the notch covers half of the field. The easily effected illumination at night (by changing the black cross lines into white ones appearing on perfectly dark ground) is another advantage. And such is the enlargement in the telescope although limited (from 2 to 6) that a more distinct perception of the target is gained (Cfr. the illustrations d and d′ on the plate), and a better observation of the hits and results of hitting.

The intensity of light in a modern sighting telescope with a "pupil of egress" of 5 to 7 millimeters will answer all requirements.

The opinion is often heard that, besides the ocular, the objective glass also ought to be focussed on objects at different ranges. Regarding this von Kodar says in his book, page 717: "With smaller ones" (meaning telescopes) "the focal distance of their objectives being short, such an appliance is unnecessary because the images of objects at different ranges always fall in practically one plane, the focal plane of the objective." Indeed, with an objective of 100 mm. focal distance, a difference of only 0.1 mm. would result, if the object was as near as 100 meters; with an objective of 150 mm. focal distance only at 225 m., with one of 200 mm. only at 400 m. distance. Focal differences of 0.1 mm. cannot be recognized with the usual oculars (one dioptric in field glasses corresponds to 0.4 mm. displacement of the ocular), so with hand telescopes a change of focus is not needed as long as they are not used for considerably shorter distances than given above. Whether with guns the telescopic sights should have a focussing apparatus to help abnormal (nearsighted or farsighted) eyes of the pointers, is a mere question of practice, on which opinions of military authorities differ. From the maker's point of view it must be said that the less there is of *adjusting* movements, the less any *disarrangements* are to be expected.

Von Kodar's saying that the Grubb sight avoids "the influences of parallax which eventually are felt with telescopic sights" is as incorrect as his similar statement regarding "the limitation of the field." The distance between the mirror or objective which changes the bundles of rays diverging from the cross into parallel rays, to the cross itself, is just as influential for an eventual parallax in Grubb's sight, as the distance between the telescopic objective and the cross-wires which should be mounted exactly in its focal plane. Also regarding the field, "it is provided that the trees shall not grow into the skies." which is easily shown. Probably a larger field than in the Grubb sight has never been reached, though a number of patents try to furnish means for a large field. It is true that the eye of the observer may freely move within certain limits without causing the slightest inaccuracy in the sighting. But this is equally true for the telescope, for here as well as there, not more nor less, "the eye is bound to one certain point in the optical axis of the instrument." For the mere *perception of the target* with the Grubb sight the eye has though not complete, yet very ample freedom; but *to see the cross at the same time*, the eye must be reached by the bunch of rays issuing from it, and its opening is equal to that of the lens or mirror projecting the cross into the distance.

Ignoring the great analogy in the composition of the Grubb sight and the telescopic, expectancies as to the merits of the former have evidently gone too far.

Among the several proposed *designs of prisms* the oldest, Porro's crossed prisms (amply described by von Kodar, page

727-9), recommends itself by its simplicity and corresponding cheapness. The use of two separate elementary prisms results in a loss of about 8% of light, which may in most cases be ignored. It might also result in an inconstancy of the adjustment. But it has been shown by careful tests under high strain, for instance by the Swedish artillery, that such is not to be feared.

The so-called "pentaprism" which von Kodar recommends as the best, does not deserve its praise for reliability and constancy; it is "of one single body" *on paper only.* In practice it can only be made of two pieces; there is perhaps a *small* gain in brightness (avoiding that 8% loss mentioned above) because the two parts touch and can be cemented; but no gain in rigidity. Cementing gives hardly any security for invariability of mutual position, when under such strains as in the present case.

The same is true of the system of prisms used in the telescopic sights of the United States Navy.*

A distinct progress in this direction was only made when the firm of Carl Zeiss produced those prisms actually consisting of one single piece which are used in the telescopic sights of the Krupp Company.

As a last objection against telescopic sights it has been said, that although the *perception* of the target is improved, there is not the same *stability of the correct sight line.*

The sight line of the open sights is determined as the line between the rear and front sight; that of a telescope as the line from the center of the cross-wires to the rear focus of the objective lens. (Only this line can be called the "optical axis" or rather takes its place in all telescopes for aiming or fixing a direction). In the former case two points whose connection indicates the direction, are 60 to 100 cm. or even more apart, in the latter case often less than 100 mm. It is argued by some that the security against error in direction is in direct proportion to this distance. From a merely geometrical view point such reasoning is undoubtedly correct. A lateral change of rear or front sight, say for 1 mm. will alter the direction only about

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* "Handbook of Telescopic Sights" (page 8 and elsewhere) calls them "the Hastings-Brashear Compound Erecting Prisms." Professor Hastings obtained a U. S. patent for this system in 1897. But it was recommended long before that by E. Abbe, and in 1894, the author showed its application to telescopes made by Carl Zeiss in Jena, and in a meeting of the German Association for Optics and Mechanics in Berlin, on December 4, 1894 showed and thoroughly explained it before a large audience. Also at a meeting of the "Verein zur Befoerderung des Gewerbleisses in Preussen" in Berlin, on January 5, 1895. He first published it in the papers of that Association (1895 No. 10) and had it protected by the German patent No. 85971 of March, 1899.

one-tenth as much as the same change in the relative position of cross-wires and objective lens. Yet the *conclusion* from the argument is *erroneous;* for the *probability* of a lateral change of position of the said parts in a telescope is *less than one-tenth* of that in an open sight. And this is proven not by argument but by *experience*, and explained by referring to the fact that a small closed instrument is much better protected than one whose parts have to be fixed separately. Experience of rather long standing has made it evident that the adjustment of telescopic sights, even when fast on the gun itself and remaining in place during the firing, not only have kept as well, but, taking enlargement into consideration, several times better than open sights. This is also indirect proof that the connection of the telescope with the sight and of the sight with the gun will, if properly made, satisfy all requirements.

While the above was written there appeared another article treating of the same subject*: Rostkoten, First Lieutenant in the German 58th regiment of field artillery, speaks in the same sense, saying: "Spirit level and sighting telescope are bound to be the foundation for all future designs of aiming apparatus for field guns."

On page 580 the same author mentions that doubts have been raised as to the solidity of telescopes, and states against such objections, that they have been introduced in the German siege and fortress material after the severest tests, and also after exhaustive trials in the artillery of Switzerland, Sweden, Denmark and Turkey. Roskoten draws from his arguments the following conclusions:

"The serviceability for war use of the telescopic sights now offered by the makers is beyond all doubt.

In spite of the apparent complication of the apparatus the drill of the pointing gunners is simplified and the quality and uniformity of sighting brought to high perfection."

The results of careful *practical tests* of the comparative accuracy of aiming with and without the telescope would be more interesting and convincing than all the more or less theoretical arguments above. The programme for such test offers no difficulty; but the author thinks he himself lacks one condition for making such tests,—finding it nececessary that the pointers in the test ought to have *full practice* in both kinds of aiming and to be *ignorant* of the *object* of the test. Perhaps

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* "Jahrbuecher fuer die deutsche Armee und Marine," No. 392, pages 571 to 581.

these lines will induce an officer in actual service to make the test. It will only be necessary to find the average error, and the probable error, easily computed from a number of single aimings on the same target by the same pointer, using the one and the other sighting apparatus. Of course, a variety of targets, of illuminations, etc., will be tested and different persons serve as pointers to obtain results free from objection. The enlargement by the sighting telescope ought to be considered separately.

HIGH ANGLE FIRE

QUADRATIC LAW OF RESISTANCE

By Captain FRANK E. HARRIS, Artillery Corps

IN high angle fire, that is, when the angle of departure exceeds about 45 degrees, the formulas employed are deduced on the assumption that the resistance of the air varies as the square of the velocity of the projectile. This law is strictly true only when the velocity does not exceed about 800 f. s.; in practice, however, this limit is greatly exceeded, the errors resulting from this and other sources being compensated by the introduction of a factor determined from the records of actual firings. This factor is called the coefficient of reduction and, in our service, is represented by "c".*

For the quadratic law of resistance we have (see equation 8′, Artillery Circular N)

$$\frac{d\theta}{\cos^3\theta} = \frac{g\,C}{A\,v_1^3} \qquad (1)$$

whence, integrating and representing the indefinite integral of the first member by (θ), we have

$$(\theta) = -\left(\frac{\kappa}{v_1}\right)^2 + B \qquad (2)$$

in which

$$\kappa^2 = \frac{g\,C}{2\,A}$$

and B is a constant of integration to be determined.

Since for the same trajectory equation (2) must be true for all values of v_1, it will be true for $v_1 = \infty$, whence, denoting the corresponding value of θ by i, we have

$$B = (i).$$

Substituting this value of B in (2) it becomes

$$(\theta) = -\left(\frac{\kappa}{v_1}\right)^2 + (i) \qquad (3)$$

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* A table giving the values of "c" for the 12-inch B. L. M. and 800 pound projectile is given in the Appendix, Table A. This table was computed by Major F. S. Harlow, A. C., from data furnished by actual firings.

At the origin where $\theta = \varphi$ and $v_1 = V_1$, equation (3) becomes

$$(\varphi) = -\left(\frac{\kappa}{V_1}\right)^2 + (i) \tag{4}$$

It is evident from the above that for every trajectory there is a constant angle i, which is the inclination of the trajectory at the point where the horizontal component of the velocity is infinite; also, that while i is a constant for the same trajectory it may have the same value for many trajectories.

We also have (see equation 32′, Artillery Circular N).

$$ds = -\frac{\kappa^2}{g}\frac{\sec^3\theta\, d\,\theta}{\left\{(i)_n - (\theta)_n\right\}^{\frac{2}{n}}}$$

which for the quadratic law of resistance becomes

$$ds = \frac{\kappa^2}{g}\frac{d\,(\theta)}{(\theta) - (i)} \tag{5}$$

whence, since $dx = ds \cos\theta$, and $dy = ds \sin\theta$ we deduce

$$\left.\begin{aligned} dx &= \frac{\kappa^2}{g}\frac{\cos\theta\, d(\theta)}{(\theta) - (i)} \\ dy &= \frac{\kappa^2}{g}\frac{\sin\theta\, d(\theta)}{(\theta) - (i)} \end{aligned}\right\} \tag{6}$$

The integration of these equations and the elimination from them of the angle θ would result in a relation between the variables x and y which would be the equation of the trajectory. But as such integration in finite forms is not practicable we proceed to obtain the desired results by the method of quadratures.

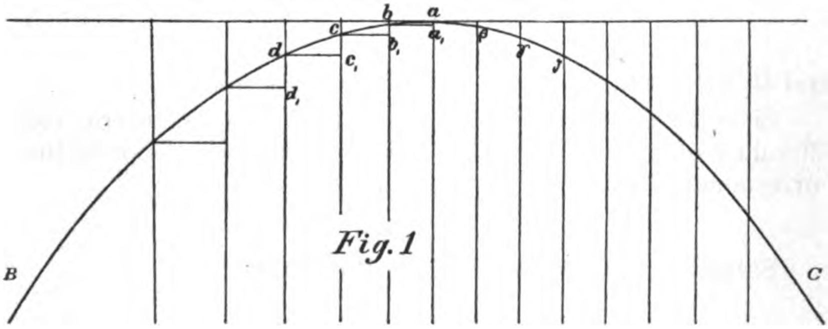

Fig. 1

Let *BaC*, figure 1, be a trajectory corresponding to an assumed set of values of i and κ^2 and let us see what will have to be done to indicate the form of this trajectory by means of a table. This object will evidently be attained by assuming a system of coordinate axes at any point of the trajectory as origin and tabulating the coordinates of a series of points taken at conveniently close intervals, in such a manner that corresponding coordinates will appear in juxtaposition in the table. For convenience the origin will be taken at the summit with the axis of x horizontal and that of y vertical. In accordance with our assumption it will now only be necessary to note the coordinates of a definite series of points suitably selected, such as b, c, d, etc. In order, however, that these coordinates may be calculated we must have expressions for x and y in finite forms. For this purpose the points b, c, d, etc., β, γ, δ, etc., are taken so close together that the arcs ab, bc, cd, etc., $\alpha\beta$, $\beta\gamma$, $\gamma\delta$, etc., may, without appreciable error, be taken as right lines. Each arc will then be the hypothenuse of a right angled triangle whose base is the increment Δx and whose altitude is the increment Δy. Denoting the inclinations of the trajectory at any two consecutive points (for example, c and d) by θ'' and θ', θ' being numerically greater than θ'', the inclination of the corresponding arc (cd) may be taken as the arithmetic mean of these two angles, or $\frac{1}{2}(\theta' + \theta'')$; then, Δs denoting the length of each arc ab, bc, etc., $\alpha\beta$, $\beta\gamma$, etc., we will evidently have

$$\left.\begin{aligned}\Delta x &= \Delta s \cos \tfrac{1}{2}(\theta' + \theta'') \\ \Delta y &= \Delta s \sin \tfrac{1}{2}(\theta' + \theta'')\end{aligned}\right\} \qquad (7)$$

To find an expression for Δs we proceed as follows:

Integrating equation (5) between the limits $\theta = o$ and $\theta = \theta$ and expressing the result in terms of common logarithms we have

$$s = \frac{M\kappa^2}{g} \log \frac{(i) - (\theta)}{(i)} \qquad (8)$$

in which s is the length of the trajectory from the summit where the inclination is zero to any other point where it is θ and M is the reciprocal of the modulus of the common system of logarithms.

Now let s' be the length of the trajectory from the summit to the point where the inclination is θ', and s'' the length to the point where the inclination is θ''; we then have

$$s' = \frac{M\kappa^2}{g} \log \frac{(i) - (\theta')}{(i)}$$

and

$$s'' = \frac{M\kappa^2}{g} \log \frac{(i) - (\theta'')}{(i)}$$

whence, subtracting the latter from the former, member from member, we have

$$s'-s''=\Delta s=\frac{M\kappa^2}{g}\log\frac{(i)-(\theta')}{(i)-(\theta'')} \qquad (9)$$

Substituting this value of Δs in equations (7) they become

$$\left.\begin{aligned}\Delta x&=\frac{M\kappa^2}{g}\log\frac{(i)-(\theta')}{(i)-(\theta'')}\cos\tfrac{1}{2}(\theta'+\theta'')\\ \Delta y&=\frac{M\kappa^2}{g}\log\frac{(i)-(\theta')}{(i)-(\theta'')}\sin\tfrac{1}{2}(\theta'+\theta'')\end{aligned}\right\} \qquad (10)$$

Having computed these increments for each arc Δs, of the trajectory, the coordinates of any point of such trajectory would be found by simply adding, for the abcissa, the several increments of x and for the ordinate, the several increments of y. Thus, for the point d, the abcissa would be $a_1b+b_1c+c_1d$ and the ordinate $aa_1+bb_1+cc_1$.

In order that the tables computed as above may be generally useful they must comprise all trajectories likely to arise in practice or at least such number of them at suitable intervals as will permit of ready interpolation between them.

It is evident (equation 3) that there will be a particular trajectory for each set of values of i and κ^2, consequently the total number of such trajectories will depend upon the possible variations in the values of these quantities. It is further evident (equation 4) that all trajectories which differ only in the values of φ (i and κ^2 being constant) are alike in forming more or less extended portions of one and the same trajectory corresponding to the assumed values of i and κ^2 and the greatest value of φ.

With reference to κ^2 we observe that since this quantity enters as a factor in the expressions for Δx and Δy (equations 10) we may assume an arbitrary value for it as a standard for use in computing the tables, which could then be made generally applicable by merely multiplying the tabular values of the coordinates by the proper factor determined from the given data.

Under this assumption it follows that if every possible trajectory be conceived indefinitely prolonged in both directions from the summit they would differ from each other solely in the values of the angle i, and as this angle must be comprised between the limits 0° and 90°, it only remains to decide upon the number of such trajectories to be calculated to meet all the requirements of practice.

Assuming $\kappa^2 = \frac{g}{M}$ and denoting the corresponding values of Δx and Δy by $\Delta\xi_1$ and $\Delta\eta_1$ respectively, equations (10) become

$$\left.\begin{aligned} \Delta\xi_1 &= \log\frac{(i)-(\theta')}{(i)-(\theta'')}\cos\tfrac{1}{2}(\theta'+\theta'') \\ \Delta\eta_1 &= \log\frac{(i)-(\theta')}{(i)-(\theta'')}\sin\tfrac{1}{2}(\theta'+\theta'') \end{aligned}\right\} \tag{11}$$

whence

$$\Delta x = \frac{M\kappa^2}{g}\,\Delta\xi_1$$

$$\Delta y = \frac{M\kappa^2}{g}\,\Delta\eta_1$$

and finally

$$x = \frac{M\kappa^2}{g}\,\xi_1 \tag{12}$$

and

$$y = \frac{M\kappa^2}{g}\,\eta_1 \tag{13}$$

the summation extending from the summit to any point where the inclination is θ.

At the muzzle, where $\theta = \varphi$ we have, for the ascending branch,

$$x_0 = \frac{M\kappa^2}{g}\,\xi_0 \tag{14}$$

and

$$y_0 = \frac{M\kappa^2}{g}\,\eta_0. \tag{15}$$

At the point of fall, where $\theta = -\omega$, we have, for the descending branch,

$$X - x_0 = \frac{M\kappa^2}{g}\,\xi_\omega$$

whence

$$X = x_0 + \frac{M\kappa^2}{g}\xi_\omega = \frac{M\kappa^2}{g}\left\{\xi_0 + \xi_\omega\right\} = \frac{M\kappa^2}{g}\,\xi. \tag{16}$$

Before proceeding further we must have a table giving the values of the functions (θ)* for the values of θ within the limits desired. Such a table for values of θ at intervals of one minute from 0° to 87° will be found in Supplement No. 2 to Circular M.

For the ascending branch, since θ' is greater than θ'', equations (11) will give negative results and as the writing of the minus sign before all these would involve a great deal of unnecessary labor in the computation, it is obviated by writing the factor $\log \frac{(i)-(\theta')}{(i)-(\theta'')}$ under the form $\log \frac{(i)-(\theta'')}{(i)-(\theta')}$.

General Otto, whose tables were calculated in accordance with the above principles, took the angular interval between successive points of the trajectory as one degree. In the ascending branch the calculations were made for each degree from $\theta = 0°$ to $\theta = i°$; in the descending branch, for which, since the angles θ are negative, the factor $\log \frac{(i)-(\theta')}{(i)-(\theta'')}$ takes the form $\log \frac{(i)+(\theta')}{(i)+(\theta'')}$, the calculations were made for each degree from $\theta = 0°$ to $\theta = 87°$.

The above computations were made for 22 values of i as follows: 6 at intervals of 4° from 35° to 55° and 16 at intervals of 2° from 55° to 87°.

As an illustration of the manner of executing the computations we will take the case of $i = 55°$. Referring to Table A, we note that the first column contains values of θ one degree apart beginning with 0°; the second column contains the corresponding values of the functions (θ) taken from a proper table of these values (the function $(i) = (55°) = 1.822067$, is also taken from this table); the third column is obtained by subtracting each quantity of the second column in turn from 1.822067; the fourth column is obtained by taking the logarithms of the corresponding quantities in the third column; the fifth column is obtained by subtracting the corresponding quantities in the fourth column from those in the same column

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* By assumption we have

$$(\theta) = \int \frac{d\theta}{\cos^3 \theta}$$

but

$$\int \frac{d\theta}{\cos^3 \theta} = \tfrac{1}{2}[\tan \theta \sec \theta + \log_e (\tan \theta + \sec \theta)]$$

hence

$$(\theta) = \tfrac{1}{2}[\tan \theta \sec \theta + \log_e (\tan \theta + \sec \theta)]$$

It will be observed that the function changes sign with θ and reduces to zero when the latter is zero.

$i = 55°$.
$(i) = 1.822067$.

ASCENDING BRANCH

TABLE A.

θ	(θ)	$(i) - (\theta)$	log $\{(i) - (\theta)\}$	Differences of these logarithms.	Logarithms of these differences.	Log $\Delta\zeta_{,,}$ or log difference plus log sin $\frac{1}{2}(\theta' + \theta'')$	Log $\Delta\xi_{,,}$ or log difference plus log cos $\frac{1}{2}(\theta' + \theta')$	$\frac{1}{4}$ log $\{(i) - (\theta)\}$	log $\Delta t'$
0°	0.000000	1.822067	0.2605644					0.06514	
1°	0.017456	1.804611	0.2563838	0.0041806	7.62124—10	5.56208—10	7.62122—10	0.06410	7.75046—10
2°	0.034928	1.787139	0.2521584	0.0042254	7.62587—10	6.04379—10	7.62572—10	0.06304	7.75286—10
3°	0.052432	1.769635	0.2478837	0.0042747	7.63091—10	6.27059—10	7.63049—10	0.06197	7.75540—10
4°	0.069984	1.752083	0.2435546	0.0043291	7.63640—10	6.42208—10	7.63559—10	0.06089	7.75835—10
5°	0.087600	1.734467	0.2391661	0.0043885	7.64232—10	6.53696—10	7.64098—10	0.05979	7.76156—10
6°	0.105298	1.716769	0.2347119	0.0044542	7.64877—10	6.63034—10	7.64677—10	0.05868	7.76524—10
7°	0.123092	1.698975	0.2301870	0.0045249	7.65561—10	6.70947—10	7.65281—10	0.05755	7.76904—10
8°	0.141002	1.681065	0.2255845	0.0046025	7.66299—10	6.77869—10	7.65926—10	0.05640	7.77321—10
9°	0.159044	1.663023	0.2208982	0.0046863	7.67083—10	6.84053—10	7.66603—10	0.05522	7.77765—10
10°	0.177237	1.644830	0.2161210	0.0047772	7.67917—10	6.89678—10	7.67317—10	0.05403	7.78242—10
11°	0.195598	1.626469	0.2112458	0.0048752	7.68799—10	6.94862—10	7.68066—10	0.05281	7.78750—10
12°	0.214147	1.607920	0.2062644	0.0049814	7.69735—10	6.99701—10	7.68854—10	0.05157	7.79292—10
13°	0.232903	1.589164	0.2011687	0.0050957	7.70550—10	7.04084—10	7.69508—10	0.05029	7.79694—10
14°	0.251888	1.570179	0.1959493	0.0052194	7.71762—10	7.08581—10	7.70545—10	0.04899	7.80473—10
15°	0.271122	1.550945	0.1905964	0.0053529	7.72859—10	7.12719—10	7.71453—10	0.04765	7.81117—10
16°	0.290628	1.531439	0.1850997	0.0054967	7.74010—10	7.16700—10	7.72401—10	0.04627	7.81793—10
17°	0.310429	1.511638	0.1794478	0.0056519	7.75219—10	7.20553—10	7.73393—10	0.04486	7.82506—10
18°	0.330550	1.491517	0.1736282	0.0058196	7.76489—10	7.24303—10	7.74431—10	0.04341	7.83258—10
19°	0.351015	1.471052	0.1676275	0.0060007	7.77827—10	7.27975—10	7.75523—10	0.04141	7.84055—10
20°	0.371854	1.450213	0.1614318	0.0061957	7.79209—10	7.31559—10	7.76644—10	0.04036	7.84871—10

$i = 55°$. **ASCENDING BRANCH** **TABLE B.**

θ	$\Delta\zeta_,$	$\zeta_,$	$\Delta\xi_,$	$\xi_,$	$\Delta t'$	t'
1°	0.0000365	0.0000365	0.0041804	0.0041804	0.005629	0.005629
2°	0.0001106	0.0001471	0.0042240	0.0084044	0.005660	0.011289
3°	0.0001865	0.0003336	0.0042706	0.0126750	0.005694	0.016983
4°	0.0002643	0.0005979	0.0043211	0.0169961	0.005733	0.022716
5°	0.0003443	0.0009422	0.0043750	0.0213711	0.005775	0.028491
6°	0.0004269	0.0013691	0.0044337	0.0258048	0.005824	0.034315
7°	0.0005122	0.0018813	0.0044958	0.0303006	0.005874	0.040189
8°	0.0006007	0.0024820	0.0045631	0.0348637	0.005932	0.046121
9°	0.0006926	0.0031746	0.0046348	0.0394985	0.005993	0.052114
10°	0.0007884	0.0039630	0.0047115	0.0442100	0.006059	0.058173
11°	0.0008884	0.0048514	0.0047936	0.0490036	0.006131	0.064424
12°	0.0009931	0.0058445	0.0048814	0.0538850	0.006208	0.070632
13°	0.0010986	0.0069431	0.0049554	0.0588404	0.006265	0.076897
14°	0.0012184	0.0081615	0.0050752	0.0639156	0.006379	0.083276
15°	0.0013403	0.0095018	0.0051824	0.0690980	0.006474	0.089750
16°	0.0014689	0.0109707	0.0052968	0.0743948	0.006576	0.096326
17°	0.0016052	0.0125759	0.0054191	0.0798139	0.006684	0.103010
18°	0.0017500	0.0143259	0.0055502	0.0853641	0.006801	0.109811
19°	0.0019044	0.0162303	0.0056915	0.0910556	0.006927	0.116038
20°	0.0020682	0.0182985	0.0058404	0.0968960	0.007059	0.123797

directly above them; the sixth column is obtained by taking the logarithms of the corresponding quantities in the fifth column; the seventh column is obtained by adding to the corresponding quantities in the sixth column the log sin $\frac{1}{2}(\theta' + \theta'')$ in which θ' is on the same horizontal line with the quantities concerned and θ'' is on the horizontal line directly above them; the eighth column is similarly obtained from the sixth except that log cos $\frac{1}{2}(\theta' + \theta'')$ is added instead of log sin $\frac{1}{2}(\theta' + \theta'')$.

Table B is an extension of Table A. The quantities in columns 2 and 4 of this table are the numbers respectively corresponding to the logarithms tabulated in columns 7 and 8 of Table A. In columns 3 and 5 each number is the sum obtained by adding all the quantities in the preceding columns from the top down to and including that on the horizontal line in question.

The descending branch is calculated in precisely the same manner except that the functions (θ) are added to the function (i) instead of being subtracted from it as above.

The time of flight.—The horizontal velocity at the point where the inclination is θ' is, equation (3),

$$v_1' = \frac{\kappa}{\sqrt{(i)-(\theta')}}$$

and for the point where the inclination is θ''

$$v_1'' = \frac{\kappa}{\sqrt{(i)-(\theta'')}}$$

Taking the geometrical mean of these velocities for the mean horizontal velocity over the space Δx, we have for the time of describing such space

$$\Delta t = \frac{\Delta x}{\sqrt{v_1' v_1''}} = \frac{1}{\kappa} \Delta x \sqrt[4]{\{(i)-(\theta')\}\{(i)-(\theta'')\}}$$

whence, substituting for Δx its value (page 47) and making

$$\Delta t' = \Delta \xi_1 \sqrt[4]{\{(i)-(\theta')\}\{(i)-(\theta'')\}}\cdot$$

whence

$$\log \Delta t' = \log \Delta \xi_1 + \tfrac{1}{4} \log \{(i)-(\theta')\} + \tfrac{1}{4} \log \{(i)-(\theta'')\} \quad (17)$$

we obtain

$$\Delta t = \frac{M\kappa}{g} \Delta t'$$

or finally

$$t = \frac{M\kappa}{g} t' \qquad (18)$$

the summation extending from the summit to any point where the inclination is θ. At the muzzle, where $\theta = \varphi$, we have, for the ascending branch,

$$t_0 = \frac{M\kappa}{g}\, t_0';$$

and at the point of fall, where $\theta = -\omega$, we have, for the descending branch,

$$T - t_0 = \frac{M\kappa}{g}\, t'_\omega$$

whence

$$T = t_0 + \frac{M\kappa}{g}\, t'_\omega = \frac{M\kappa}{g}\,(t_0' + t'_\omega) = \frac{M\kappa}{g}\, T'. \qquad (19)$$

The values of $\Delta t'$ and t' are calculated as follows:

In Table A, if we divide the quantities in the fourth column by 4 we obtain column 9 of that table; column 10 is obtained by adding to each quantity in column 8 the corresponding quantity in column 9 plus the quantity in the same column directly above it. The numbers corresponding to the logarithms tabulated in column 10 constitute column 6 of Table B. Column 7 of the latter table is found from column 6 precisely as columns 3 and 5 of this table were found from columns 2 and 4.

Having computed the values of ξ_1, ζ_1, and t' for both branches of each trajectory as above, the values of ξ, ζ_0, T', and ω for any particular complete horizontal trajectory, that is, for particular values of φ and i, are found as follows:

With $\theta = \varphi$ enter Table B for the ascending branch of the trajectory corresponding to i and take out the corresponding values of $[\zeta_1]_a$, $[\xi_1]_a$, and $[t']_a$; with the value of $[\zeta_1]_a$ thus found as argument enter Table B for the descending branch of the same trajectory and take out the corresponding values of $[\xi_1]_d$, $[t']_d$, and θ, interpolating if necessary. Then $[\zeta_1]_a = \zeta_0$; $[\xi_1]_a + [\xi_1]_d = \xi$; $[t']_a + [t']_d = T'$; and $\theta = -\omega$.

In the same manner the values of ζ_0, ξ, T' and ω for any other values of φ and i can be found.

*Otto's Tables.**—(Tables I, II and III.) These tables, published by General Otto in 1842, give the values of ζ_0, ξ, T' and ω for values of φ at intervals of 5° from 30° to 75°, the argument being the angle i. They were computed as just shown for the above values of φ and for the 22 values of i previously noted. They were then extended by interpolation to include the values of i as given in the tables.

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* Tafeln fur den Bombenwurf. Berlin, 1842.—Tables balistiques pour le tir eleve. Paris, 1844. (Translation by Rieffel).

Ingalls' Tables.—(Table IV, Supplement to Artillery Circular M). These tables are a modification of Otto's tables computed originally for values of φ at intervals of 5° from 30° to 65° and since extended by the Artillery Board to include angles of departure at intervals of one degree from 45° to 70°. The argument of these tables is the quantity $\frac{V}{\sqrt{C}}$ which extends from 100 to 800 with the common difference of 10.

These tables are constructed as follows:

Starting with any assumed value of $\frac{V}{\sqrt{C}}$ and angle of departure φ, compute the angle i by equation (4). With this value of i and the assumed value of φ enter Otto's tables and take out the quantities ξ, T' and ω.

We then have

$$\frac{X}{C}=\frac{M\kappa^2}{gC}\xi=[4.3912943]\xi^*$$

and

$$\frac{T}{\sqrt{C}}=\frac{M\kappa}{g\sqrt{C}}T'=[1.6230970]T'^*$$

At the point of fall where $\theta=-\omega$ and $v_1=v_\omega\cos\omega$, equation (3) becomes

$$-(\omega)=-\left(\frac{\kappa}{v_\omega\cos\omega}\right)^2+(i)$$

whence

$$v_\omega=\frac{\kappa\sec\omega}{\sqrt{(i)+(\omega)}}$$

from which we find

$$\frac{v_\omega}{\sqrt{C}}=\frac{\kappa}{\sqrt{C}}\frac{\sec\omega}{\sqrt{(i)+(\omega)}}=[2.7681973]\frac{\sec\omega}{\sqrt{(i)+(\omega)}}^*$$

These values together with that of ω are thus determined for each value of φ and for values of $\frac{V}{\sqrt{C}}$ varying by 100 from 100 to 800. The tables thus found were then extended by interpolation to include values of $\frac{V}{\sqrt{C}}$ having a common difference of 10.

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* The numbers in the brackets are the logarithms of the corresponding factors in each case and are found by substituting for M, g and A, their proper values, namely, $\log M = 0.3622157$, $\log g = 1.5073160$ and $\log A = 5.6698914-10$.

In addition to Ingalls' Tables as above described we give, see Table IV, values of $\frac{V^2}{X}$ for each value of $\frac{V}{\sqrt{C}}$ from $\varphi = 45°$ to $\varphi = 70°$. These values were obtained by squaring the values of $\frac{V}{\sqrt{C}}$ in the first column of Ingalls' Tables and dividing the result by the corresponding values of $\frac{X}{C}$ in the same tables.

Correction for altitude.—We have (Artillery Circular N, p. 42)

$$\log(\log f) = \log y_0 - 4.98235$$

in which f is the altitude factor and y_0 is the summit ordinate.

Dividing (15) by (16), member by member, and solving for y_0 we have

$$y_0 = \frac{y_0}{X} X$$

Substituting this value of y_0 in the above we obtain

$$\log(\log f) = \log X + \log \frac{y_0}{X} - 4.98235$$

An examination of the values of the ratio $\frac{y_0}{X}$ for the different values of i shows that for the same value of φ these values differ so slightly from each other that they may for the purpose here considered, be taken as constant and hence equal to their arithmetic mean. Substituting this mean value of the ratio in the above equations for each tabular value of φ we obtain the coefficient of X and thence the subtractive terms of the expressions for log (log f) as given at the head of each page of Ingalls' tables.

Determination of the angle of departure for a target below the level of the battery. Approximate method.—Since Otto's tables and therefore those of Ingalls' are only applicable for the case of the complete horizontal trajectory, it is evident that for a target below the level of the battery we must know the complete horizontal range of the trajectory passing through the target before we can determine the correct angle of departure from the tables.

To find this range we proceed as follows:

Let a, figure 2, represent the position of the target, $ba = y$, its depression below the battery and $Ab = x$, its range; then, if

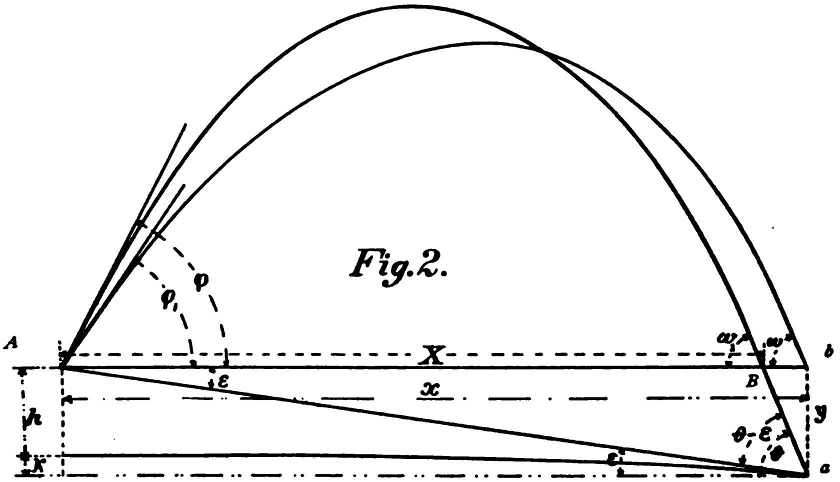

Fig. 2.

y be not too great, the portion of the trajectory Ba may without appreciable error, be taken as a right line; whence the angle ω_1 at B equals the angle θ at a. Now in the trajectory drawn for the point b the angle of fall ω, at b will not differ materially from $\theta-\varepsilon$ at a; whence, substituting for θ its value ω_1, we have

$$\omega_1 = \omega - \varepsilon$$

in which

$$\varepsilon = \tan^{-1}\frac{y}{x}$$

From the above we readily find

$$X = x - y \cot(\omega - \varepsilon)$$

which, with V and C, suffice to determine φ.

If a range table be at hand the value of φ corresponding to X can be taken out directly. In the latter case the application would be greatly simplified were the angle of fall included in the range table.*

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* The range tables for the 12-inch B.L.M., $w = 800$ lbs., including the angle of fall, is given in the appendix herewith.

EXAMPLES.

Example 1.—Given $V = 1000$ f.s.; $\phi = 59°$; $X = 7780$ yards: $d = 12''$; $w = 1000$ lbs.; thermometer 65°; barometer 31″.

Compute the coefficient of reduction, or "c".

With the given data we first find $\frac{V^2}{X}$, thus,

$$\begin{aligned} \log V^2 &= 6.00000 \\ \log X &= 4.36810 \\ \hline \log \frac{V^2}{X} &= 1.63190 \\ \frac{V^2}{X} &= 42.85 \end{aligned}$$

Refering to Table IV, we find for $\frac{V^2}{X} = 42.85$, $\frac{V}{\sqrt{C}} = 386.6$.

We then have,

$$\begin{aligned} \log V &= 3. \\ \log \frac{V}{\sqrt{C_c}} &= 2.58726 \\ \hline \log \sqrt{C_c} &= 0.41274 \\ \therefore \ \log C_c &= 0.82548 \\ \log X &= 4.36810 \\ \text{Const log} &= 5.32914 \\ \hline \log (\log f) &= 9.03896 \\ \therefore \ \log f &= 0.10939 \\ \log \frac{\delta_{\prime}}{\delta} &= 9.98989 \\ \log w &= 3. \\ \text{colog } d^2 &= 7.84164 \\ \text{colog } C_c &= 9.17452 \\ \hline \log c &= 0.11544 \\ \therefore \ c &= 1.3045 \end{aligned}$$

Example 2.—Find the length of the ascending branch of the trajectory of a 7-inch siege mortar shell, $w = 125$ lbs., $c = 1.07$, when $V = 720$ f.s. and $\phi = 61°$. Assume $f = 1$.

The calculations may be arranged as follows:

$$s = \frac{M\kappa^2}{g} \log \frac{(i) - (\phi)}{(i)} \qquad (i) = \left(\frac{\kappa}{V_{\prime}}\right)^2 + (\phi)$$

$$\kappa^2 = \frac{gC}{2A} = [5.53639]C. \qquad \frac{M\kappa^2}{g} = [4.39129]C$$

$$C = f\frac{w}{c\,d^2} \qquad V_{\prime}^2 = V^2 \cos^2 \phi.$$

$$
\begin{aligned}
\log w &= 2.09691\\
\text{colog } c &= 9.97062\\
\text{colog } d^2 &= \underline{8.30980}\\
\log C &= 0.37733\\
\text{Constant log} &= \underline{5.53639}\\
\log \kappa^2 &= 5.91372\\
\text{colog } V^2 &= 4.28534\\
\text{colog } \cos^2\phi &= \underline{0.62886}\\
\log\{(i)-(\phi)\} &= 0.82792\\
(i)-(\phi) &= 6.72853\\
(\phi) &= \underline{2.53678}\\
(i) &= 9.26531\\
\log\{(i)-(\phi)\} &= 0.82792\\
\log (i) &= \underline{0.96686}\\
\log \frac{(i)-(\phi)}{(i)} &= 9.86106-10\\
&= -\ 0.13894\\
\log\left(\log \frac{(i)-(\phi)}{(i)}\right) &= 9.14283_n\\
\log \frac{M\kappa^2}{g} &= \underline{4.76862}\\
\log s &= 3.91145_n\\
s &= -\ 8155.5 \text{ feet.}
\end{aligned}
$$

The negative sign merely indicates that the arc is reckoned in a direction contrary to that of the motion.

Example 3.—Given $d = 12''$; $w = 800$ lbs; $\phi = 58°40'$ and $X = 9000$ yards. Correcting for c and f compute V, T and y_0.

$\phi_{,} = 58°$	$\phi_{,,} = 59°$
From Table a, Appendix, we find	
$c = 1.43$	$c = 1.50$
$\log X = 4.43136$	$\log X = 4.43136$
Const log $= 5.34888$	Const log $= 5.32914$
$\log\ (\log f) = 9.08248$	$\log\ (\log f) = 9.10222$
$\log f = 0.12091$	$\log f = 0.12654$
$\log w = 2.90309$	$\log w = 2.90309$
colog $c = 9.84466$	colog $c = 9.82391$
colog $d^2 = 7.84164$	colog $d^2 = 7.84164$
$\log C_c = 0.71030$	$\log C_c = 0.69518$
$\log X = 4.43136$	$\log X = 4.43136$
$\log \frac{X}{C_c} = 3.72106$	$\log \frac{X}{C_c} = 3.73618$

$$\frac{X}{C} = 5260.9 \qquad\qquad \frac{X}{C} = 5447.3$$

$$\therefore \frac{V_{\prime}}{\sqrt{C}} = 490 + \frac{20.9}{171} \times 10 = 491.2 \quad \therefore \frac{V_{\prime\prime}}{\sqrt{C}} = 500 + \frac{133.3}{168} \times 10 = 507.9$$

$$\log \frac{V_{\prime}}{\sqrt{C}} = 2.69126 \qquad\qquad \log \frac{V_{\prime\prime}}{\sqrt{C}} = 2.70578$$

$$\log \sqrt{C} = 0.35515 \qquad\qquad \log \sqrt{C} = 0.34759$$

$$\log V_{\prime} = 3.04641 \qquad\qquad \log V'' = 3.05337$$

$$\therefore \quad V_{\prime} = 1112.8 \qquad\qquad \therefore \quad V_{\prime\prime} = 1130.8$$

$$\therefore \quad V = 1112.8 + \tfrac{2}{3}(1130.8 - 1112.8) = 1124.8 \text{ f.s.}$$

To find T, we have

$$\frac{T_{\prime}}{\sqrt{C}} = 24. + \frac{20.9}{171} \times .4 = 24.05 \qquad \frac{T_{\prime\prime}}{\sqrt{C}} = 24.7 + \frac{133.3}{168} \times .4 = 25.02$$

$$\log \frac{T_{\prime}}{\sqrt{C}} = 1.38112 \qquad\qquad \log \frac{T_{\prime\prime}}{\sqrt{C}} = 1.39829$$

$$\log \sqrt{C} = 0.35515 \qquad\qquad \log \sqrt{C} = 0.34759$$

$$\log T_{\prime} = 1.73627 \qquad\qquad \log T_{\prime\prime} = 1.74588$$

$$\therefore \quad T_{\prime} = 54.48 \qquad\qquad \therefore \quad T_{\prime\prime} = 55.70$$

$$\therefore \quad T = 54.48 + \tfrac{2}{3}(55.70 - 54.48) = 55.29 \text{ seconds.}$$

To find y_0, we have

$$\phi = 58^\circ \qquad\qquad \phi = 59^\circ$$

$$y_0 = 0.43\,X \qquad\qquad y_0 = 0.45\,X$$

$$\log 0.43 = 9.63347 \qquad\qquad \log 0.45 = 9.65321$$

$$\log X = 4.43136 \qquad\qquad \log X = 4.43136$$

$$\log y_0' = 4.06483 \qquad\qquad \log y_0'' = 4.08457$$

$$\therefore \quad y_0' = 11610 \qquad\qquad \therefore \quad y_0'' = 12150$$

$$y_0 = 11610 + \tfrac{2}{3}(12150 - 11610) = 11970 \text{ ft.}$$

Example 4.—Given $d = 12''$; $w = 1000$ lbs.; $\phi = 58^\circ$; $V = 750$ f.s. and $c = 1.11$. Correcting for altitude find X, v_ω and ω.

With the given data we find

$$\log C = 0.79632$$

and

$$\log \frac{V}{\sqrt{C}} = 299.8$$

From Table IV (Supplement to Artillery Circular M) we find on the page where $\phi = 58^\circ$ and corresponding to the value of $\frac{V}{\sqrt{C}}$ above

$$\frac{X}{C} = 2135 + .98 \times 136 = 2268.3$$

$$\log \frac{X}{C} = 3.35570$$

$$\log C = 0.79632$$

$$\log X = 4.15202$$

$$\text{Const log} = 5.34888$$

$$\log (\log f) = 8.80314$$

$$\begin{aligned} \therefore \quad \log f &= 0.06355 \\ \log C &= 0.79632 \\ \hline \log C_o &= 0.85987 \\ \log V &= 2.87506 \\ \log \sqrt{C_o} &= 0.42993 \\ \hline \log \frac{V}{\sqrt{C_o}} &= 2.44513 \\ \therefore \quad \frac{V}{\sqrt{C_o}} &= 278.7 \end{aligned}$$

With this value of $\frac{V}{\sqrt{C}}$, proceeding as before, we find

$$\frac{X}{C_o} = 1872 + .87 \times 130 = 1985.1$$

$$\frac{V_\omega}{\sqrt{C_o}} = 253 + .87 \times 8 = 259.96$$

and

$$\omega = 59°49' + .87 \times 7 = 59°55'$$

To find X, we have

$$\begin{aligned} \log \frac{X}{C_o} &= 3.29778 \\ \log C_o &= 0.85987 \\ \hline \log X &= 4.15765 \\ \therefore \quad X &= 14376 \text{ ft.} \end{aligned}$$

To find v_ω, we have

$$\begin{aligned} \log \frac{v_\omega}{\sqrt{C_o}} &= 2.41491 \\ \log \sqrt{C_o} &= 0.42993 \\ \hline \log v_\omega &= 2.84484 \\ \therefore \quad v_\omega &= 699.6 \text{ f.s.} \end{aligned}$$

Example 5.*—What elevation must be given to a 12-inch B.L.M. to reach a target distant 7700 yards, the M.V. being 970 f.s. and w being 800 lbs.?

We have $d = 12''$; $w = 800$ lbs.; $V = 970$ f.s., $X = 7700$ yds. or 23100 feet.

$$\begin{aligned} \log w &= 2.90309 \\ \log d^2 &= 2.15836 \\ \hline \log C &= 0.74473 \\ \log X &= 4.36361 \\ \hline \log \frac{X}{C} &= 3.61888 \\ \therefore \quad \frac{X}{C} &= 4158 \end{aligned} \qquad \begin{aligned} \log V &= 2.98677 \\ \log \sqrt{C} &= 0.37237 \\ \hline \log \frac{V}{\sqrt{C}} &= 2.61440 \\ \therefore \quad \frac{V}{\sqrt{C}} &= 411.5 \end{aligned}$$

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* This solution is due to Major F. S. Harlow, A. C.

By inspection of Table IV (Supplement to Artillery Circular M) we find that these values are nearest together, with $\frac{X}{C}$ above $\frac{V}{\sqrt{C}}$, on the page where $\phi = 54^\circ$; consequently the true value of ϕ lies between 54° and 55°.

$\phi_{,} = 54^\circ$	$\phi_{,,} = 55^\circ$

From Table *a*, Appendix, we find

$c = 1.188$	$c = 1.225$
$\log X = 4.36361$	$\log X = 4.36361$
$\text{Const} \log = 5.41415$	$\text{Const} \log = 5.40257$
$\log(\log f) = 8.94946$	$\log(\log f) = 8.96104$
$\log f = 0.08901$	$\log f = 0.09142$
$\log C = 0.74473$	$\log C = 0.74473$
$\text{colog } c = 9.92518$	$\text{colog } c = 9.91186$
$\log C_c = 0.75892$	$\log C_c = 0.74801$
$\log X = 4.36361$	$\log X = 4.36361$
$\log \frac{X}{C_c} = 3.60469$	$\log \frac{X}{C_c} = 3.61560$
$\therefore \frac{X}{C_c} = 4024.3$	$\therefore \frac{X}{C_c} = 4126.7$
$\therefore \frac{V_{,}}{\sqrt{C_c}} = 400 + \frac{40.3}{169} \times 10 = 402.4$	$\therefore \frac{V_{,,}}{\sqrt{C_c}} = 410 + \frac{24.7}{170} \times 10 = 411.5$
$\log \frac{V_{,}}{\sqrt{C_c}} = 2.60466$	$\log \frac{V_{,,}}{\sqrt{C_c}} = 2.61437$
$\log \sqrt{C_c} = 0.37946$	$\log \sqrt{C_c} = 0.37401$
$\log V_{,} = 2.98412$	$\log = V_{,,} = 2.98838$
$\therefore V_{,} = 964.1$	$\therefore V_{,,} = 973.6$

$$\therefore \phi = \phi_{,} + \frac{V - V_{,}}{V_{,,} - V_{,}} (\phi_{,,} - \phi_{,}) = 54^\circ 37.'3.$$

Example 6.—A 12-inch B.L. mortar, $w = 800$ lbs., is fired at a target, distant 7600 yds. with a M.V. of 990 f.s. What should be the elevation assuming the mortar located 102 feet above mean low water?

Here we have $d = 12''$; $V = 990$ f.s.; $x = 22800$ ft.; $h = 34$ yards; $k = 4.15$ yards; (see Table *b*, Appendix) and $y = h + k = 38.15$ yards.

Applying the method outlined above, we first compute ϕ and ω, assuming x to be the complete horizontal range, thus,

$\log x = 4.35793$	$\log V = 2.99564$
$\log C = 0.74473$	$\log \sqrt{C} = 0.37237$
$\log \frac{x}{C} = 3.61320$	$\log \frac{V}{\sqrt{C}} = 2.62327$
$\therefore \frac{x}{C} = 4103.9$	$\frac{V}{\sqrt{C}} = 420.$

By inspection, as in the preceding example, we find that the value of ϕ sought lies between 57° and 58°.

From Table a, Appendix, we find

$\phi = 57^\circ$	$\phi = 58^\circ$
$c = 1.296$	$c = 1.342$
$\log x = 4.35793$	$\log x = 4.35793$
Const $\log = 5.36957$	Const $\log = 5.34888$
$\log\ (\log f) = 8.98836$	$\log\ (\log f) = 9.00905$
$\log f = 0.09736$	$\log f = 0.10211$
$\log C = 0.74473$	$\log C = 0.74473$
colog $c = 9.88739$	colog $c = 9.87225$
$\log C_c = 0.72948$	$\log C_c = 0.71909$
$\log x = 4.35793$	$\log x = 4.35793$
$\log \dfrac{x}{C_c} = 3.62845$	$\log \dfrac{x}{C_c} = 3.63884$
$\therefore \dfrac{x}{C_c} = 4250.6$	$\therefore \dfrac{x}{C_c} = 4353.5$
$\therefore \dfrac{V_{,}}{\sqrt{C_c}} = 420 + \dfrac{101.6}{166} \times 10 = 426.1$	$\therefore \dfrac{V_{,,}}{\sqrt{C_c}} = 430 + \dfrac{108.5}{163} \times 10 = 436.7$

and

$\omega_{,} = 60^\circ 59' + \dfrac{101.6}{166} \times 9 = 61^\circ 4'.5$	$\omega_{,,} = 62^\circ 04' + \dfrac{108.5}{163} \times 9 = 62^\circ 10'$
$\log \dfrac{V_{,}}{\sqrt{C_c}} = 2.62951$	$\log \dfrac{V_{,,}}{\sqrt{C_c}} = 2.64018$
$\log \sqrt{C_c} = 0.36474$	$\log \sqrt{C_c} = 0.35955$
$\log V_{,} = 2.99425$	$\log V_{,,} = 2.99973$
$\therefore\ V_{,} = 986.8$	$\therefore\ V_{,,} = 999.4$

$$\therefore\ \phi = \phi_{,} + \frac{V - V_{,}}{V_{,,} - V_{,}}\,(\phi_{,,} - \phi_{,}) = 57^\circ 15'.2$$

$$\therefore\ \omega = \omega_{,} + \frac{V - V_{,}}{V_{,,} - V_{,}}\,(\omega_{,,} - \omega_{,}) = 61^\circ 21'.1$$

We also have

$$y = -\,(h + k) = -\,(34 + 4.15) = -\,38.15 \text{ yds.}$$

$$\begin{aligned} \log y &= 1.58149_n \\ \log x &= 3.88081 \\ \hline \log \tan \varepsilon &= 7.70068_n \\ \therefore\ \varepsilon &= -\,17'\ 15'' \\ \omega &= 61^\circ\ 21'\ \ 6'' \\ \hline \therefore\ \omega - \varepsilon &= 61^\circ\ 38'\ 21'' \\ \log \cot\,(\omega - \varepsilon) &= 9.73224 \\ \log y &= 1.58149 \\ \hline \log\,(x - X) &= 1.31373 \\ x - X &= 20.6 \text{ yards} \\ \therefore\ X &= 7600 - 20.6 = 7579.4 \text{ yards.} \end{aligned}$$

With X, V and C we now proceed to find φ precisely as before. We have $X = 22738.2$ feet; $V = 990$ f.s.; and $\log C = 0.74473$

$\log X = 4.35676$	$\log V = 2.99564$
$\log C = 0.74473$	$\log \sqrt{C} = 0.37237$
$\log \dfrac{X}{C} = 3.61203$	$\log \dfrac{V}{\sqrt{C}} = 2.62327$
$\therefore \quad \dfrac{X}{C} = 4092.9$	$\therefore \quad \dfrac{V}{\sqrt{C}} = 420$

By inspection we find as before that the value of ϕ sought lies between 57° and 58°.

$\phi = 57^\circ$	$\phi = 58^\circ$

From Table *a*, Appendix, we find

$c = 1.295$	$c = 1.341$
$\log X = 4.35676$	$\log X = 4.35676$
$\text{Const} \log = 5.36957$	$\text{Const} \log = 5.34888$
$\log (\log f) = 8.98719$	$\log (\log f) = 9.00788$
$\log f = 0.09709$	$\log f = 0.10183$
$\log C = 0.74473$	$\log C = 0.74473$
$\text{colog } c = 9.88773$	$\text{colog } c = 9.87257$
$\log C_o = 0.72955$	$\log C_o = 0.71913$
$\log X = 4.35676$	$\log X = 4.35676$
$\log \dfrac{X}{C_o} = 3.62721$	$\log \dfrac{X}{C_o} = 3.63763$
$\therefore \quad \dfrac{X}{C_o} = 4238.5$	$\therefore \quad \dfrac{X}{C_o} = 4341.4$
$\therefore \quad \dfrac{V_{\prime}}{\sqrt{C_o}} = 420 + \dfrac{89.5}{166} \times 10 = 425.4$	$\therefore \quad \dfrac{V_{\prime\prime}}{\sqrt{C_o}} = 430 + \dfrac{96.4}{163} \times 10 = 435.9$
$\log \dfrac{V_{\prime}}{\sqrt{C_o}} = 2.62880$	$\log \dfrac{V_{\prime\prime}}{\sqrt{C_o}} = 2.63939$
$\log \sqrt{C_o} = 0.36478$	$\log \sqrt{C_o} = 0.35957$
$\log V_{\prime} = 2.99358$	$\log V_{\prime\prime} = 2.99896$
$\therefore \quad V_{\prime} = 985.3$	$\therefore \quad V_{\prime\prime} = 997.6$

$$\therefore \quad \phi = \phi_{\prime} + \frac{V - V_{\prime}}{V_{\prime\prime} - V_{\prime}} (\phi_{\prime\prime} - \phi_{\prime}) = 57^\circ 24.'6$$

Example 7.—The range table for the 12-inch B.L. mortar, (see Appendix) $w = 800$ lbs., gives, for $X = 7400$ yards and $V = 917$ f.s., $\phi = 50^\circ$ and $\omega = 53^\circ 34'$. What would be the elevation if the mortar were 363 feet above mean low water?

Here we have, $\omega = 53^\circ\, 34'$, $x = 7400$ yards, $h = 121$ yards, $k = 3.93$ yards (see Table *b*, Appendix); and $y = h + k = 124.93$ yards.

$$\log y = 2.09667_n$$
$$\log x = 3.86923$$
$$\log \tan \epsilon = 8.22744_n$$
$$\therefore \quad \epsilon = -58'$$
$$\omega = 53^\circ 34'$$
$$\omega - \epsilon = 54^\circ 32'$$
$$\log \cot (\omega - \epsilon) = 9.85273$$
$$\log y = 2.09667$$
$$\log (x - X) = 1.94940$$
$$\therefore \quad x - X = 89 \text{ yards.}$$
$$\therefore \quad X = 7400 - 89 = 7311 \text{ yards.}$$

Referring to the range table we find for $X = 7311$ yards

$$\phi = 51^\circ\ 13'$$

A second approximation, using the value of ω corresponding to $X = 7311$ yards, gives a value of ϕ of 51° 12′ and as this value differs by but one minute from the value obtained by a single approximation it would appear that a single application of the method outlined gives sufficiently approximate results for all practical purposes.

APPENDIX.

TABLE a. Values of "c" for 12-inch B.L.M. W = 800 lbs.

Range	4000	5000	6000	7000	8000	9000	10000
φ	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*
45°	1.19	1.01	1.01	1.00	1.01	1.05	1.14
46	1.20	1.03	1.02	1.00	1.01	1.07	1.15
47	1.21	1.06	1.03	1.01	1.02	1.09	1.16
48	1.23	1.08	1.04	1.02	1.03	1.11	1.18
49	1.25	1.11	1.05	1.03	1.04	1.13	1.20
50	1.27	1.13	1.07	1.05	1.06	1.15	1.22
51	1.30	1.15	1.08	1.07	1.09	1.16	1.24
52	1.33	1.17	1.10	1.10	1.12	1.18	1.26
53	1.36	1.19	1.12	1.13	1.16	1.20	1.29
54	1.39	1.21	1.15	1.16	1.20	1.23	1.32
55	1.42	1.24	1.18	1.19	1.24	1.27	1.35
56	1.45	1.27	1.22	1.22	1.28	1.32	
57	1.48	1.30	1.26	1.26	1.32	1.37	
58	1.51	1.33	1.30	1.30	1.37	1.43	
59	1.54	1.36	1.35	1.34	1.42	1.50	
60	1.56	1.40	1.40	1.39	1.47	1.58	

TABLE b.

Curvature of the Earth Computed by the Formula.

$$k = [2.8561406]R^2.$$

k = curvature in yards. R = range in yards.

R	k	R	k	R	k	R	k	R	k
yds.	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*	*yds.*
1000	0.07	4000	1.15	7000	3.52	10000	7.18	13000	12.14
1100	0.09	4100	1.21	7100	3.62	10100	7.32	13100	12.32
1200	0.10	4200	1.27	7200	3.72	10200	7.47	13200	12.51
1300	0.12	4300	1.33	7300	3.83	10300	7.62	13300	12.70
1400	0.14	4400	1.39	7400	3.93	10400	7.77	13400	12.89
1500	0.16	4500	1.45	7500	4.04	10500	7.92	13500	13.09
1600	0.18	4600	1.52	7600	4.15	10600	8.07		
1700	0.21	4700	1.59	7700	4.26	10700	8.22		
1800	0.23	4800	1.65	7800	4.37	10700	8.37		
1900	0.26	4900	1.72	7900	4.48	10900	8.53		
2000	0.29	5000	1.80	8000	4.60	11000	8.69		
2100	0.32	5100	1.87	8100	4.71	11100	8.85		
2200	0.35	5200	1.94	8200	4.83	11200	9.01		
2300	0.38	5300	2.02	8300	4.95	11300	9.17		
2400	0.41	5400	2.09	8400	5.07	11400	9.33		
2500	0.45	5500	2.17	8500	5.19	11500	9.50		
2600	0.49	5600	2.25	8600	5.31	11600	9.66		
2700	0.52	5700	2.33	8700	5.43	11700	9.83		
2800	0.56	5800	2.42	8800	5.56	11800	10.00		
2900	0.60	5900	2.50	8900	5.69	11900	10.17		
3000	0.65	6000	2.59	9000	5.82	12000	10.34		
3100	0.69	6100	2.67	9100	5.95	12100	10.51		
3200	0.74	6200	2.76	9200	6.08	12200	10.69		
3300	0.78	6300	2.85	9300	6.21	12300	10.86		
3400	0.83	6400	2.94	9400	6.34	12400	11.04		
3500	0.88	6500	3.03	9500	6.48	12500	11.22		
3600	0.93	6600	3.13	9600	6.62	12600	11.40		
3700	0.98	6700	3.22	9700	6.76	12700	11.58		
3800	1.04	6800	3.32	9800	6.90	12800	11.76		
3900	1.09	6900	3.42	9900	7.04	12900	11.95		

5900	57	12	60	27	43.1	4	09														
6000	56	21	59	47	42.7	4	00				10000	59	17	65	07	61.0	4	30		51.60	1220
6100	55	24	58	38	42.2	3	51				10100	58	57	64	47	60.8	4	27			
6 6200	54	19	57	34	41.6	3	41				10200	58	35	64	25	60.6	4	23			
6300	53	06	56	21	40.9	3	30				10300	58	11	64	03	60.4	4	19			
6400	51	45	55	00	40.1	3	18				10400	57	45	63	37	60.2	4	15			
6500	50	15	53	27	39.2	3	05				10500	57	17	63	11	59.9	4	10			
6600	48	10	51	20	38.0	2	50				10600	56	47	62	43	59.5	4	05			
6700	45	00	48	01	36.1	2	34				10700	56	15	62	14	59.1	4	00			
											10800	55	40	61	43	58.7	3	54			
6300	59	51	63	29	47.2	4	36		36.40	917	10900	55	02	61	11	58.3	3	48			11
6400	59	10	62	49	47.0	4	29		or		11000	54	21	60	33	57.9	3	42			
6500	58	29	62	21	46.7	4	22		70.00		11100	53	37	59	53	57.4	3	35			
6600	57	48	61	28	46.4	4	15				11200	52	49	59	10	56.8	3	27			
6700	57	06	60	46	46.0	4	08				11300	51	57	58	22	56.1	3	19			
6800	56	21	60	00	45.6	4	00				11400	51	02	57	30	55.3	3	11			
6900	55	33	59	11	45.2	3	52				11500	50	03	56	34	54.5	3	03			
7 7000	54	40	58	18	44.7	3	44				11600	49	00	55	33	53.7	2	54			
7100	53	41	57	18	44.1	3	35				11700	47	45	54	20	52.3	2	45			
7200	52	35	56	13	43.4	3	25				11800	45	00	51	41	50.0	2	34			
7300	51	22	54	58	42.6	3	14														
7400	50	00	53	34	41.7	3	03														
7500	48	20	51	50	40.7	2	50														
7600	45	00	48	34	38.6	2	34														

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* Each *smokeless powder* cartridge to have 10 ounces igniter (black rifle powder) at each end, in addition to above charges

† B. P.—Brown Prismatic.

TRAINING RANGES AND LONG RANGE-FIRING

BY LIEUT.-COMMANDER W. S. SIMS, U. S. N.

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WHILE it is true that the principles of gunnery training, long-range firing, and range-firing are well known and have been explained in publications within the past few years, it is also true that many officers are apparently not sufficiently acquainted with them. This is due partly to the inaccessibility of these publications, partly to the almost universal disinclination to read anything not contained in current numbers; but, doubtless, also to their being written in a form not always easy to comprehend, because of the assumed acquaintance on the part of the readers with certain of the essential principles involved.

It is for the above reasons that I have attempted the following explanation of this important subject; and I hope that it will be the means of changing certain opinions (that I believe are now impeding our progress), held by many whose present duties necessarily prevent them giving these matters close attention.

The conditions of record target practice, having been frequently published, are two well known to require a detailed description. The firing is conducted during fair weather, the speed of the ship is prescribed, the course is marked by a line of buoys, the limits of range are between 1400 and 1600 yards and the target is a rectangle, 17 feet high by 21 feet wide. Manifestly, these are not the conditions we may expect in battle; then we shall have to take the weather as it comes, there will be no line of buoys, the enemy will not be stationary, the ranges will vary continuously and sometimes rapidly, and will probably never be as small as 1600 yards. Therefore, certain critics declare that this is "trick shooting," and is of no practical value; that the range for record practice should be largely increased; that the ships should fire in a sea way; that there should be no line of buoys; that the target should be under way, that ammunition should not be wasted upon cut-and-dried shooting, and, in a word, that all firing should be at battle practices, in order that our gunnery training may always be of a "practical" nature.

There are many other opinions that closely resemble those just quoted; and besides there is the persistent traditional opinion that the famous man behind the gun (the gun-pointer) should be a real marksman (not simply the man that points the gun), and should be trained to estimate the distance of the enemy, to observe the fall of his shot and correct the sight-bar setting accordingly, to allow for the change of bearing due to the speed of his ship and that of the enemy, to estimate and allow for the force of the wind, etc., etc.

The object of this paper is to show that such opinions, though formed in all honesty, are founded some upon misconceptions of the requirements indispensable to success in teaching men to *aim* accurately, and some upon certain mistaken facts.

It is admitted, of course, that the ultimate object of all gunnery training is that when we meet the enemy upon the sea, we may be able, no matter what the weather conditions, range, etc., to hit him more times per minute than he can hit us. It follows that any stage or any feature of the training that does not contribute directly to this result, may be either unnecessary, and therefore simply a waste of ammunition, or it may be false training, and perhaps dangerously misleading.

Before we can discuss profitably the question of proper methods of training pointers, we must first settle the fundamental principle upon which our system is to be based; that is, we must decide whether the man that fires the gun is to be trained as a gun-pointer, whose sole duty is to aim as ordered, or as a *marksman,* that is, a man that estimates the range, directs the setting of the sight, aims, fires, observes the effect of his shot, etc.

It goes without saying that if this could be successfully accomplished, the advantages would be very great, and the whole question of gunnery training would be simplified; for if the men that fire the guns could be trained to expertness as marksmen, in the same sense that a hunter is a marksman, the commanding officer of a man-of-war would need only to designate the target and give the order: "You may fire when you're ready," and the duty of his divisional officers would consist in seeing their guns served with rapidity and safety. The advantages of such a system are so manifest that there could be no valid reason for not adopting it unless it could be shown to be quite impracticable. This therefore, is the first question to be settled, for, otherwise, the advocates of the different systems cannot advance beyond the stage of reflecting upon each others intelligence.

The whole question of the possibility of training a man as a successful great-gun marksman depends upon the possibility of training the human eye (either naked or using a telescope, and whether observing from a casemate, a turret, or an open gun-port—all relatively near the water) to estimate distances with sufficient accuracy to insure hitting—or, what will answer the same purpose, to estimate with sufficient accuracy the amount by which his shots miss his target. If distances up to about the maximum battle ranges can be estimated with accuracy by the eye, then it might be possible to train the pointer as a marksman—though even then it would be exceedingly difficult, as it would require a very cool and nimble brain to apply all the necessary corrections with sufficient rapidity and accuracy. If, on the contrary, the errors in estimating the distance are in the majority of cases so great as to render the method useless—that is, so great as to render hitting very improbable, then the traditional marksman is a myth, at least as applied to the conditions of modern gun-fire.

Fortunately, it is no longer a question of opinion, but of fact; and, as usual, it is a case of the familiar shield with different colored sides. From the time that great-guns were first used on board fighting ships, up to a comparatively recent date, the guns were so weak that ranges were necessarily very short, the vertical angle subtended by the enemy was consequently large, and the accuracy required to make hits was not great. In those days the pointer habitually estimated the distance of the enemy with considerable success. In some cases he made his estimates by an unconscious method depending upon the quality of the so-called "nautical eye," which, we are informed, is no longer found in the theoretical heads of those who have never really acquired the "sea habit." Sometimes the method was more scientific, if not more successful. When all men on the enemy's decks looked alike, the range was 1000 yards, or over; at 800 yards you could distinguish a man from an officer; at 600 yards you could make out a pair of well-developed side whiskers; at 400 yards you could hear the men swearing; and so on down to the range at which you could see the whites of their eyes. The traditional pointer made his allowance for range by selecting his point of aim, the topsail yard being a favorite. He was the Captain of his gun, and he did not want advice from anybody.

Since the introduction of rifled guns of high velocity, and the consequent increase in fighting ranges, all this is changed—except the opinions above indicated. As a matter of fact, it has been demonstrated by exhaustive experiments that it is quite impossible for the eye to estimate distances greater than about 2000 yards with anything like sufficient accuracy to be of use in directing gun-fire. For example, the following conclusions derived from a test made by about 30 observers (one-third being experienced officers and the remainder principally gun-pointers) will show the futility of such a method.

"(1) The estimates are so wild as almost to preclude laying down any laws or drawing any conclusions. The averages of errors, however, compare favorably, increasing with an increase of range, as would be expected, and from these averages certain deductions may be drawn.

"(2) The probable error on a single estimate at any range is so uncertain as to be worthless for any gunnery purposes. At 1193 yards, when the vessels were broadside on, 19 out of 20 observers on the battleship, and 4 out of 6 observers on the torpedo boat estimated the range within one-half of the danger space of a 20 foot target, but even at this short range there was a variation of 1200 yards between extreme estimates; and, later on, at the same range, with vessels end-on, the number of these same observers who estimated within one-half of the danger space of the target were reduced, respectively, to 8 and 3, and the extreme limits of variation of estimates rose to 2400 yards, showing the great effect of the difference of conditions of position alone on estimates made by the same men.

"(3) Beyond 2100 yards, in no case did more than one observer on each vessel estimate within one-half of the danger space of a 20-foot target. Between 2000 and 2100 the number who estimated with this degree of accuracy were, battleship 5; torpedo boat 2; but it must be noted that the observers who estimated with this degree of accuracy, say at 2100 yards, would not be the ones who did it at 2000 or 2095 yards, thus showing the mere chance of the estimates, and the futility of ever counting on this method of range-finding in action." [*]

If anything further is needed to demonstrate the uselessness of attempting to train a modern pointer as a marksman, the results of similar and equally conclusive tests show that,

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[*] The half danger spaces above referred to are those of the 6-inch 40-caliber gun, I.V. 2400 f.s., which are about as follows: 260 yards at 1200, 140 at 2000, 75 at 3000, 45 at 4000, 30 at 5000, and 20 at 6000. For comparison, the half danger space of the 12-inch 40-caliber gun, I.V. 2800 f.s., is as follows: 395 yards at 1200, 230 at 2000, 140 at 3000, 100 at 4000, 70 at 5000, and 55 at 6000.

even if the pointer were able to estimate the amount that his shots fall short, it would be, in the great majority of cases, impossible for him to identify his own shots, when a number of guns were firing at the same time, because the smoke and gases from his own and from adjacent guns very seldom permit him to observe his projectiles throughout their flight, though his opportunities for aiming and firing may be very frequent.

Assuming, therefore, that the pointer is to be trained simply to point his gun as directed. and that his sight will be set by direction of skilled range-officers advantageously placed for observing, it remains to discuss the means by which we can *train* pointers, in the shortest space of time, and with the least expenditure of ammunition, to such a degree of expertness that they may be *depended upon* always to point their guns quickly and with unfailing accuracy.

It is, of course, not proposed to give a detailed description of these methods, but simply to determine, if possible, the conditions that are indispensable to success in *training* a man to *aim* with accuracy, the requirements of a method that will test fairly his skill and his nerve, and the rational way of employing the pointers after they have achieved expertness.

Before proceeding with the exposition of the simple principles involved, I feel that almost an apology is due for the elementary nature of some of the following explanations and illustrations; but I believe that they may be useful in dislodging certain singularly tenacious opinions held by men of influence who have apparently not taken the pains to analyze the basis of their convictions.

It will at once be admitted that no real progress could be made in *training* a recruit unless you use a gun that is accurate enough to make a hit every time it is accurately aimed. This applies, of course, to sub-calibre practice of any kind. For example, suppose your sub-calibre tube is an old-fashioned blunderbuss that cannot be depended upon to make one hit out of 10 shots on a target of a certain size at a certain range, even if the gun and the target are solidly planted on shore, and the gun is accurately aimed by an expert. Manifestly, any attempt to *train* a recruit with such a machine would be a waste of ammunition, not to mention your time and his; for when the recruit fires and makes a miss, he learns nothing by the experience. If, however, you substitute a modern rifled tube that can be depended upon to hit every time when accurately aimed, then when the recruit fires and misses, he has learned something;

he knows, in the first place, that the fault was his and not the gun's, and the position of the miss, with reference to his supposed point of aim, shows him where he made his error in aiming.

The principle involved is that, for efficiency in training pointers to aim, the conditions must be such that the gun will make a hit in the bull's-eye *every time* it is accurately aimed thereat; in other words, that the shot and the line of sight will always pierce the target in practically the same place. I say in "practically" the same place, because no gun is absolutely accurate, no matter how short the range. The point is that the range must be short enough and the target large enough to ensure a hit every time the gun is accurately aimed. This is the gist of the whole matter, and its very simplicity is possibly the reason of its being so persistently misunderstood. Therefore, at the risk of being tedious, I will further illustrate it as follows:

Suppose you secure a modern, high-powered, .30-calibre rifle in a heavy vise in such a manner that it will not be deranged in the least by the shock of discharge; and suppose the line of sight to be directed at the middle of a screen placed at a distance of, say, 300 yards. Fire a few shots, and you will probably find that no two of them have pierced the screen at the same point. The best cartridges differ slightly in power from each other, the bullets are not absolutely uniform in shape, weight and position of centre of gravity, there are slight differences in the way they "take" the rifling, the latter is not perfect, etc., etc. I assume all other causes of deflection to be eliminated, as, for example, the effect of wind, etc. If, therefore, you fire 1000 shots, you will find that the holes in the screen are distributed about uniformly over a certain area. Draw a line around these holes, including all of them, and you will find that the figure is nearly a circle (more nearly an ellipse, I believe) of a certain diameter, say 4 inches. If you fire a second string of 1000 shots, with the same quality of ammunition and under the same conditions, they will all fall within this circle.

Similarly, a "perfect shot" who aims exactly at the center of this circle will make a hit every time he fires. Of course a perfect shot does not exist; no man can train his muscles to such a degree of refinement as to hold a rifle perfectly still. Experience shows, however, that a man can be trained so that his line of sight will not vary from the point of aim more than a certain amount. Suppose this amount to be such that the line of sight remains within a circle 4 inches in diameter on the screen at 300 yards. Such a man we will call a "good shot." Then, if the diameter of the circle enclosing the shot holes be increased from 4 to 8 inches, it is evident that a "good shot" could hit this bull's-eye, 8 inches in diameter, every time. Therefore, in order to train men (using this gun and ammunition) to *aim accurately*, the relation between the size of the bull's-eye and the range at which it is used, should be as 8 inches is to 300 yards (for ranges not differing much from 300 yards). If the range is reduced to 150 yards, the diameter of the bull's-eye should be something less than 4 inches; similarly, if the range is increased to 600 yards, the bull's-eye should be somewhat more than twice as great as at 300 yards. As a matter of fact, it is made 2.5 times as great for 600 yards, or six times as great in area.* Neglecting for the sake of simplicity of explanation, all causes of error except those above mentioned, we see, therefore, that a "good shot" can hit with equal facility at any of the three ranges indicated, provided the diameter of the bull's-eye bears a certain necessary relation to the range.

For the remainder of this illustration, I assume the bull's-eye to be used as the target—that is, the bull's-eye alone, not surrounded by a screen that will show the amount by which shots miss it, as is the case with the regulation army target. The reason for this assumption will be shown later when an essential feature of great-gun targets is explained.

If, then, such a bull's-eye target is made much too large (to put the extreme case, suppose it to be 10 feet in diameter), a man need not be a "good shot" to hit; therefore a green man cannot be trained to expertness by the use of it. If, on the contrary, the target is much to small (say one inch in diameter), it is almost entirely useless to attempt to train him to expertness by firing at it. For example, suppose that the 8-inch bull's-eye is used as a target at 600 yards, instead of the 20-inch one. As the former is but one-sixth of the area that it should be at this range (600 yards),. it is evident that even the "good shot" cannot expect to hit it more than once in six shots, on an average. Therefore, to attempt *to train a green man* by using the 8-inch bull's-eye as a target at 600 yards is largely a waste of time and ammunition.

The above will, I believe, make it clear, that for purposes of *training a pointer to aim accurately*, or *as a test of his*

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* The diameters of the bull's-eyes of regulation army targets are as follows: 8 inches for 200 and 300 yards, 20 inches for 500 and 600 yards, and 36 inches for 900 and 1000 yards.

acquired accuracy, the size of the target must bear a certain definite relation to the range—depending both upon the unavoidable errors of the gun used and upon the normal error in aiming of "good shots." It follows that if the target is reduced in the proper proportion, a very short range may be used with equal advantages, as far as concerns training a man in *accuracy of aiming alone*, which, of course, must first be attained before any further progress is possible. For example, a man can be trained to aim accurately by practicing at a range of less than 50 yards, provided the target is reduced in size to correspond therewith; or by placing a small 22-calibre tube in a rifle, he may practice with advantage at 50 feet or less. Most officers are familiar with this principle, and with its important application.

It may be replied that if the above is true, there would apparently be no reason for training riflemen at long ranges; and this would be true if the fire of riflemen could always be controlled in battle in the same manner and with the same efficiency as that of a number of heavy guns firing from the same position—grouped on the same ship. The frequent necessity for independent action on the part of the rifleman forbids this, to a large extent. Therefore the rifleman must be trained as a *marksman*. He must have the skill of the big-game hunter in estimating the distance, setting the sight, allowing for wind, etc., when firing at long ranges. In order to give him this skill, he must be trained by actually firing at long ranges—but each range must have a target of the proper size, otherwise the firing is not a training.

If the fire of riflemen could, upon all occasions, be controlled by their officers much more effectively than is now possible by the best riflemen acting independently, it would be advisable to train them as accurate pointers only, and not as marksmen. Battle firing at long unmarked ranges is, necessarily, not very accurate, even under favorable conditions. The average of shots fired to men killed is very great.

The principle of the proper relation between the range and the size of the target necessary for successful training applies to all calibre of guns from .30-calibre rifles to 13-inch turret guns; and, for certain calibres of naval guns, the dispersion of accurately aimed shots has been obtained by actual firing on shore against a screen target. Experience in firing guns of different types mounted on board ship has supplied similar, though less accurate, information. It is from a consideration of such data that the relation between the record-practice range and the size of the target has been determined. It would, of course, be desirable to have a different sized target for each calibre of gun that fires at the same range, but as this is impracticable, the target is made large enough to include all the unavoidable errors of any of the guns that use it.* Thus, the target for all guns above 3-inch in calibre is 17 feet high by 21 feet long, and the range is 1400 to 1600 yards.

This target is larger than would be necessary to catch all shots that are aimed with perfect accuracy and fired at a distance that is exactly known—which would be the conditions existing if the gun and target were on shore. But when firing at sea, perfect accuracy in aiming cannot often be attained, and there is always more or less error in range; therefore the screen must be enlarged accordingly. It may be a trifle too small for some conditions of sea firing and a trifle too large for others, but this is not apparent from the results of firing under the condition of record practice. For convenience of illustration, it will therefore be assumed to be of exactly the correct size for the gun in question, when firing at 1600 yards.

Note that the entire area of this target (assuming it to be the correct size) corresponds to the bull's-eye of a rifle target, and the so-called "bull's-eye" (51 inches square) that is painted in the middle of the 17 by 21 rectangle, corresponds to the 4-inch circle, mentioned above in connection with the 8-inch bull's-eye of the small-arm target used at 300 yards. In one case, the rifleman ("the good shot") is supposed to keep his line of sight within a 4-inch circle, at 300 yards; and in the other case, the gun-pointer (also a "good shot") must not aim outside of the 51-inch square, if he wants to be *sure* of making a hit. Of course it would be a great convenience in spotting misses, if we could use a very large great-gun target, say, 60 feet square, with the present target (17 by 21) painted in the middle of it, and hits on the latter only to count; but such targets would be impracticable to handle, not to mention the expense of mounting them.

The requirement that the great-gun pointer shall aim within the 51-inch square (assuming this to be the proper size for the aiming spot) refers to firing under the conditions of record practice. These limits are necessary on account of the difficulty of holding the line of sight steadily within them during the

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* For reasons that need not be stated here, we continue to fire some guns on the 1000-yard range when a consideration of their ballistic qualities alone would assign them to a longer range.

"firing interval," while the ship has a certain amount of motion; of course with a naval gun and target on shore, an entirely unskilled person can place the wires on any indicated point, within a few inches.

Record "target practice" is a misnomer which we have inherited from the past, but which it would be inadvisable to change at this time. It is, in reality, principally a "firing test" to determine the actual skill of the pointers and gun crews. Before it begins, a division officer knows almost exactly the relative accuracy and rapidity with which his various pointers can aim, but in the case of untried pointers, he does not know whether or not they will show the necesary nerve and steadiness under the excitement of firing. Sometimes he is disappointed to find that an otherwise excellent pointer gets "rattled"; but there is one thing that both he and all of his pointers understand thoroughly, namely, that a hit will be made every time that the gun is accurately aimed and no mistakes are made in ranges, etc.; that the target is large enough to include all of the errors of gun-fire afloat, that cannot be avoided by any precautions on their part, such us differences in the initial velocity of different charges, etc., etc. In other words, the relation between the range and the size of the target is such that all hands know that the result of the shooting is a fair comparative test of the skill of the personnel, and that success does not depend upon luck; hence the intensity of loyal competition, without which only indifferent success can be attained in gunnery training, or in any other training requiring skill and dexterity.

As far as concerns training alone, there would be no objection to doubling the present range, provided the target were made just large enough to catch all well-aimed shots. For most guns this would probably require a screen somewhat more than twice as high and twice as wide, or more than four times as great in area as the present one. To hold up the present screen (17 by 21) in a moderate breeze, requires a target raft weighing 6 tons, and 700-pound anchors with 3½-inch mooring lines; so it may be imagined what gear would be necessary to carry more than four times as much sail; and in many respects the result of the firing would be less satisfactory than under the present condition,—not to mention the increased difficulties of spotting and of handling heavier screens, the longer distances to be travelled by the ship and the repair boat, and the consequent loss of time, etc.

If the present target were used at 3200 yards, the best pointers could not make more than about one hit out of four shots, under the ordinary conditions of practice, and, consequently, the firing would not be a true test of skill ; the element of luck would enter so largely into the result that the spirit of competition would disappear, and with it the efficiency of team-work and the skill of the pointer.

Firing under such conditions would be, in effect, the same as using the blunderbuss to test the skill of a rifleman. As an instrument for training pointers, the very best gun becomes a blunderbuss when the range is much too great or the target much too small. Many years ago, all of our target practice was exclusively blunderbuss training. We fired at a small triangular target (about one-seventh the area of the present one) that a perfect pointer could not hit once out of many shots. Consequently, we did not expect to hit it. We estimated the amount by which a pointer missed this target, and we now know these estimates to have been greatly in error. Unless the misses were very wide, we were quite satisfied. We had to be, for there was no standard with which the accuracy of a shot could be compared. The consequence was that the pointers learned almost nothing. To double the present range without doubling the size of the target, which is impracticable (as well as useless), would be to reproduce the blunderbuss training of the past in all the essential particulars that rendered it largely a waste of ammunition.

It is therefore apparent that in order to *train the individual pointer* and test the effectiveness of his training, we must fire at about the present range (1600 yards) as long as we use a target of the present size (17 by 21). In any event, we must always maintain a certain definite relation between the size of the target and the range at which it is used. In all cases where this relation pertains, it would be convenient to call it a "training range."

I am aware that, for this year's prize firing, the British have changed the range from 1600 to 2700 yards, but they have not thereby changed the principles involved. They have increased the area of the target somewhat, but if they have not given it the size necessary to insure a hit for every shot that is well aimed, the consequence will be that the result of their prize firing of 1904 will not be a true test of the skill of the pointers, and the efficiency of the training of the latter must inevitably suffer.

We all know that we can train gun-crews and gun-pointers to a high degree of skill—this skill being measured by firing under the conditions of record practice. "But," object the critics, "of what use are such pointers if they cannot make a large percentage of hits at long range?" "Why do we waste ammunition on 'fool shooting' at 1600 yards when we should be teaching our pointers to make 60% of hits on an enemy at 5000 or 6000 yards?" "What is the sense in conducting practice always under favorable conditions when we may have to fight an enemy in an ocean swell?" etc., etc.

I beg that it will not be assumed that these questions represent straw men that I have set up in order to demolish them. They are actual questions propounded, not in the winning spirit of the seeker after useful information, but with a marked elevation of one side of the lip, a habit peculiar to the unthinking. The confusion of thought indicated by such questions may be shown by a few simple illustrations.

A perfect pointer, firing a perfect gun, with the sight-bar correctly set, could put every shot through a bull's-eye, equal to the diameter of the projectile, at any distance up to the maximum range of the gun. Even the critics know this, but they greatly underestimate the influence of the errors involved when they insist that a system of training is not a practical one unless the pointer can eventually make a large percentage of hits at a long range.

In principle the matter is so simple that it would seem that all differences of opinion should disappear with a careful consideration of the facts.

When a great gun is fired at a target at a considerable range, there are a dozen or so different errors that may contribute to decrease the possible percentage of hits. It will not be necessary to consider all of these individually, in order to illustrate the combined influence of certain errors in decreasing hits at all ranges that are greater than the "training range,"—that is, greater than the maximum range at which a good shot can make a clean string of hits on the target used. For the sake of simplicity, only errors in range will be considered.

Though the charges of smokeless powder are made up at a proving ground with all possible care, it is found that even those of the same index will vary in initial velocity from 15 to 25 foot-seconds from the desired velocity. Thus the extreme variation of one of these charges from another may be from 30 to 50 foot-seconds. The temperature at which they are fired may increase or decrease this variation. The powder sometimes becomes irregular with age. The weight of the shell or the diameter of the rotating band, may change the range appreciably. Usually the effect of such errors cannot be anticipated and allowed for by the personnel on board ship. They are commonly called the "unavoidable errors" of the gun. Suppose that, with a certain gun firing at 1600 yards, their maximum effect, when they all act in the same direction, is to displace the shot four feet vertically, either up or down from the point of aim. If such a gun were mounted on shore, and each shot accurately aimed at the center of a screen, this screen would have to be eight feet high in order to catch all shots fired at its center. Therefore, if the same screen is placed at 3200 yards from the gun, it is evident that more than half of a large number of shots will miss it—going either too high or too low—and at 6000 yards, more than two-thirds will miss it; and these misses, being due to the "unavoidable errors" of the gun, cannot possibly be diminished, except by diminishing the errors. That is, if a pointer can be trained to absolute perfection, it would be entirely impossible for him to avoid making the percentages of misses indicated while using the gun in question, at this range.

Now suppose the gun described above to be fired from a ship's deck, at the same range (1600), under the usual conditions, i.e., aimed and fired rapidly in fair weather. Several additional errors are at once introduced. The pointer is not perfect. The best he can do is to keep his aim within a certain distance of the center of the target, the range is not very accurately determined, even when marked by buoys; the sights are inevitably somewhat out of adjustment; the jump of the gun varies sometimes according to the angle (from abeam) at which the gun is fired. etc., etc. Suppose that these additional errors, when acting in the same direction, amount to 4.5 feet, either up or down. The "unavoidable errors" of gun-fire (with this particular type of gun) on board ship are, therefore, 4.5 feet, either way, consequently the target must be 9 feet higher, or 17 feet in all to catch all shots. In other words, when a 17-foot target is used for this gun, the proper "training range" is 1600 yards. No attempt at exact accuracy is made in the figures used—they are assumed for purposes of illustration only.

It is evident, therefore, that with a ship anchored in fair weather, the range known within narrow limits, and the gun fired by a good pointer, it is possible to hit the target every time only when the range is 1600 yards or less (supposing the figures assumed to be correct). If the range is doubled, then less than half the number of hits can be made. It is simply impossible to make, on an average, more than 50% of hits on this target, at this range, and with the unavoidable errors assumed. No amount of training can improve the results appreciably, as I have assumed the pointing to be done by one of the most expert pointers (whose error in aiming is assumed to be very small), and all the other errors are unavoidable with the gun in question. The percentage of hits at this range (with this gun) can be increased only by more uniform powder, more accurate sights, more accurate methods of determining range, etc.

This should dispose at once of the astonishing opinions one frequently hears expressed, to the effect that a large percentage of hits should be made at long ranges, when the fire control system is sufficiently improved and the *pointers become expert at those ranges*—the assumption being that when we can determine the range accurately, the pointers should hit every time.

Thirty-two hundred yards is not a very long range. If the screen in question is placed at 6000 yards, it is evident that less than one-third of the shots will hit. As a matter of fact, very much less than one-third will hit, as the dispersion of the shots becomes greater with the range, which must be known within much narrower limits in order to make a hit, even with a gun free from error, because the danger space of the target at a long range is relatively very small. Knowing the maximum errors of pointing, the errors in range of the guns, etc., the probability of hitting could be calculated for this range, but as this paper concerns only the principles involved, this is not necessary. It may be assumed, however, that at 6000 yards the probability of hitting under the conditions in question (a ship at anchor, etc.), would not be greater than one hit in six shots. Therefore the maximum that the best pointers could do under the very best conditions, with this gun, is 100% at 1600; 40%, say, at 3200 yards, and 16% at 6000 yards; and this will be considerably diminished, especially at long ranges, by lateral misses.

Nor is this all; for when you come to practice shooting at a towing target, from a moving ship, the most fruitful source of error is in keeping the range. As an example, take the conditions at 6000 yards. The danger space of the target is, say, 50 yards, i.e., a shot that just misses the top of the target will strike 50 yards beyond. You must therefore know the actual distance (or correct sight-bar range) within 25 yards in order to hit every time with an *errorless gun*; and the best range-finders have an error of 100 yards at this range. Therefore, with both an *errorless gun and an errorless pointer* the chances of hitting are very small. Add to this all the unavoidable errors of gun-fire and of aiming at sea, and it requires no calculation to see that the maximum possible hits on a target 17 feet high at 6000 yards would be exceedingly small.

Previous explanations have shown, I believe, that it would be absurd to attempt to *train* green men by firing at a 17 foot target at 3200 or 6000 yards, but that, with this target, the 1600 yard range fulfils approximately the requirements for training a man to aim accurately, and for testing the results achieved. With permanence in gun stations we can doubtless bring up the general average of our pointers and thereby increase our efficiency, but there is a limit to the degree of skill to which a man's muscle can be trained in handling a heavy gun. For purposes of illustration suppose that the best pointers can aim within a bull's-eye, or aiming spot, 4 feet in diameter at 1600 yards. That is to say, the angular variation of the line of sight from the center of the bull's-eye, while aiming, is not more than 2 feet, or 1 minute 35 seconds of arc. Improvements in gun-gear and sights may enable us to reduce this somewhat; but let us suppose this to be the least variation at present attainable under moderately favorable weather conditions.

As this angular variation of the line of sight will be the same at all ranges, it follows that the longer the range the greater the vertical error in the fall of the shot, due to the error in aiming. For example, under the conditions assumed. this error is 2 feet at 1600, 4 feet at 3200, and 7.5 feet at 6000 yards. That is to say, the vertical dispersion of shots, fired by the most skilful pointer will be 4, 8 and 15 feet, respectively, at 1600, 3200 and 6000 yards; and still those who do not take the trouble to reason out these simple propositions, have shown themselves ready to condemn all systems of training pointers, or of controlling gun-fire, that do not produce as great, or nearly as great, a percentage of hits at a long range as at a relatively short one.

When the pointers have been trained to such a degree of skill that they can make a very large percentage of hits at the training range, under the favorable conditions prescribed for record practice, they have demonstrated their fitness for further training under less favorable conditions. To exercise them at the latter before they have achieved reasonable expertness at the former, would be as unjustifiable a waste of ammunition as to exercise green riflemen at long ranges before they could hit the standard small-arm target at 200 yards.

When the conditions are unfavorable, the shooting will be neither so rapid nor so accurate, but when pointers have attained their maximum efficiency under unfavorable conditions, their education is finished. They are ready to render us the best possible service in hitting an enemy under any conditions when they have been so trained that we can depend upon them to aim always as directed, and always with the maximum accuracy to which men can be trained to aim under the various conditions in which shooting is possible.

Such pointers will make the maximum number of hits that can be made under the circumstances—the circumstances being (1) the unavoidable errors in aiming of the best pointer, under the weather conditions existing at the time; (2) the unavoidable errors of their guns (sights, powder, etc.); (3) and the accuracy with which we, their officers, can keep the range and set their sight-bars.

Better than this no pointer can do (until more accurate means are invented), and it necessarily follows from the above, that such pointers, trained at "fool shooting" on the training range, will render us better service, no matter what the conditions under which the enemy is met, than pointers trained by any other system in which the accuracy and reliability of the pointers is not the prime object.

If it were possible to rig mechanical appliances that would at all times automatically keep the line of sight exactly on the center of a target, we would then have ideal pointers, and could dispense with human ones. With such aiming appliances, and a perfectly accurate range finder, we would have no errors to contend with except those due to the gun (sights, powder, etc.); but these are so considerable at long ranges, and the danger space is so small, that few hits could be made. Simple as this is, it is constantly being lost sight of; and it is important that it be clearly understood; otherwise the extent of the inevitable errors of long range firing will be seriously misapprehended, and the consequence will be disappointment and dissatisfaction with the pointers, even though they be practically perfect, and distrust of the system of training. The following example will, I believe, make this point clear:

Suppose that at a certain long range, the danger space of a vertical screen target is 40 yards. Then, with a perfect pointer aiming at the bull's-eye, a perfect range finder and an errorless gun, all shots would pass through the center of the target, and would strike the water 20 yards beyond. Now suppose the gun's errors in range, due to powder, etc., to be such as to cause shots to fall anywhere between 100 yards short and 100 yards beyond the point of impact of a shot passing through the center of the target. Evidently, the chances of hitting would be as 40 is to 200, or one in five; and these chances cannot possibly be increased by any refinements of training or of range-finding, since we have assumed these to be perfect.

To many readers these principles will appear so self-evident that I am sure many will suspect me of amusing myself by demolishing straw men, but such is not the case. Actual statements are made, with evidently sincere conviction, substantially as follows: "I have known pointers that could estimate the range at 6000 yards within a few yards, and make a hit nearly every time; and that's what we should be doing now instead of wasting ammunition in this manner".

Many of the persons who made such statements enjoy such a high reputation for ability that those who suffer from chronic cerebral inactivity have accepted them without question; and such "opinions" have doubtless influenced writers of reputation to make similar statements in deliberate articles and sell them to responsible publications.

SUMMARY OF CONCLUSIONS.

1. Great-gun pointers cannot be trained to be efficient *marksmen;* and if this could be done, we could not utilize their skill on account of the impossibility of their being able to identify the splash of their own shots when many guns are firing, because this requires an *uninterrupted* view of the projectile during its entire flight; which can be obtained only from a comparatively elevated position, well above the smoke and hot gases from the guns.

2. Given a certain gun, in order to train pointers to the highest possible expertness in aiming, or in order to test the expertness they have achieved, firing on a training range is essential; that is, a range which bears such a relation to the size of the target used that a "good pointer" can hit it every time, notwithstanding all unavoidable errors.

3. When the same target is used at a much greater distance than the training range, as above defined, the shooting is not a training for the pointer—it is blunderbuss training.

4. Having trained pointers to the highest expertness in aiming that experience shows to be possible at present, they can be utilized at any range to make the greatest possible percentage of hits that the range (angle of fall), the unavoidable errors of the gun, and the conditions of the firing will permit—provided, of course, the range-finding is efficient.

5. The three principal causes of missing are (*a*) errors of pointing; (*b*) unavoidable errors of gun-fire at sea (due to powder, etc.), and (*c*) errors in establishing the range.

6. Of these, the first (the error of pointing) is by far the least; and if it could be entirely eliminated, the difficulties of hitting at long ranges would be but slightly decreased.

7. As the present skill of the best pointers is such that no very considerable improvement in aiming is possible, it follows that the effectiveness of gun-fire at sea can be materially increased only by more accurate methods of finding, and keeping, the sight-bar range, and by diminishing the present unavoidable errors of the gun.

8. With all of the unavoidable errors just mentioned, it is possible to make, with a certain gun, at a certain range, only a certain maximum percentage of hits on a target of a given size.

9. If we actually make this maximum possible percentage of hits, say 20 per cent, at a certain long range, it shows (*a*) that our pointers have faithfully applied their skill by aiming accurately, as directed, and (*b*) that the range party has established the correct range. If we make less than 20 per cent, either the aiming or the range-finding has been inaccurate—we cannot tell which, but the chances are very large that the range-finding is at fault.

10. With reliable pointers at the guns, long-range firing becomes, therefore, principally a training in range-finding—whatever the method employed.

11. With unreliable pointers at the guns, long-range firing is an inexcusable waste of ammunition, because, when you do not make the percentage of hits that you should (say, 20% in this case), it is impossible to tell where the fault is, therefore the firing is not training for anybody concerned.

12. In order to train new pointers, and maintain and test the skill of old ones, we must always fire at training ranges; and this practice can never be abandoned without an immediate loss of *accuracy in aiming*, which is the *first essential* to the success of gun-fire at sea; for if the pointers are not both *skilful and reliable*, all firing at battle ranges is practically use-

less as a training of the "ship" in the *second essential* requirement—accurate range-finding. For upon accuracy of pointing and accuracy of range-finding depend the success that it is possible to achieve with the guns you are given to shoot with.

You must first train your pointers always to aim accurately, then train your "ship" to get the maximum results from their skill. At long ranges, even perfect pointers would be useless on an untrained "ship," and *vice versa.*

The foregoing explanations refer only to the vertical errors due to errors of pointing, errors of the gun and errors of range-finding; but, while these are not so easy to avoid as lateral errors, still the latter present many difficulties. The most serious of these can be compensated for only by fitting the guns with properly designed sighting appliances. It follows, therefore, that long-range firing, underway, carried out with guns not so fitted, is profitable only to the manufacturers of ammunition.

GUN ARM FOR A MORTAR BATTERY PLOTTING BOARD

BY CAPTAIN JOHNSON HAGOOD, ARTILLERY CORPS

THERE is a growing feeling in the service that some uniform system of position finding should be adopted, and that the necessary implements should be manufactured and issued. The development of such a system can only be a matter of evolution, and as far as guns are concerned, it looks as though the 'matter is very rapidly crystalizing. The best energies of the artillery have been at work in all parts of the country, and by these efforts, under a wide range of circumstances, a system has been evolved, that in the main will be satisfactory to the whole service. Case II., the Whistler plotting board with the Hearn gun arm, and the combined vertical and horizontal base, are pretty well established as meeting all requirements.

It is probable that not so much attention has been given to plotting boards for mortars as has been given to those for guns. The problem is simpler in that no allowances are made for atmospheric conditions, but more complicated in that the time of flight is very great. At any rate, for mortars, there are two very important factors that remain to be determined. One is a prediction scale for determining the predicted and set-forward points, and the other is the gun arm.*

Among the gun arms or rulers described in the service magazines, it is probable that Major Best's (ARTILLERY JOURNAL July-August, 1902), Captain Bishop's and Corporal Van Beek's (both ARTILLERY JOURNAL January-February, 1904) are in more general use. They are all based upon more or less the same principles but Corporal Van Beek's seems to lend itself most readily to improvement and to adaptation to the Whistler plotting board.

The Drill Board at Fort Monroe also has a gun arm for mortars that is going to be tried on the Whistler board. Its most distinctive feature is that corrections in azimuth, including drift, are made automatically at the mortar, and not in the plotting room.

With the Van Beek ruler† as a basis the writer has devised

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* The name gun arm is used because that is the name used on the plotting board for guns.

† See ARTILLERY JOURNAL January-February, 1904.

a gun arm which may contribute something to the evolution of a plotting board for mortars. In the first place the Van Beek gun arm proper contains too many numbers. Nothing is really required but the powder and corresponding elevation, and everything in addition to this adds another cause of confusion and error. In the second place, no means is furnished for making arbitrary corrections in elevation or in azimuth (result of trial shots).

In order to meet these conditions the following is suggested:

First. The range is not necessary. It should therefore not be on the gun arm at all, or should be placed somewhere, inconspicuously, so that it cannot be confused. Some methods of prediction require the range, but others do not. With the latter methods the range is only required occasionally for purposes of identification, or in connection with target practice for locating fixed targets, splashes, etc. A method of predicting then that requires the range is less advantageous, in that it requires an additional operation of the already overburdened chief plotter.

Second. The times of flight are more conveniently placed on the plotting board. They should be written in three or four radial double columns, the overlap being provided for by having the odd numbered zones in one half of the column and the even numbered zones in the other. See the elevations on the gun arm shown in the photograph.

Third. The arbitrary drift numbers are unnecessary. The angular drift is constant for a given elevation however much the muzzle velocity may vary. See Graphic Range Table 12″ B. L. M., Office Chief of Ordnance, June 9th, 1903. The elevation itself then is the only argument that is needed for the drift.

In order to convert a Van Beek ruler that is already constructed, the following is suggested. The range table above quoted gives the following relation of drifts and elevations.

45°	2°34′	50°	3°03′	55°	3°47′
46°	2°37′	51°	3°11′	56°	3°57′
47°	2°42′	52°	3°20′	57°	4°07′
48°	2°48′	53°	3°29′	58°	4°17′
49°	2°55′	54°	3°38′	59°	4°27′
				60°	4°37′

a total change of 123′ for 15° of elevation.

Paste a piece of paper on the drift device where the drift numbers are, and mark 45° and 60° over the graduations corresponding to drifts 2°34′ and 4°37′ respectively. Divide and graduate the distance between these two points in the following proportions:

45°	0	50°	29/123	56°	83/123
46°	3/123	51°	37/123	57°	93/123
47°	8/123	52°	46/123	58°	103/123
48°	14/123	53°	55/123	59°	113/123
49°	21/123	54°	64/123	60°	123/123
		55°	73/123		

Subdivide into half and quarter degrees.

If upon trial the scale does not fit exactly, it can be made to do so by shifting the divisions slightly. Mathematical proofs and deductions have been made but are omitted.

Fourth. In order to make arbitrary corrections in azimuth.

Referring to Corporal Van Beek's "quadrilateral", the side opposite the scale of drift numbers, should be movable instead of fixed, and the two parallel sides should be graduated to regulate the adjustment of the movable side. A parallel motion of the adjustable side gives accurate results within limits, and the motion is easily controlled by any kind of set screw or clamp.

This will be referred to more in detail later.

Fifth. In order to make arbitrary corrections in elevation.

It is well to note in this connection—

(a.) The time of flight does not change more than a second for one or two hundred yards, and a second or two is so small compared with the prediction interval plus the time of flight, that we can always use the tabulated values of the time of flight without correcting it. This allows the time of flight to be put on the plotting board.

(b.) The angular drift being a function of the elevation only, a correction in elevation carries with it a correction in azimuth. For instance, we fire two hundred yards short, line shot. The elevation being corrected for this would give us a different drift from that we had used at first. But if we use the drift corresponding to the new elevation we should nevertheless expect a line shot.

(c.) In addition to having three kinds of powder, black, brown and smokeless, it is probable that a mortar battery would be furnished with powder of different lots of each kind. It would be best under these circumstances, as far as possible to make up the different zones out of the same lots. Under these conditions it is seen that each zone is practically a different unit. An elevation in one zone might give too great a range and in the next too small a range, due to the fact that we were using a different kind or lot of powder. Each zone should therefore be separately adjustable to its particular conditions.

To make arbitrary corrections in elevation, then, the following is suggested.

Let the elevations for each separate zone be placed upon a slide that can be moved in or out to meet the conditions of the trial shots. The slides can be adjusted accurately for the zones in which trial shots are fired, and approximately for other zones from the best data obtainable.

A gun arm to meet the conditions can be constructed with the material and labor usually found at artillery posts. The details of construction will depend upon the particular conditions in each case.

The photograph shows the gun arm in use by the 69th Company, Coast Artillery. It was constructed by company labor and while mechanically it is little more than a makeshift, it meets the requirements for drill and target practice. It is used with a string plotting board with horizontal base.

Description. Gun arm proper: Poplar strip 57" long, $2\frac{1}{2}''$ wide, $\frac{1}{2}''$ thick. Bottom and left side covered with mounted drawing paper. Top contains two undercut grooves, 42" long, $\frac{1}{4}''$ deep, $\frac{5}{16}''$ wide at top and $\frac{6}{16}''$ wide at bottom. The grooves are $\frac{5}{16}''$ apart. In these grooves are eleven poplar slides. Upon each slide is glued a strip of mounted drawing paper containing the elevations (for every twenty-five yards) for one of the eleven powder zones. The odd numbered powder zones are in the left groove and the even numbered zones in the right groove. The paper extends over the edge of the slide $\frac{1}{16}''$ on the left and $\frac{4}{16}''$ on the right. The range is indicated on the left vertical side of the poplar strip. The slides are adjusted to their proper ranges and held in place by a very small tack at each end, the head of which is below the level of the top of the grooves. For convenience in reading, a sliding index is provided (not shown). It consists of a strip of galvanized iron 1" wide, about $3\frac{3}{4}''$ long, the two ends bent down about $\frac{9}{16}''$. This index is covered with mounted drawing paper. It slides along the gun arm, the edges resting upon the plotting board with sufficient clearance not to catch the edges of the slides.

On the inner end of the poplar strip is the usual brass centering device, and on the outer end is the drift device.

The drift device: A brass plate with movable drift scale graduated in degrees, half degrees. and quarter degrees of elevation. Motion of drift device is regulated by set screw and the beveled edges near "D" and "E". Limits of motion ½ degree on each side of normal setting. Adjusted for arbitrary correction by scales "D" and "E", graduated to .05 degrees. The edge "A" gives the uncorrected azimuth of predicted or set-forward point. The edge "B" reads one degree less than "A", the edge "C" reads two degrees less than "A". The drift scale in its mean position, a pin set opposite 45 and the range arm shifted, the edge "A" will indicate an azimuth 34′ less than it did before it was shifted. The edge "B" will indicate an azimuth one degree and thirty-four minutes less than did the edge "A" before it was shifted, and the edge "C" will indicate an azimuth two degrees and thirty-four minutes less than the edge "A" did before it was shifted. Correspondingly the changes for 60 would be 2°37′, 3°37′ and 4°37′.

To make corrections of less than half a degree, the drift scale is shifted and the azimuth read on the edge "C". For corrections more than half a degree, the edges "B" and "A" are utilized, or a whole number of degrees are added to or subtracted from the reading of edge "C". The uncorrected azimuth is always read on the edge "A".

The object of all these different edges is to reduce the size of the drift device. It would be better accomplished by having the edge "C" adjustable.

For use with the Whistler plotting board, or with any plotting board with the azimuth readings on the opposite side of the center, the drift device would consist of that part to the right of the edge "A". The uncorrected azimuth would be read upon one index corresponding to the edge "A", and the corrected azimuth would be read upon another index, adjustable and separated from the first by a whole number of degrees. It would correspond to the edges "B" and "C".

In the photograph the drift scale and some of the zones are not at the normal setting. The photograph was made just after target practice and the arm was at the time adjusted for use during the firing.

PROFESSIONAL NOTES

THE WAR AND FIELD ARTILLERY

The splendid progress made by the Japanese Army in their great struggle with Russia, and especially in recent great battles in Manchuria, directs attention once more to the subject of field artillery. The Islanders of the East have shown the same calm determination and fearless courage which were displayed by our troops in the South African campaign; and the contrast between their continuous success and our checkered progress, notably in Natal, is largely explained by the type of gun used, as well as by their adoption of tactics to suit the country and the war operations of the enemy. Amidst the mass of somewhat confusing detail which has come to hand there is the one dominant fact that, as at Liaoyang, so at Sha-ho, the quick-firing guns and effective explosive shells of the Japanese army have spelt victory. The rally of the Russian forces is even confirmatory of this, for it was in part due to the arrival of more of their 15-centimetre guns. In fact, as one military correspondent has pointed out, the most striking feature of the war has been the tremendous development of rapid artillery fire.

Mr. Bennett Burleigh, in his graphic narratives of Liaoyang, makes frequent reference to the efficacy of the 15-centimetre (5.9-inch) guns. Those captured from Russia by Japan saved our allies in some tight corners. General Kuropatkin, who has displayed skill and courage far in excess of that with which he is credited in some pro-Japanese newspapers, had a captive balloon 1000 feet above Sou-shan, from which an aeronaut accurately directed the fire of the Russian heavy artillery. The ordinary Japanese guns failed to reach the altitude of the balloon with their shell, but the 5.9-inch guns, when brought into service, materially affected the result, not only directly but indirectly, by making the balloon impossible. Again, the same authority states :—"Oku sent several batteries of artillery to assist his hard-pressed right, but these were unable to master the Russian fire or to get within effective range of the enemy's well-placed batteries." Many other instances might be quoted of the efficacy of powerful long-range guns. Time and again "the Russian works were far too many, and far too strong and too well defended to be taken by an off-hand onslaught. The distances to be traversed by the attacking troops before they could gain the trenches were too great. Behind these were the Russian fortifications, which arose almost tier upon tier upon the hill sides." With long-range guns there would have been a greatly increased area within which cover could have been sought for the Japanese field artillery to support the infantry in such attacks on heavily armed works. On the night of August 31, in the terrible night bombardment before Liaoyang, "the Japanese had their artillery strenghtened with modern quick-firers," which were admirably served, and thus did very effective work. In face of all the facts no one can gainsay that gun-power tells, and is, indeed, the first consideration. This lesson cannot be to strongly urged, even although we learned it at great cost during the South African War, because up till now we have failed to give effect to it.

We are among the last of the great nations to enter upon the re-arming of our field forces. The new French quick-firing Schneider-Canet gun uses a 15-lb shell, and there will be four such guns in a battery, with three ammunition wagons to each gun, making 312 rounds apiece. The German field piece is of 75 mm. (2.95-in.) caliber, using 15.1-lb. projectiles. Russia is re-arming her field artillery with 15-pounder quick-firers, Italy with a 14½-lb., and the Swiss Government is adopting a 14.3-pounder. Our new field-gun will probably excel all of these weapons being of 3.3-in. caliber, using an 18½-lb. shot, with a maximum velocity of 1600 ft. per second, and equal to firing nearly 25 rounds per minute. The great ordnance manufacturers, notably the Vickers and Armstrong companies, have strongly insisted on the importance of a large caliber and great rapidity of firing, and the views which have been expressed by the great military authorities of Europe, as a result of mature reflection on carefully-tested facts in connection with the Russo-Japanese War and the Boer War, have amply justified the recommendations made by the manufacturers, whose business is not only to reconcile the conflicting elements in design, but also to study most carefully, with the help of their intelligence departments, the lessons of successful campaigns and maneuvers.

An argument used against the long range of new guns has reference to the distance at which objects can be clearly discerned. We have been told, for instance, that the clear atmosphere of South Africa was a unique factor, facilitating long range; but the same atmospheric clearness has been found elsewhere—in Egypt, in Greece, and in the East during the present war, where fighting has taken place at nearly five miles range. It is admitted that at long range the shrapnel was not successful in South Africa, fragments losing their force at 10 to 15 yards from point of explosion; but in the East the explosive shells, corresponding to our lyddite and the French melinite, have proved exceptionally satisfactory. Such difficulties in detail should be easily overcome. The question of weight and mobility is another obstacle urged against the more powerful weapon; but we understand that the facts do not justify the attitude taken up by the critics. The proposed British guns do not involve any greater weight behind the horses than the old 15-pounders. The gun may be heavier, but the Vickers breech and its mechanism counter-balances this; and while more weight is involved in the carriage, and perhaps also in the arrangement to ensure greater accuracy, this may be nullified in other directions. There is no reason why the ammunition carried by the limber should not be reduced, or, rather, transferred to separate carriages. The weight question is not serious, and should certainly not be permitted to influence the more important matter of power and rapidity of fire. The relative functions of horse artillery and field-guns should not be confused. Field-guns having the ballistic qualities requisite to meet modern conditions must be heavy; but even in a country devoid of roads there should be no impossibility in moving and placing such guns. The Japanese troops found it hard work to move their guns forward after each battle; but in no case was the disadvantage of weight found to over-ride the undoubted gain of long range and rapidity of fire of shells. In the latter days of the South African War traction engines were effectively used for moving these guns into position, and this, according to the new tactics, is the main thing. Where guns are too heavy—a disadvantage not obvious in case of the proposed British weapons—there might be difficulty in moving them from their position in effective cover in the event of sudden retreat. They might thus become serious impediments to a rapid and orderly movement. This partly explains how guns have been so frequently lost and retaken during the present war. But to this objection it can only be urged that in the equipment of an army the dominant consideration must be to insure success, not to simplify retreat from an advancing enemy. Destruction of guns which cannot be moved, or their forfeiture to the enemy, is the penalty of failure, and it is to obviate this that effective artillery must be ordered. This demands the highest ballistics on the minimum of weight behind the horses. Horse artillery is quite another affair. It serves a function quite distinct from that of the large pieces usually occupying masked positions. It is principally to cover a running fight after a retreating enemy or to shield a retreat, and lightness is a desideratum.

The increased range of rifles, machine-guns, and field artillery generally has brought about a complete change in the functions of the respective weapons, and our failures in the earlier stages of the Boer War were due to inability or indisposition to assimilate the new tactics to meet the new conditions. Japan, in her steady advances in Manchuria, is, however, acting more in accordance with the modern state of affairs. In this matter there is, perhaps, a tendency to generalise more or less from isolated cases; but one cannot ignore the teaching of so many experienced European authorities, axiomatically expressed recently by a Swiss expert:—"Artillery must support the attack of the infantry by its fire, but must never advance in the open under the enemy's fire." The days of the artillery duel pure and simple are over. Mr. Burleigh also indicates that this was so at the battles preceding the taking of Liaoyang. Should the enemy's guns be discovered, then the long-approved principle of concentrated firing may still be successful; but the enemy will not be easily disposed to unmask his guns, except an obvious advantage is to be gained.

Just as the Boer infantry succeeded in minimising their losses by seeking cover at all times, so artillery in the future must seek cover; and it will be the duty of each contending force to destroy, not the cover so much, but rather the defenders behind the cover. It is immaterial what the nature of the cover may be. "Any kind of work is good if it serves to render more difficult the enemy's observation," as the German regulation puts it. A Belgian expert has said that the two adversaries will try to hide themselves as much as possible; but it will be necessary for the assailant to end by showing himself if he wants to advance, and for the defender to let his emplacement at least be seen if he wants to repel the attack. Quoting again from the German regulations:—"It is always desirable to protect oneself against the enemy's firing by throwing up works as soon as there is time, even in an offensive action." In no campaign has this been so fully established as in the recent operations in Manchuria. Every night the Japanese advanced their cover to suit the ground gained in the preceding day's fighting. It will be recognised that the range of guns in such a case must be very considerable, and that mobility is not of so much consequence. The

German authorities put the probable fighting range at between four and five miles.

Rapidity of fire is second only to range in importance. There are many who oppose this principle, on the score that it tends to waste of ammunition if not to inaccuracy. Even admitting that it is seldom that quick firing is justified for any lengthened period, and that accuracy is best attained by the observation of each successive shot, there are still occasions when the issue is settled irrevocably by a squall of shot, or, as the French say, a *rafale*, with its demoralising effects. As Mr. Burleigh says, in war even minutes spell victory or defeat. Such moments occur in every battle, and it would be a grave error to let the problematic waste of ammunition overcome the necessity of being able thus to demoralise the enemy. Every soldier knows that life or death may hang on the last shot, and discipline probably restrains him in the earliest stages. But, apart from this, there is the widely accepted principle that with the modern fieldgun and modern conditions there must be more intimate co-operation in the future than in the past between the infantry and the artillery. This doctrine, so admirably enunciated and enthusiastically defended by General Langlois, of the French Army, has sometimes been rejected by England, notably in the Boer war, and defeat has resulted. It is, on the other hand, admirably practised by General Oyama in Manchuria. Instead of having an independent duel preparatory to infantry operations, the view is that the preparation by the artillery must take place during the actual advance of the infantry. By this means each combatant force will unmask his guns to deter the advance of the opposing infantry. The one branch becomes the support of the other, and hard rapid firing is an essential to success. The infantry will naturally seek cover, advancing by rushes from one shelter to another, and during these rushes through the danger zone the field guns must be active. The maximum of destruction within the minimum of time is the important factor in the demoralisation of forces. Unmasked forces may be destroyed; each general will exhaust his ingenuity in forcing his adversary to unmask his position while remaining sheltered himself. To attain this result it may be necessary to push the infantry to the front. The artillery may, by its fire, force an adversary to shelter himself, whereby the attack of the infantry would be facilitated; or the enemy's artillery may be drawn by the advance of infantry, and thus a commander may ultimately succeed in silencing the artillery opposing him when it has been unmasked. These are lessons which have been most forcibly exemplified during the war now being prosecuted with so much courage and skill by both combatant armies, and they fully establish, so far as British readers are concerned, the immense importance of the work of re-arming our field forces being prosecuted with vigor and with a due appreciation of the importance of power and rapidity of fire, even at the expense of mobility. That this latter, however, should be affected to any serious extent does not seem to be a necessity.

—*Engineering*, October 21, 1904.

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FIELD ARTILLERY FOR THE BRITISH ARMY

After a delay extending over three years, orders have been given out for the complete rearmament of the British field artillery. The work will be undertaken by the Ordnance factories, and by the three civil firms on the War Office list, Elswick, Vickers, Sons and Maxim, and Cammell and Company.

While other nations were equipping their artillery with quick-firing guns, employing not only case ammunition containing its own means of ignition, but also hydraulic buffers or a system of springs calculated to absorb completely the recoil of the firing, our authorities were content with the separate loading of projectile and ammunition and with a recoiling gun. It is true that the spade device of Sir George Clarke was an improvement, but even its adaptation to our ancient system of armament could not modernize weapons hopelessly antiquated in pattern.

In 1901, it was decided to take official cognisance of these things, and a committee took the matter in hand. The Committee decided that the field artillery gun should not only be modern, but should throw a more powerful projectile, and accordingly, certain firms were asked to manufacture sample guns and carriages. The Ordnance factory at Woolwich, the Elswick firm, and Messrs. Vickers, Sons and Maxim accordingly entered into what virtually was a friendly combination to produce the best weapon. The result was a not unnatural compromise, a second specification being drawn up embodying what were considered the best points in all the guns and equipments submitted, and these new guns underwent a further exhaustive trial. For this trial it was also decided to have a larger number of guns and carriages manufactured; and two batteries of horse artillery and two of field artillery were ordered from Elswick and from Messrs. Vickers, Sons and Maxim, one battery of each kind from each firm. The batteries quite fulfilled the expectations of the Committee, alike as regards accuracy, range, and rate of fire. A rate of fire of 20 rounds per minute was obtained from each type of gun, and the effective shrapnel range was only limited by the length of fuze, which with the fuzes supplied gave good results at 7000 yards. As the result of these trials, the Committee were able in March, 1904, definitely to recommend the new model 18½-pounder quick-firing gun for the field artillery, and the new 12½-pounder quick-firing gun for the horse artillery.

Although the total cost of re-arming ninety batteries of field artillery and seventeen batteries of horse artillery is estimated at only £2,500,000, the Treasury refused to find the money for the manufacture of guns for the Home Army, and allowed the whole thing to be hung up for an indefinite period. Fortunately, it was decided that the Indian artillery should be re-armed pending the decision of where the money for dealing with the Home Army was to come from. Three batteries of horse and eighteen of field artillery was accordingly ordered for India. It is hoped that these guns may be ready this year. The further needs of India will be met by manufacture in that country.

With regard to the Home Army, the War Office and the Treasury have at last reached an arrangement to provide funds for the rearmament of the artillery, and it is understood that the Secretary of War has signed contracts which, with the guns to be built at Woolwich Arsenal, will result in the supply of 130 batteries of field artillery and 30 batteries of horse artillery, with guns of new pattern.

While the guns ordered will not suffice to re-arm absolutely the whole of the military forces of the King, they will go a very long way towards rendering the army capable of taking the field. The extent of the order will be indicated by the fact that it will probably keep the extensive gun departments of the firms named fairly well employed for two years. The new weapons are to be 3.3-in. caliber, firing 18½-lb. shot with the velocity of 1600 ft. per second and having a rate of fire of 20 rounds per minute under all conditions. This is the largest field-gun of any of the European armies, but experience in the war in the Far East shows that what is wanted is the largest possible gun with the longest possible range and the highest possible rapidity of fire. Most of the other powers, notably France, Germany, and Russia, have 15-pounder quick-firers; but already there is a strong agitation, particularly in Germany, in favor of the rearmament of the forces with a larger gun than that to which we have referred.

—*Page's Weekly; Engineering.*

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SCHNEIDER-CANET DU BOCAGE AUTOMOBILE BATTERY OF RAPID-FIRE HOWITZERS

Messrs. Schneider and Co. have recently completed, at their Havre Ordnance Works, an automobile battery of four 150-millimetre (5.9 inch) 14-calibre R. F. howitzers, on the plans of Colonel C. R. du Bocage, of the Portuguese Corps of Engineers; the battery forms part of the armament of the Lisbon entrenchments. The four howitzers are of the Schneider-Canet type, firing a projectile weighing 40 kilograms (88 lb.) with a powder charge of 1.625 kilograms (3.58 lb.), over a maximum range of 8 kilometres (5 miles), at an angle of 45 degrees. The piece weighs 1335 kilograms inclusive of the breech-block; the weight of the carriage is 2000 kilograms. The cradle has slides for a normal length of recoil of 0.980 metre (38.6 in.), the total length of recoil permissible in certain conditions of firing being 1.030 metres (40.55 in.). The breech is opened or closed by one motion of the breech-block lever; the projectile is separate from the cartridge-case, and charging is facilitated by an automatic loading-tray. The cradle is fitted by trunnions in the carriage-cheeks; it contains an hydraulic brake, with compressed-air recuperator for running the piece out again. Lateral training is by sliding the carriage on the axle, and the required elevation is secured by means of a segmental rack worked by a hand-wheel. The trail-spade suffices to hold the gun in position when firing. A shoe-brake operated by a small hand-wheel is provided for the road.

The automobile was built by Messrs. Schneider and Co., to the designs of Mr. E. Brillie, a French specialist in automobile construction. The conditions laid down were the following:—The automobile was to carry a useful load of 5 tons, made up of ammunition, fittings, driver and gunners, and to haul the four howitzers, weighing approximately 14 tons, at a speed of 3.4 miles per hour over roads, the gradients in which did not exceed 1 in 12.5. The higher gradients up to 1 in 8.35 were to be mastered by clamping the automobile, and hauling the battery of howitzers by cable worked by a winch driven by the motor. These conditions have been fully met in the trial runs carried out both in France and in Lisbon. The automobile is driven by a four-cylinder four-cycle motor, placed over the leading axle, the motion being transmitted to the rear axle by a clutch, a main shaft, change-speed gear, and a counter-shaft fitted at both ends with a sprocket-wheel.

The chassis is built throughout of steel; the sides, back, and front are steel channels, and the motor is contained in a stiff casing, over which are carried the driver's flooring and the liquid-fuel and cooling-water tanks. The motor works equally well with petrol or alcohol. The winch above referred to is placed directly beneath the driver's seat; it contains a toothed wheel, which can be driven by a pinion, by the action of a special clutch and gearing fitted in the top of the gear-case. The cable is guided by two small pulleys underneath the frame, one being below the winch-drum, and the other at the back of the rear axle.

There are two brakes—a clamp-brake which acts on a pulley forming part of the differential mechanism, and a shoe-brake on the rear wheels; the former is operated by a foot-lever, and the latter by a hand-wheel on the driver's right-hand side. The automobile weighs in working order 7 tons, and 12 tons with its complete load; it carries 40 gallons of petrol and 6.6 gallons of water—sufficient quantities for a run of 50 miles. A number of projectiles and cartridge-cases are placed in the after body of the automobile. Four ammunition wagons, to contain each about forty rounds, are to be dragged in addition to the guns, and the length of the whole battery train is only 65 yards. The ammunition carried and dragged by the motor gives 72 rounds per gun.—*Engineering.*

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INJURIES TO THE CESAREVITCH

On August 10 at six o'clock in the morning, the Russian fleet under command of Rear-Admiral Witthoeft, and sailing under orders from a higher authority, left Port Arthur to attempt to join the cruiser squadron at Vladivostock.

The sortie of the Russian fleet began with the sending forth of the mine removal division. For this purpose steamers joined together in pairs by steel cables were used. The mines, caught in the bight of such a cable, which did not explode at the impact or from the consequent shaking up, were dragged from the channel. The mine-grappling vessels were followed by the fleet in line-ahead the flagship Cesarevitch leading. The cruisers in this order, Novik, Askold, Pallada, Diana, and the torpedo boats, closed up with the battleships.

After the harbor had been cleared at 8 o'clock, the fleet steered in a southeast direction toward the Shantung Cape for about an hour, at a speed of 12 knots. Meanwhile the Japanese cruisers of the blockading fleet, closing in upon the enemy from port and starboard, came in touch with the Russians, while the torpedo boats running ahead dropped floating mines in the course. Because of this the Russians were obliged to proceed in a sinuous line, and their advance was consequently considerably retarded.

According to a description, four large and small cruisers were in touch with the Russians, both to starboard, near the head of the Russian line, and to port astern, while at a greater distance several other small cruisers were in sight when the main Japanese fleet appeared to port ahead about 11 A.M. For a short time a running fight at very long range (apparently not less than 8000 meters) took place.

The accounts of the second phase of the battle which now followed are entirely contradictory and confused. No conjectures need be made however as the action was practically without effect until after 1 P.M.

After the fleets had passed each other, the Russians steadily pursued the southeast course, while the Japanese, turning to port and swinging into the same direction, remained far behind—apparently 10 to 12 knots(?). The Russians, believing themselves able to outfoot the Japanese, because the boilers and engines of the latter had been strained by long service on blockade, now proceeded at full speed in order to escape. However, as early as 3 P.M. the Japanese had so far overhauled the Russians that they could renew the battle. As a matter of fact, the Japanese had only temporarily fallen back to allow a number of armored cruisers to reach the scene of action. These cruisers appeared between 2 and 3 o'clock, aft to port, and, with the Japanese battleships, began firing at excessively long range.

In the running fight that now developed, the Japanese steadily drew up on the Russians and concentrated their fire upon the leading vessel, which was repeatedly struck by shells of large caliber fired from the cruisers to port and the battleships to starboard, and at 3 P.M. had lost her commander and could no longer be steered.

At this point the heads of the two fleets were about on a line. At no time had the Japanese allowed the range to become less than six or seven thousand meters.

A 12-inch shell that struck the foremast had killed Admiral Witthoeft, and a second, hitting the conning tower, either killed the members of the staff or rendered them unconscious. The rudder had jammed hard to port, so that the Cesarevitch circled to the left and thus sheered out of line to the lee of the firing.

Hereupon the Retvisan, the second in line, swung around without apparent reason and started toward the main Japanese fleet, which proceeded to meet the seeming attempt at ramming by a corresponding turn of eight points to port.

The breaking from the line by the Retvisan was the signal for the general dissolution of the same. After she had approached the Japanese line by some 1500 meters, she again swung to port, and circling around the Cesarevitch, laid her course for Port Arthur. The Pobieda followed her maneuver, while the three rearmost battleships, turning to starboard, had already taken the same direction.

The Japanese main fleet had meanwhile ceased firing, remained for a time motionless, and proceeded in a northeast direction without attempting further to molest the Russians flying toward Port Arthur.

And so, at the fall of darkness, the Cesarevitch alone remained at the scene of action, surrounded by Japanese torpedo boats. The original intention also to return to Port Arthur was given up, as the injuries received did not warrant even the chance of a second meeting with the main fleet of the enemy. It was determined to proceed toward the southeast and eventually force a passage single-handed to Vladivostok.

The repeated attempts by the Japanese to torpedo her during the night were successfully nullified by steaming at full speed. In consequence of the injured funnels, enormous quantities of coal were thereby consumed, the total amount used during the day being some 470 instead of 80 tons.

After the action the difficulties of navigation were greatly increased. The conning-tower compass had been shot to pieces. The remaining compasses are supposed to have become unreliable in consequence of the concussion incident to the explosions, and the vessel had to be steered by the stars. By mere chance, daylight discovered the ship near the northeast Shantung Cape.

A determination of the injuries showed that in the estimation of the acting commander, Capt. Schoumoff, the ship was not sufficiently seaworthy to steam to Vladivostok. It was therefore decided to go to the nearby neutral port of Tsingtau, and this harbor was reached at 11 o'clock the same night. Among the serious injuries which were the cause of this determination, are mentioned:

1. The striking of the foot of the foremast by a 12-inch shell, which killed Admiral Witthoeft, and whereby the support of the mast was so far shot away that the latter threatened to fall.

2. The injuries to the funnels whereby the coal consumption was increased so much that the fuel would have been insufficient to carry the vessel to Vladivostok.

3. A 12-inch shell hit on the starboard side under the forward 6-inch turret, below the waterline, which caused a small leak in the compartment in question.

According to the reports of the Russian officers the ship was struck by fifteen 12-inch and a greater number of shells of smaller caliber.

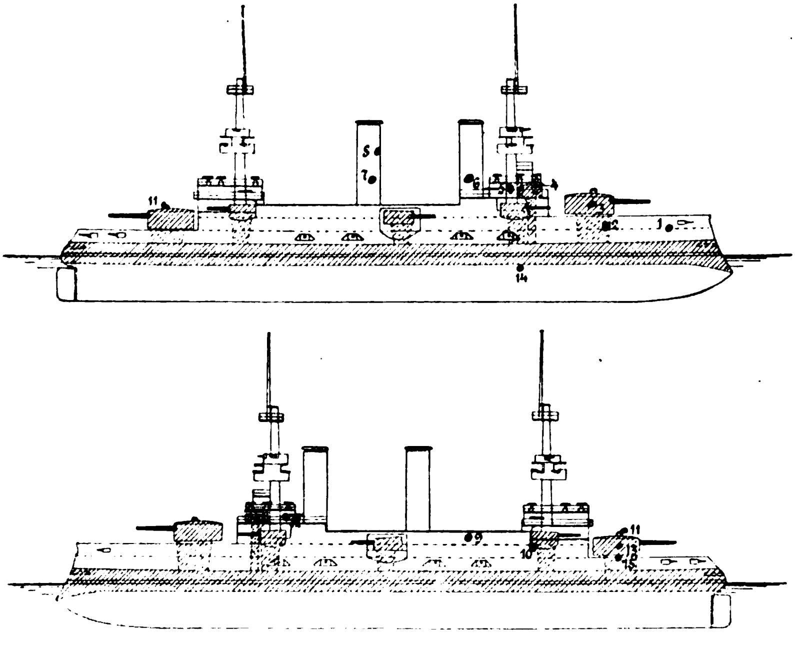

Fig. 1. Diagrams showing hits on starboard and port sides of the Cesarevitch.

Hit No. 1: A 12-inch shell forward on the starboard side at the level of the upper deck, striking the hogs-back of the bow anchor. The projectile tore a hole in the ship's side 2 x 2 meters, passed through the bow and sheet anchor chains, but hardly left a trace of its passage in the hold. Both anchors were lost.

Hit No. 2: 12-inch shell on the starboard side, level with the upper deck, and just under the forward 12-inch turret. The shell tore a hole in the ship's side 1 x 1 meter, but did practically no damage in the interior.

Hit No. 3: 12-inch shell that struck the armor of the forward 12-inch turret. Ineffective.

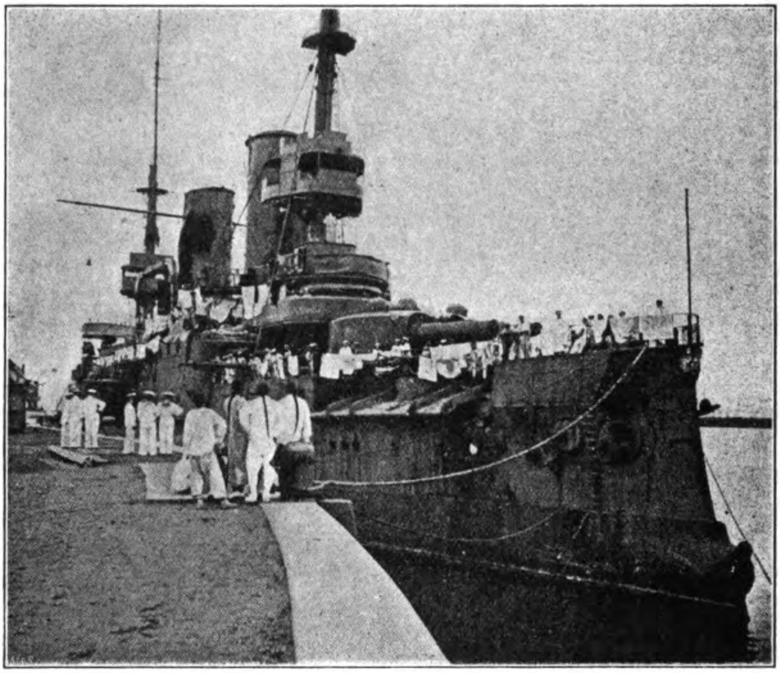

Fig. 2. Hit 1. Starboard Side.

Hit No. 4: 12-inch shell squarely striking the starboard side of the forward conning-tower. The path of the shell is shown in Fig. 3. Of the persons in the conning tower, the ship's navigator, a sub-lieutenant, the helmsman, and two or three orderlies were killed, their heads being blown off, while two officers were stunned. Through the falling bodies, the wheel was turned hard to port, the steering gear being uninjured. The compass was destroyed. The cables running along under the roof of the conning-tower were torn away and the mechanical connection with the engines destroyed. The head of the shell passed out of the tower in the direction of the arrow and buried itself in the hammock boxes that form the forward bridge rail, and here it was later found.

Hit No. 5: A 12-inch shell that squarely struck the foot of the foremast between the upper and lower bridges. The projectile pierced the starboard side of the mast and burst against the port side. Toward the bow the iron plates of the mast are entirely torn away. At the back only a connection between the two bridges remains, but this not strong enough to bear the weight of the heavy fighting mast. The latter actually rests on the upper bridge only, being joined to this by strong angle irons that were uninjured. The searchlight cables in the mast were broken. The shot killed Admiral Witthoeft, the fleet navigator and some fifteen men. The chief of staff, Admiral Matusewitch, and the commander, Capt. Ivanoff, were wounded. The officers were probably in the fire lee of the tower.

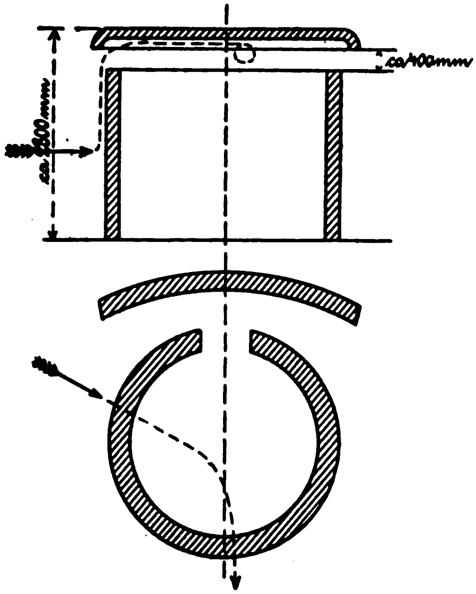

Fig. 3. Hit 4. Showing path of projectile.

Hit No. 6: A 12-inch shell squarely struck the lower part of the forward funnel. The shell pierced the starboard side and exploded against the port side which was torn to pieces.

Hits No. 7 and 8: Two 12-inch explosive shells injured the upper and lower parts of the rear funnel. They struck and exploded against the starboard side of the smokestack which was ripped up and torn from top to bottom. The port side shows no injury that can be traced to either of these shots.

Hit No. 9: Probably an 8-inch projectile fired from a cruiser. The shell pierced the portside wall of the superstructure below the launch. Several injuries resulted, among them the destruction of the bakery. The shell made a round hole about 1 meter in diameter.

Hit No. 10: Another 8-inch shell that pierced the port side of the forward lower edge of the rear 6-inch turret, leaving a hole 1 x 0.55 meter in the wall. The covering of the lower turret structure in the admiral's mess was torn away.

Hit No. 11: A 12-inch explosive shell struck the top of the after 12-inch turret near the sighting-hood. The top was slightly dented and some of the rivets of the angles joining the turret and the hood were driven in killing a man inside of the turret. The man inside of the sighting-hood was rendered unconscious for a short time only. Pieces from the bursting shell pierced the after chart room.

Hit No. 12: 12-inch explosive shell destroyed the forward chart room, abaft the foremast.

Hit No. 13: 12-inch explosive shell struck the after 12-inch turret on the port side. The shell probably burst at impact and did no damage.

Hit No. 14: Probably a 12-inch shell that struck some 2½ meters below the waterline, under the forward 6-inch turret, and under the armor belt. According to the reports of divers the projectile struck the joint of two of the outer skin plates. The plates, frames and supports are said to be dented and bent, but not torn, for a longitudinal distance of about 3½ meters. The covering-strap is supposed to have jarred off (see fig. 7) and about 150 tons of water allowed to enter the compartment behind the downward curved armor deck, through the rivet holes. The Cesarevitch entered the harbor with a barely perceptible list to starboard.

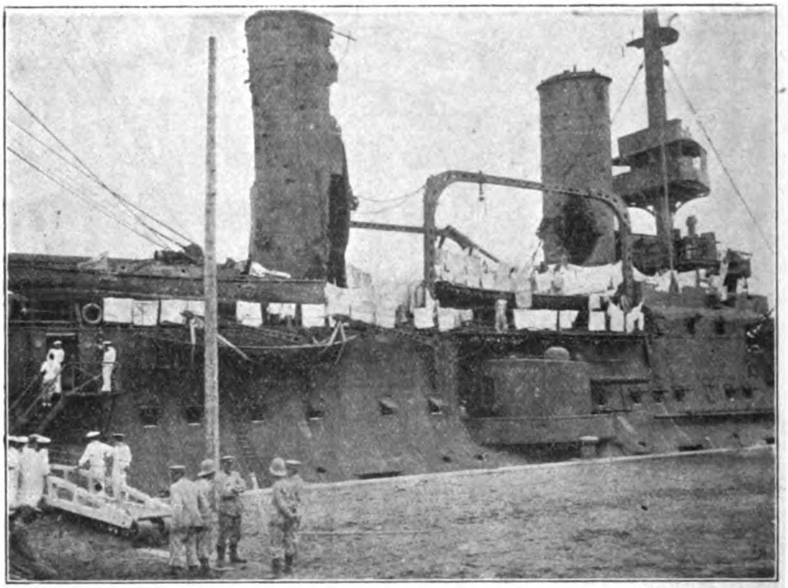

Fig. 4. Hit 6. Showing damage to the forward funnel.

Hit No. 15: A 12-inch explosive shell passed through the port after-deck railing and the upper deck. The bollard is half torn away. The teakwood covering of the upper deck is ripped up for about 4 square meters. The wood did not burn and the deck planking splintered little.

The following facts may be noted in respect to these injuries:

1. As but part of the Japanese shells pierced the sidewall or did barely perceptible damage in the interior of the vessel, we may conclude that they exploded too soon. However, in this respect, the shots that struck the foremast and the funnel differ very widely from most of those that struck the hull. Much may be considered due to the difference in the effect of a shell and an explosive shell. It will probably not be far from the truth to conclude that the Japanese used some "half-armor-piercing shells with bottom ignition."

2. In spite of the wooden deck and of the fact that all boats were on board the splintering effect was small.

3. The wooden decks did not catch fire as was the case in the Chino-Japanese war.

4. In no place was the armor pierced; all the vital parts lying underneath the upper armored deck were absolutely uninjured. Some pieces of the burst shell fell through the after funnel upon the boilers under it and damaged a few superheater pipes. The explanation of the ineffectiveness of the heaviest Japanese shells against the Russian armor may be found in the tremendously long range and the apparent non-use of armor-piercing projectiles.

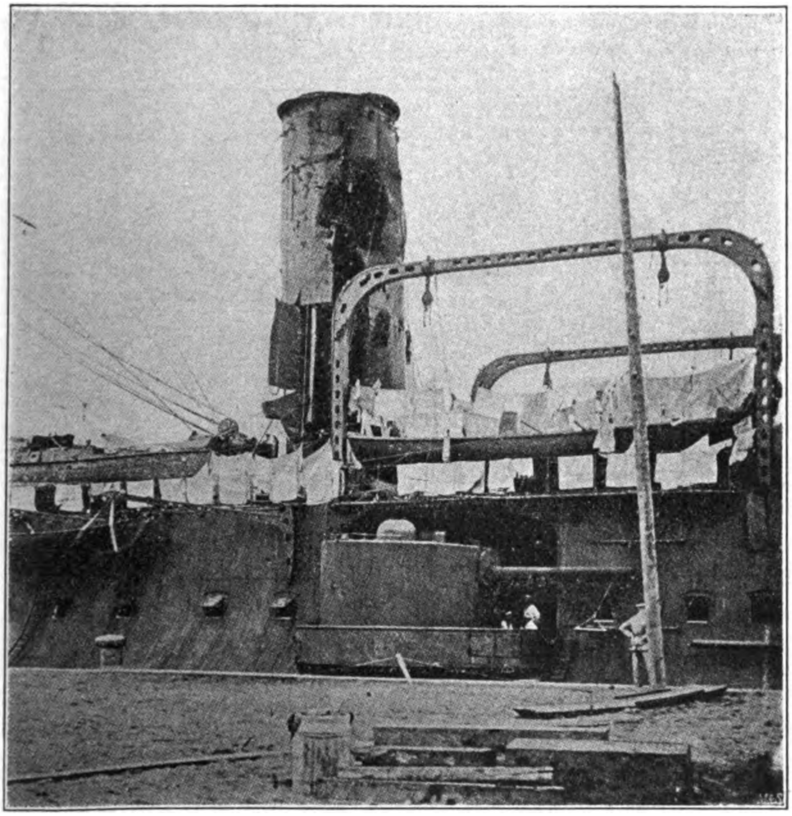

Fig. 5. Hits 7 and 8.

5. The hit below the starboard waterline under the forward 6-inch turret did not perforate the outer skin. The entrance of the water was due to the loosening of the rivets incident to the denting of the outer plates.

6. Both the fore and after 12-inch turrets were struck without injury to the revolving mechanism of the turret or the ammunition-serving apparatus of the guns. However, according to the statement of a German officer who

visited the Cesarevitch, the forward turret shows a large groove on the starboard side.

There is no reliable information at hand concerning the quantity of ammunition used by the Russians. According to one of the officers the lack of 12-inch shells—it appears 74 to 76 were fired from the forward turret and 40 to 45 from the rear turret—was one of the reasons for putting in to Tsingtau.*

According to the report of the ship's doctor four officers and eight men were killed and fifty officers and men were wounded. Nothing detailed concerning the nature of the wounds is known. Stress is laid by all upon the terrible and deadly effect of the explosive shell. As long as 24 hours after the action many complained about deafness, dizziness, loss of memory and headaches without directly being injured. The hair and beards, and partly also the skin, of those who were in the neighborhood of a bursting explosive shell were colored an intense yellow. A similar discoloration shows on the ship at the points of the explosions.

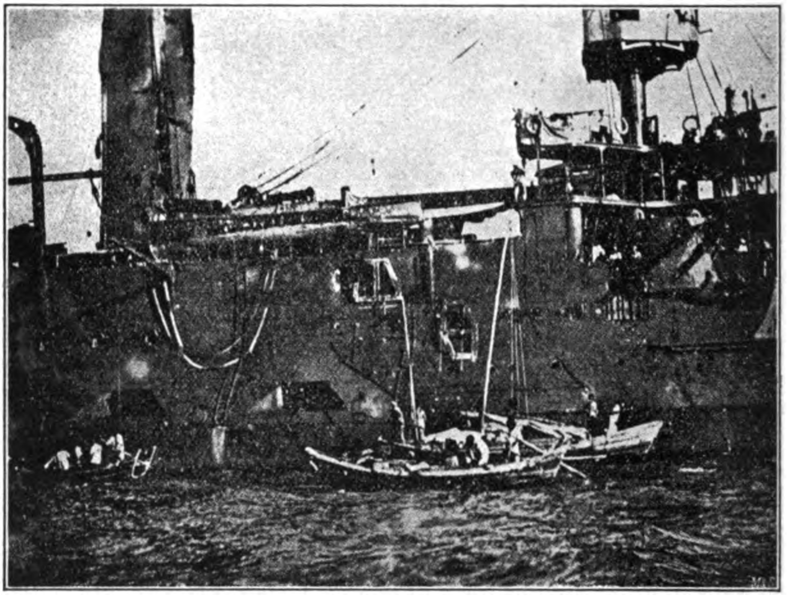

Fig. 6. Hits 9 and 10.

When we regard the actions of the two naval forces in this last battle, considering the enormous value which the control of the sea means to both belligerents, and when we understand what both sides risked and what they could have gained, many of the proceedings of the Russians as well as of the Japanese seem puzzling to us.

Without doubt, since the beginning of the war the Russian fleet has had very little confidence in its capability and its ability to use the weapons intrusted to it. Not only was confidence and tactical knowledge missing because of the lack of squadron training, but the use of the weapons was not understood. Up to the present no Russian torpedo boat has fired a torpedo.

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* It was afterward learned that 580 to 600 shots were fired from the 6-inch guns.

As stated by Russian officers, the boats were exclusively used for laying mines, for scout duty and to fight the Japanese torpedo boats. The uniform lack of success in the last was due to the fact that the Russian torpedo boats were neither accompanied nor backed up by larger and more powerful ships without which the Japanese boats never advanced. The Russians never seem to have thought of using the boats at night. It can therefore be understood why the Russian cruisers and torpedo boats were considered a hindering addition that had to be protected during the sortie of August 10, instead of an offensive instrument which could have done good service in preparing for the sortie as well as during the following night.

But the Japanese also were unable to use their torpedo boats properly. All Russian officers remark that the Japanese torpedo tactics lack nothing in dash, but that the weapon itself is not on a level with its capability. The comparatively insignificant result of the first torpedo attack of February 8 and 9 upon the unconscious Russian fleet lying at anchor in double formation in Port Arthur, sems to confirm this statement. The opportunity in this case could not have been more favorable for the Japanese, and still out of 23 torpedoes fired only 3, or 13 per cent., scored hits.

And so it is explainable that the Cesarevitch was able to escape from the torpedo boats surrounding her, during the night from the 10th to the 11th of August, although the opportunities for attacking the thoroughly battered vessel were excellent.

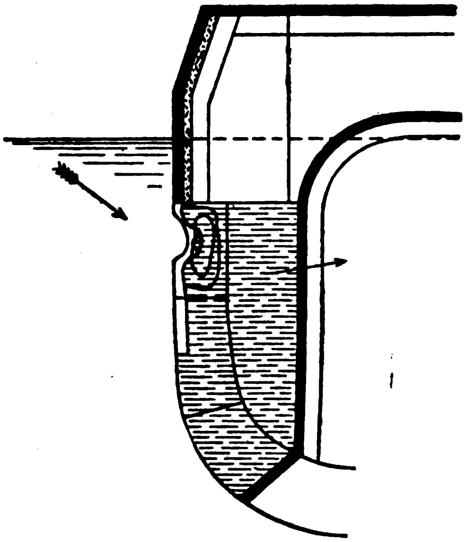

Fig. 7. Hit 14.

Judging from the information at hand we can understand the tactics of both participants in the action of August 10, with the exception of the last phase of all. By means of an exceptionally well organized scout service the Japanese cruisers were able to put their main fleet in touch with the Russians, within 3 hours of the latter's sortie. This maneuver was simplified because geographical necessities to a certain extent prescribed the Russian course. The great superiority of the Japanese in gunnery and in artillery appliances induced them to give battle at extremely long range with the intention—which has been the Japanese policy throughout the entire naval proceedings of the war—to injure the enemy as much as possible with the least danger to themselves in order to remain strong enough to encounter the threatening Baltic fleet. If we consider this point we can understand why the Japanese were satisfied with driving back the Russian fleet to Port Arthur, and why they did not attempt its annihilation. This tactical proceeding of the Japanese was only made possible by the superiority in speed which enabled them to choose their own distance without being placed at a disadvantage in other matters.

Incomprehensible, on the other hand, is the course of the main Japanese fleet as soon as the enemy began to retreat to Port Arthur. But until the Japanese version of the action is obtainable it would be a waste of time to attempt to explain this point.

The markmanship of the Japanese is regarded with undisguised wonder by the Russian officers. The range at which the Japanese had to score their hits is, according to Russian estimates, between 7000 and 8000 meters. We must not lose sight of the fact, however, that these are only estimates, for, as the Russian officers admit, the range-finders in use were not available for such distances. All the same, the marksmanship of the Japanese was excellent and far superior to that of the enemy, inasmuch as the Japanese possessed telescopic-sights which the Russians did not.

In criticising the Russian gunnery we must not forget that the fleet, bottled up in Port Arthur, had very little opportunity for practice. Thus, the Cesarevitch used her heavy guns for the first time during the war, in the action of August 10.

Nothing, in our estimation, can better prove the necessity for having a battleship backbone for a fleet, than the past occurrences of the war, and England has acted upon this belief with the foresight peculiar to her in naval matters. She has greatly increased the offensive and defensive characteristics of the battleships of the Lord Nelson class as compared to those of the King Edward class, and has sought to decrease the building of armored cruisers. After all has been said, the mastery of the sea, in spite of mines, torpedoes, and submarines, lies with the powerful and sufficiently speedy battleship. And so it will remain so long as the gun can hold its own as a long-range weapon with the torpedo, for "no one can get around the fact that where he wishes to rule, there he must strike."

—*Marine Rundschau*, November.

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ARMAMENT OF CRUISERS.

The war has confirmed the oft-expressed expectation that long range must be the order in future engagements. In the few opportunities presented to Admiral Togo of engaging with his adversaries from Port Arthur, the distance between the combatants seems to have been not less than four miles, and as a consequence 6-inch guns were of comparatively little value. They no doubt succeeded in silencing some of the guns in the Russian ships, but this must be attributed in large part to the deficient protection of these quick-firing guns, especially in the cruisers. In the design of the Russian vessels, except in the case of the very latest, the desire has been to instal an enormous number of guns without due regard to the protection of the gun crews; but where, as in Continental navies, the guns are protected by 6-inch armored casemates or turrets, the same result would not be achieved. Thus, although there are no doubt many unprotected ships against which the 6-inch gun would prove effective, it is worthy of consideration whether a designer is justified in placing a large installation of guns of this caliber in modern cruisers, which are expected to be able to "face" any cruiser afloat, and also to be powerful enough to pierce the screen of the enemy's squadron after its position has been located by a fast scout. This latter will be one of the most important duties of powerful cruisers attached to battleship squadrons, because the high-speed scout will only be utilized for reconnaissance work where force is not to be employed. The more important intelligence as to the strength of the enemy must be discovered by the armored cruiser breaking through the screen, and this may involve very serious fighting.

The 6-inch gun of 50 calibers is undoubtedly a good weapon; it fires a 100-pound shot, which attains a muzzle energy of 6493 foot-tons under the very best conditions; it has the advantage that all operations, including the manipulation of the shot, can be done by manual effort. In service practice nine hits per minute have been achieved, but the average is considerably less. Even if we give it credit for a fighting range of three miles, this gun, using capped shots with direct impact, could only penetrate 3½ inches of the latest cemented armor. As a consequence no impression could possibly be made on the armor of any first-class cruiser likely to be opposed to it. It is, indeed, improbable that the 6-inch gun, even at the range indicated, could effectually disable a well-designed second-class cruiser. But very few second-class cruisers are now being built, the tendencies in all important navies being to confine attention to battleships, first-class cruisers, scouts, and torpedo craft. No battleship laid down by a foreign Power last year had a 6-inch gun; Britain alone committed the serious error of equipping some of their ships—the ships of the King Edward class—with this weapon. The 6.4-inch guns fitted in some of the later French ships can, with capped shell, penetrate 5 inches of the latest armor, the German 6.7-inch gun 5½ inches, and the American 7-inch gun 6 inches—all results comparing with the 4 inches of the British 6-inch weapon.

The Black Prince is fitted with ten of these 6-inch guns, along with six of 9.2-inch caliber. This, it is true, is a decided advance on what has been done in previous cruisers for the navy; yet many naval critics regard this armament as unsatisfactory. The 9.2-inch guns can deal effectively with possible opponents, but for many conflicts the 6-inch gun is of so little avail that the weight involved could have been much more effectually utilized in 7.5-inch or more 9.2-inch guns. Many prefer the entire elimination of the 6-inch gun for the reasons that we have indicated; indeed, such a well-informed experienced authority on naval construction as Mr. Albert Vickers, one of the managing directors of the well-known Vickers Company, has characterized the 6-inch weapon as now obsolete. In battleships he would confine the primary armament to 12-inch guns, and in cruisers to 9.2-inch guns. One cannot help feeling that even the Board of Admiralty recognized that they had made a mistake, because in the four cruisers given out a few months after the Black Prince was ordered, they did dispense with the 6-inch guns, changing the armament from six 9.2-inch and ten 6-inch guns to six 9.2-inch and four 7.5-inch guns. This is the only difference made between the class to which the Black Prince belongs and the Achilles type, of which four are being built. At first sight it might seem as if four 7.5-inch guns could scarcely equal ten 6-inch guns; but experience in the Far East suggests that energy must be considered even before rapidity of fire and numbers. There will always be occasions when it must be of vital importance to get in as many shots within a given time as is possible; but if the range is to be at least four, and perhaps five, miles, the 6-inch gun cannot do effective work, and its rapidity of fire becomes a useless quality. With the same velocity the penetration through the most modern armor of the 6-inch gun is 4 inches, as against 6½ inches for the 7.5-inch weapon; so that the latter is capable of dealing by direct impact with the 6-inch armor, with which foreign cruisers are for the most part clad. Sixteen shots per minute, when effective against the armor of the enemy's ship, are certainly more to be desired than even 60 or 70 shots which may be powerless against armor. The 9.2-inch guns, also using capped shell, are capable of penetrating 10 inch armor at the same range—three miles—so that with six guns of this caliber and four of 7.5-inch caliber, the newer cruisers are superior to the Black Prince. The laying down of the two ships for the Chilian Government early in 1902, in which the 6-inch gun was discarded, ought to have given pause to the Admiralty in their continued appreciation of the 6-inch weapon.

In the cruisers given out this year they have followed the lines of these two Chilian ships. In this Minotaur class, of which three are being built, the armament consists of four 9.2-inch guns and ten 7.5-inch guns. The weight involved in this latter combination is slightly greater than in the two preceding ships; but, notwithstanding this, and an increase in engine power and speed, the displacement has only been increased 1000 tons, as compared with the Black Prince and Achilles classes.

We may add a short table to show the comparison between these three ships in respect of the three main features. They do not differ materially in armor protection. Their auxiliary ormament will be practically the same. In size, speed and gun-power there has been advance:

		Black Prince.	Achilles.	Minotaur.
Length between perpendiculars	ft.	480	480	490
Displacement	tons	13,550	13,550	14,500
Indicated horse-power		23,500	23,500	27,000
Speed	knots	22.33	22.33	23
9.2-in. guns		6	6	4
7.5-in. guns		none	4	10
6-in. guns		10	0	0

The 6-inch 50-caliber gun has a muzzle energy under the best conditions of 6493 foot-tons, the 7.5-inch 50-caliber gun of 11,700 foot-tons, and the 9.2-inch 50-caliber gun 24,190 foot-tons—figures which alone demonstrate the immense superiority of the increased caliber. It is true that the larger guns involve more weight, but the increase in power is more than compensation for this. It is a question of strategy rather than of naval architecture; but the designer is ever anxious to attain the highest results, not only in gun-power, but also in fighting efficiency and speed.—*Engineering.*

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H.M.S. DOMINION.

The first-class battleship Dominion, built for the British Navy by Messrs. Vickers Sons and Maxim, Limited, at their Naval Construction Works at Barrow-in-Furness, and supplied with her armor and armament from the same company's Sheffield Works, has completed the steam trials prescribed by contract. The results from every point of view were thoroughly successful, the speed attained at full power was, on a deep-sea course, 19.5 knots—one nautical mile per hour greater than was anticipated in the design; so that, excepting the Triumph and Swiftsure (the former, by the way, also built by the Vickers Company), she is the fastest battleship in the fleet, which, in view of her 16,400 tons displacement, and her powerful primary armament—four 12-inch and four 9.2-inch guns—is specially satisfactory. The power realized was 18,438 indicated horse-power—438 indicated horse-power over the contract requirement—notwithstanding that the machinery was worked under war conditions, with closed-in engine-room and other restrictions, never before exacted on contract tests.

The Dominion—a view of which under easy steam is reproduced on our plate—belongs to the King Edward VII. class, and has a length between perpendiculars of 425 feet, a beam of 77 feet 9 inches, and a depth moulded of 42 feet 11 inches. At a draught of 26 feet 9 inches she displaces 16,400 tons. She has a belt, extending from the after armored bulkhead forward to the ram, 9 inches in thickness for the greater part of the length, reduced in three stages at the forward end to 2 inches. The maximum thicknes extends along the citadel from 5 feet below the load-line to about 3 feet above it; the next strake is 8 inches, and the top strake 7 inches, the latter reaching to the upper deck. The 12-inch guns are in barbettes of 12-inch armor, with hoods having sloping sides. The 9.2-inch guns are mounted separately in turrets of 7-inch armor on the upper deck—one at each quarter. The 6-inch guns are mounted within the 7-inch broadside armor in a concentrated casemate, as introduced first by the Vickers Company in the Mikasa. These 6-inch guns—five on each broadside—are on the main deck of 2-inch armor, while the upper deck is of 1-inch. On convenient positions for defense against torpedo-boat attack are fourteen 12-pounders, fourteen 3-pounders, and two Maxims. The armament includes also four submerged tubes for firing torpedoes.

The view we reproduce indicate several interesting departures in detail, to which reference may be made. Military tops have been dispensed with; but on the masts there have been constructed large observation stations which will carry Barr and Stroud range-finders, and from these stations the guns will be trained and directed. The after navigating-bridge has been abolished; although towers for searchlights still remain. There is, however, an admiral's bridge immediately abaft the main navigating station—a feature more usual on foreign warships. As to ventilating cowls, the sails tried a year or two ago have been discarded, and the shafts to stokeholds, etc., are now fitted with mushroom-shaped covers, which can be raised and rotated on roller bearings. For the boat derrick on the main mast, vertical hydraulic engines are now substituted for the horizontal machines, not only because they require less deck room, but they are more efficient. The conning-tower is larger; steam heating pipes and radiators are laid throughout the habitable quarters; baths are provided for all classes, and more attention has been paid to mechanical ventilation, especially in 'tween decks, as no port-holes are possible in the armored sides of the vessel.—*Engineering.*

BOOK REVIEWS

The Elastic Strength of Guns. By Philip R. Alger, Professor of Mathematics, U. S. Navy. Ed. 1. 80 p. il. O. Baltimore: The Lord Baltimore Press. 1904.

We have in this book a very concise and logical exposition of the theory of the elastic strength of built-up forged steel guns as presented by Clavarino in his second treatise on the "Resistance of Hollow Cylinders and of Cannon," published in the "Giornale d' Artiglieria e Genio," 1879, and modified through the results of experiments conducted by the Ordnance Department, U. S. Army. It also includes a chapter on wire-wound guns with formulas applicable to a constant and to a variable tension of winding. The context is admirably arranged by the competent author to demonstrate the principles involved, enforced by numerous examples, and is distinguished by a system of nomenclature which is commendably brief.

The theory employed is generally regarded, it is believed, as the best and as leading to results more nearly in accordance with experience than any other yet developed for gun construction. A conception of its guiding principles may be derived by stating the general case that each of the concentric hollow cylinders, superimposed and assembled by shrinkage in forming a built-up gun, is subjected to an interior and an exterior pressure covering the circular surfaces; that these pressures induce strains (either extensions or compressions) in the metal of the cylinder which are evaluated in the direction of the principal axes of resultant strains or stresses, that is, circumferentially, radially and longitudinally, and finally that the limit of elastic resistance of the cylinder is reached when the total strain in any one of these directions equals that which would be caused in a free specimen of the metal loaded to the elastic limit under a single stress of tension or compression as the case may be.

The scope of the book in its practical application to gun construction is chiefly limited to the conditions involved in assembling the gun body by suitable shrinkages of the elementary cylinders so that the gun will afford a maximum elastic resistance to pressure in the bore. The book is primarily intended for the student as stated in the preface but would be more valuable for that purpose as well as for the engineer if place had been given to the strains in the breech recess resulting from the shrinkages and particularly to the pressure on the breech threads, which fill an important place in the elastic strength of guns.

The formulas of this text will be found fundamentally the same as those given in Notes on the Construction of Ordrance No. 59, and used for the construction of army cannon. Where differences occur we can readily pass from one to the other by substitution. The radical difference in the two "methods of procedure" or the application of the formulas, consists in that Professor Alger gives a subsidiary place to the pressures in the state of rest, which form so important a part of Note 59, and uses the pressures pertaining to the state of action in the shrinkage formulas. In so doing he has succeeded in introducing a very clear demonstration of principles generally in connection with a comparatively brief nomenclature. When however we come to consider the practical application of the formulas to the variety of problems that arise in practice, it will be found that Professor Alger's methods must be amplified very largely and lose their apparent simplicity. His method lacks elucidation, if not availability, especially in regard to adjustment of the θ values. On page 78 are given the formulas for compound cylinders of four layers and the statement:

> "If $P_0(\theta)$ is greater than $[P_0]$, the tube will be compressed beyond its elastic limit of compression (ρ_0) by shrinkages determined with the values of $P_3(\theta)$, $P_2(\theta)$, $P_1(\theta)$ and $P_0(\theta)$ and so the values of one or more of the assumed elastic limits θ_3, θ_2 and θ_1 must be reduced until $P_0(\theta)$ equals, or is less than, $[P_0]$."

This is too indefinite since the reduced θ values referred to cannot be assumed at will and there should be a logical demonstration to indicate the minimum values which can be assigned to θ_3, θ_2, and θ_1 without leading to an improper adjustment of the system or sacrificing the value of P_0 representing the elastic strength of the gun. The difficulty in assigning *appropriate* reduced values to θ_3, θ_2 and θ_1 is particularly to be met in the case of four layers, where as will frequently occur we find $P_1(\rho) < P_1(\theta)$ as well as $P_0(\rho) < P_0(\theta)$ showing that the jacket cylinder is liable to excessive radial compression. Hence in any adjustment that is made, a sufficient value of P_2 and therefore of θ_3 and θ_2, must be preserved to avoid excessive radial compression of the jacket in the state of action. It may be noted that this case is not exemplified in the three layers example (5-inch B.L.R. Mark V) worked out in the text, but it will frequently occur in guns of larger caliber.

The tendency of the author to favor comparatively light shrinkages cannot be wholly commended. Where latitude is permitted the values become a matter of judgment within limits, and this should be exercised with due regard to all circumstances, including for example the desirability of placing a light shrinkage upon the jacket in order to facilitate its assemblage. This may involve relatively heavy shrinkages for the outer cylinders to maintain a given resistance to pressure in the bore. Ordinarily, we should say, no sacrifice in the safe maximum value of P_0 should be made in the chamber section and it is not out of place to utilize the full elastic limits of all the elementary cylinders for this purpose.

To the preceding general remarks may be added the following suggested by a perusal of the book.

Reference is made in the preface to the need of experiments to prove "that permanent set will not occur unless the resultant *strain* in some direction exceeds the limit of elastic strain, regardless of what the stresses may be." In this connection I may quote from a letter of James E. Howard, C.E., in charge of the testing machine at Watertown Arsenal:

> "Some results in Tests of Metals 1886, Part 2, page 1664, and following, bear on the subject. Perhaps the experimental data are not so direct as might be desired still it is difficult to do as much in this line as we might wish. I have for a long time made a statement of this kind, that it was a question of strain and not stress with which we were most concerned in dealing with metals. That while we could

> not conceive of a tensile stress without a corresponding tensile strain, yet on the other hand we could see that a compressive stress might be applied without a corresponding compressive strain. The latter as witnessed in cubic compression. It has appeared as a corollary that the intensity of the stress might be very great, which however would be immaterial provided no two adjacent particles were displaced relatively beyond the range of their elastic orbits.
>
> Experimentally it is not clear how to conduct a test by tension which shall strain the metal in three directions in planes normal to each other, unless we regard a grooved form of specimen adequate to assimilate to such conditions. In compression the case is simplified, and I am not certain that a closer approach to desired conditions may be obtained than are found in the tests referred to in the report of 1886. At all events I have regarded the evidence therein contained as satisfactory and convincing. What we have in these tests are as follows, taking the case of the mild steel specimens, Nos. 1 to 4. The uncompressed specimen, No. 2, page 1677, has an elastic limit of 37,000 pounds per square inch, while the compressed one, No. 4, on the following page has an E.L. of 38,000. The rate of compression was such that both might almost as well have been taken at 38,000. As shown on page 1664, sample No. 4 had been subjected to a pressure of 117,660 pounds per square inch cubic compression. This high pressure therefore had no effect on the compressive elastic limit. We know from other experience that cold flow caused by a much lower pressure applied to the sides only would have resulted in a decided modification of the elastic limit. (The figures, ".0039" opposite 36,000 on page 1678 should read ".0030").
>
> Turning now to the tensile tests of this same steel, tabulated on page 1687, substantially no difference was shown between the compressed and the uncompressed samples. These tests show no changes in these physical properties resulting from exposure to very high cubic compression loads, which attained a limit several times the value of the compression elastic limit of the metal. Had there been a strain accompanying this high cubic stress disturbing the metal beyond its elastic range, we know from common experience in other tests that the physical properties would have been changed in their values. I think this nearly amounts to a demonstration of the 'hypothesis' of Professor Alger."

An apparently erroneous assumption has been made in paragraph 14 in stating that "it will be convenient to call the radial stress (p) plus when it acts to compress the material of the cylinder," and again reflected in paragraph 38, where it is said of the radial pressures in the state of rest and of action that "they are always plus." Equations (2) expressing the values of the strains are the fundamental ones of the whole theory and they are actually derived from (1) by substituting t for X, $-p$ for Y and q for Z. The construction of Equations (2) is apparent in connection with the direction of the forces acting in Fig. 1 in considering that strains of extension are distinguished by + and strains of compression by − signs; also that a pull acts to elongate the metal in the direction of the force and to contract it in perpendicular directions, whilst a compression acts to contract the metal in the direction of the force and to elongate it in perpendicular directions. In deducing Equations (2) and (1) the simplest reasoning appears to be that while Y in (1) represents a pull, p (as applied to the annular fillet of a cylinder) represents a compression and therefore should have a contrary sign. The direction chosen for the forces acting on the annular fillet as shown in Fig. 1 is reasonable and entirely in accordance with fact, t and q are tractions and p a compression or negative traction and hence should enter the equations with a contrary sign from t and q. The fundamental equations being so constructed there appears no necessity for calling p or P plus.

In the deduction of Equations (22), (24), (26) and (27) it may be remarked that in the expression $-\rho$ given in each case, the minus sign is not characteristic of the symbol ρ which stands throughout for a compression without the negative sign prefixed. It somewhat confuses the reader to find it written here in the abbreviated method of the text with a negative sign. Consideration will show, however, that the minus sign arises in these cases because the *strains* to be derived from Equations (13) and (14) are contractions and hence their first members become $-e_t$ and $-e_p$ in the special cases considered.

The conclusion drawn from Equation (26), viz. that it gives the "maximum allowable internal pressure" for the case where $P_n > P_0$ needs modification. As it stands the equation indicates only the P_0 value needed to prevent excessive tangential compression of the bore for a given value of P_n. But this is not the maximum P_0. If we place $P_0 = 0$ in (26) there results an equation similar to (24), as should be. It will be seen that for all values of $P_n < \frac{R_n^2 - R_0^2}{2R_n^2}\rho$ Equation (26) will give a negative value for P_0 which is inadmissible, and P_0 could certainly be increased over the zero value without overstraining the cylinder. We know that, in general, if a simple hollow cylinder is subjected to an exterior pressure the relation $P_0 > P_n$ instead of $P_n > P_0$ will subsist when the elastic resistance to interior pressure is fully developed. Equation (26) might preferably be solved for P_n and explained as expressing the maximum allowable *external* pressure for a given value of the internal pressure P_0.

In the adopted nomenclature, (par. 38) it would appear that the symbols T_0, T_1, etc., are superfluous since the circumferential stress at the surfaces whose radii are R_0, R_1, etc., must be expressed by the symbols θ_0, θ_1, etc., which are dependent upon the strains produced by the extraneous pressures P_0, P_1, etc. It would be well also to call the latter *pressures* in this place rather than "stresses," to correspond with the rest of the text. It cannot be too clearly expressed for the benefit of the student that in neglecting any extraneous longitudinal force that may be present, we have agreed to consider the extraneous pressures P_0, P_1, etc., acting in the direction of the radius, whether inside or outside of each elementary cylinder, as the only real or true forces present and that it is the strains resulting from these pressures which determine everything relating to the elastic resistance of the structure. The designation "true stresses" applied to the products Ee_t, Ee_p, and Ee_q (par. 20 et seq.) might be altered with advantage inasmuch as these are the resultant stresses only or the indicated working limits of the material under the action of the extraneous pressures.

Reverting again to the stipulated direction of the forces in deducing equations (2) and considering the changes of algebraic signs which might be afterwards applied to extraneous forces acting on the cylinder, it will be noted that q was introduced with a positive sign, representing a longitudinal tensile force. If this condition be reversed, that is if it were desired to introduce the effect of an extraneous longitudinal compressive force then its resultant value represented by Z would be substituted with a negative instead of a positive sign. As regards the radial pressures P_0, P_1, etc., however, there arises no case of a real pressure acting in a reverse direction to that indicated for p in equations (2). Any extraneous longitudinal force to be considered will usually be tensile for we would deal ordinarily with the action of the powder pressure on the bottom of the bore in producing strains at cross-sections in front of the breech thread; but we would have a compressive longitudinal force, for example, in the section of a gun between the foremost thread in the breech and the rear face of the breech, supposing that face to be rigidly supported against recoil. To a very minor degree the same conditions are exemplified when the pistons of the recoil cylinders are attached to a yoke around the breech of the gun.

The valuable attributes of the equation

$$P_0 = \frac{3(R_n^2 - R_0^2)}{4 R_n^2 + 2 R_0^2}(\rho_0 + \theta_0) \qquad (42)$$

and the uses to which it may be put are well brought out in the text. This equation, it is perhaps not out of place to remark, was originally published in "Gun Making in the United States," (Mimeograph VIII., Military Service Institution) 1888, Appendix B, where it was employed to discuss the elastic resistance of a gun made in a single piece with the initial tension produced by interior cooling.

A typographical error in the 8th line, page 64 makes $P_0(\theta) = 24.23$ tons. This should be 27.79 tons. Evidently this value must be greater than the adjusted value 24.75 given at the middle of page 65. R. B.

Military Government and Martial Law. By William E. Birkhimer, LL. B., Major, General Staff, U. S. Army. Ed. 2 Rev. 30 + 672 p. O. Kansas City, Mo: Franklin Hudson Publishing Company. London: Kegan Paul, Trench, Trubner & Co., Ltd. 1904. Cloth $3.00.

The work of Major Birkhimer, General Staff, the result of some twenty years of study of this particular field of legal science, is practically *the* authority on the subject for the Anglo-Saxon countries.

Previous writers, as well as members of the legal profession of all grades of rank, had always approached the subject with considerable hesitation, in their writings as well as in giving their legal opinions and decisions, and the literature relating thereto was consequently indefinite and limited.

As Judge Advocate of the Department of the Columbia in 1886, then commanded by Brigadier-General John Gibbon, Major Birkhimer was compelled to take up the study of this special branch of law on account of the existing conditions.

The anti-Chinese riots had broken out, and the Governor of (then) Washington Territory, had called upon the President for assistance. General Gibbon took the 14th Infantry to Seattle, and the Governor declared martial law there. We happened to be on General Gibbon's personal staff at the time, and were with him during these trying times. On the restoration of peace and the return of the troops to their proper stations, both the Governor and General Gibbon were proceeded against in the civil courts for illegal violation of the rights of certain citizens. At this point Major Birkhimer took up the subject in defense of his commanding officer. His investigations led him to go deeper into the subject, and being naturally of a fearless disposition, he soon (in 1892) produced the first reliable and thorough treatise on the subject, which at once took its place as an accepted authority. That was the first edition of the present work.

Meanwhile Great Britain and the United States have both had occasion to inaugurate and enforce military government on an extensive scale and under varied circumstances, the former in South Africa and the latter in Cuba, Porto Rico and the Philippines. On a smaller scale several of the States recently declared martial law, for example, Idaho, in 1899; Pennsylvania, in 1902; and Colorado, in 1903-4; and in 1894 the general government sent troops to Chicago to quell riots which interfered with the United States mails. All these cases the author followed in the courts with great care, and the results are embodied in the present edition.

The work is divided into two parts, Military Government and Martial Law. After a brief introduction on the origin of the powers of the government to institute either of these, the author takes up their discussion separately.

Under **Military Government** he considers the power to declare war, the right to establish military government, the extent of the territory affected and its effect upon the inhabitants and on private and public property, as well as the responsibilities of commanders.

Under **Martial Law**, after discussing the distinction between it and Military Law, he considers its theory in England and the United States, and then discusses its nature and necessity, as well as its authority and administration, and the responsibility of commanders.

The work has met the approval of the Judge Advocate General of the Army, in terms which admit of no misinterpretation. He states that it is "the most complete treatise on the subject in the English Language, and embodies the views which prevail in Anglo-Saxon countries on the subject", and adds that in his official duties he has constant occasion to refer to it.

It is a work which should be in the hands of every navy and army officer, since the occasions requiring its use are apt to arise unexpectedly, and the prompt action required leaves little time for preparation or consultation, the officer being, in general, thrown on his own resources.

The publishers have done their part well. The printing, paper and binding leave nothing to be desired.

An excellent index adds to the convenience of using and consulting the volume.

There is probably no more important or difficult duty which an officer of either service is called upon to perform than that of enforcing military or martial law under the conditions here considered, and yet there is hardly an officer of more than a few years of service who has not been compelled to take part in such work. It is never an agreeable duty, and requires the assumption of great responsibilities. A full knowledge of the legal aspects of the subject is, therefore, of vast importance to the government as well as to the officer. The present work furnishes that, and should contribute greatly to inspiring confidence in the officer and promoting good administration in the territory affected.

The Development of Tactics. By T. Miller Maguire, M.A. LL.D. Ed. 2. 218 p. maps. O. London: Hugh Rees, Ltd., 124 Pall Mall, S.W. 1904. 5s net.

We have already endeavored to give an outline of the contents of the first edition of the excellent book, with an opinion on its merits,* and now it is a pleasure to add a few more remarks with reference to this second edition.

In the first place, the work has been considerably enlarged to meet the requirements of the new regulations whereby the study of the History and Development of the Tactics of the three arms has been carried back to 1740, instead of to 1866. But in addition to the new chapters, covering the extended period, the previous edition has been extensively revised, and in places entirely new matter has been substituted for much of that previously published.

Beginning with the period of Frederick the Great, the "Historical Summary of Tactical Changes" includes the Napoleonic era, the Crimean war, the American Civil War, and from the Campaigns of 1866 to date.

Chapter III. on the tactics of to-day contains fresh matter and some interesting remarks on Japanese tactics 1904. Leuthen, Victoria and Alma have been added to the examples of modern battles, the descriptions being accompanied by excellent maps.

The book gains in interest also. With a deep knowledge of military history and a comprehensive grasp of the science of war, the author has also the faculty of setting forth clearly and tersely the lessons the facts reveal, in a manner at once entertaining and instructive. To those who desire to gain a clear and satisfactory knowledge of the development of tactics since 1740 the book can be commended as a fully efficient and masterful summary of the subject.

Military Studies. By Frederic Louis Huidekoper. The International Military Series. No. 8. 227 p. maps. O. Kansas City, Mo. Hudson-Kimberley Publishing Co., 1904.

This new addition to the *International Series* consists of a series of essays on strategy and tactics by a student who derived his first impulse from the military course in Harvard University. It is therefore of peculiar interest as one of the results of the work of this department, established by the general government at our great universities.

The author, as a graduate of Harvard and Oxford, England, represents a class of military students of more than ordinary *general* education, and the latter seems to be the great essential for the writing of good military history. John Fiske gave us the best account of the strategy and tactics of the Revolution, Professor Sloane, of Princeton University, gave us the broadest and most complete life of Napoleon, and J. C. Ropes gave us the first true account of Waterloo, and the most reliable history of our Civil War, as far as it went. These were all men of excellent general education; none were practical military leaders, nor military men in any sense.

The collection of essays before us relates mainly to the campaigns and battles of Napoleon, although some of the battles of Moltke and Frederick the Great are included.

The article on *Napoleonic Strategy* is the most general in mode of treatment of its subject, and discusses in an intelligent way the fundamental principles of strategy applicable to-day.

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* JOURNAL, May-June, 1904.

The articles entitled *The Campaign of Eckmuhl* and *Did Grouchy by Disobedience of Orders Cause the Defeat of Napoleon at Waterloo?* deal with both strategy and tactics, while the other two articles, *Koln—Rossbach—Gravelotte—Leuthen,* and *Jena—Mars la Tour—Vionville,* involve only tactics.

The article on Grouchy at Waterloo appeared originally in the *United Service Magazine,* and the others in the *Journal of the Military Service Institution,* but in their present form they have been carefully revised, the maps have been redrawn, and several new maps have been added. In this revision the author had the good fortune to enlist the interest and secure the assistance of the late John Codman Ropes, well-known as one of our greatest writers of military history and as a man of splendid character and achievement.

There are sixteen maps to illustrate the battles and campaigns discussed, a very generous supply, accurate in details, and adequate for a clear understanding of the movements and actions involved.

In his studies the author has been particularly careful in the accurate wording of all the *orders* quoted and in basing his conclusions mainly on these and other attainable facts, and he has spared no pains to secure accuracy in his maps and descriptions of ground and other conditions.

The study of military history is essential for all military men from the lowest to the highest, and however much experience an officer may have, he cannot fully profit by it without studying campaigns other than those in which he himself participated, thus learning to apply his experience to other and new conditions.

The present work should prove interesting and invaluable to every military student, not only because of the great leaders, Napoleon, Frederick and Moltke, whose masterpieces are here discussed, but also because the matter presented has been viewed in the light of the latest researches and highest authorities.

The Auxiliary Officer's Hand-book of General Information and Company Officer's Lecture Book. By Captain R. F. Legge. 12 + 234p. S. London: Gale & Polden, Ltd., Aldershot.- 1904. 3s. 6d.

This is a handy pocket volume in Gale & Polden's Military Series, intended as a book of reference for officers of the Auxiliary forces of the British army and intending candidates for commissions. While embracing those things that most intimately concern such officers, it also contains a large amount of useful information on military subjects, that applies to all ranks. For example, field training, the attack and defense, scouting, judging distance, rifle practice, field sketching, and map reading, and a number of other subjects are introduced in the form of lectures characterized by simplicity of expression, and a lucid explanation of all points dealt with.

In a brief introduction Field Marshal Lord Wolseley recommends it for study, with the remark "it is full of useful military information."

Syllabus of Davis' International Law. By C. A. Seoane, 3rd U. S. Cavalry. 127p. S. Kansas City, Mo. Franklin Hudson Publishing Co. 1904. $0.75.

The officers of the army will find this little volume extremely useful, not only in studying for their examinations for promotion and during the courses at the post schools, but also in their general reading on the subject of International Law.

The work is really a very compact abridgement of the original and will thus also serve as a quick means of reviewing it, or refreshing the memory on certain parts without reading through its more voluminous pages.

The author has had the advantage of the experience of the instructor and students in the course of Law at the *General Service and Staff College*, and some of the material is derived from that Department of Instruction.

The little book is conveniently arranged not only with references to the pages of the original, but also with blank leaves interspersed for further notes and additions.

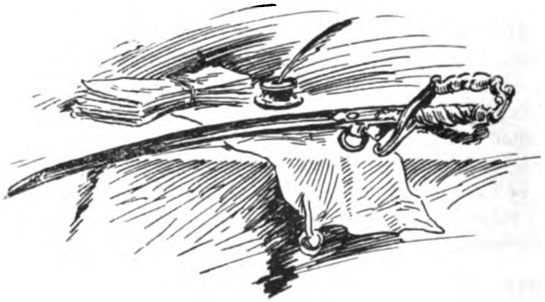
Estimating Distance Tables. By Captain Edwin Bell, 8th U. S. Infantry. 67p. T. Kansas City, Mo. Franklin Hudson Publishing Co. 1904.

The exercises of estimating distances are most useful to the soldier and cannot be too thoroughly practiced.

Under the provisions of recent General Orders errors less than certain prescribed percentages must be made for proficiency as a sharpshooter, a marksman, a first classman or a second classman.

The purpose of this little book is to relieve the company commander of the work of calculating this percentage in each case. By these tables the percentage of error is at once determined. Knowing the *actual* distance to an object and given any *estimated* distance thereto (as made by a soldier) the percentage of error is read off at a glance. Any intelligent soldier can quickly learn to use the tables, thus relieving the captain of all computation, expediting the process of the exercise, and allowing more practice to be had in a given time.

It should prove a very useful book to every company officer.



JOURNAL
OF THE
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"*La guerre est un metier pour les ignorans,*
et une Science pour les habiles gens."

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GUNS FOR THE DEFENSE OF THE OUTER HARBOR

BY CAPTAIN JAMES F. HOWELL, ARTILLERY CORPS

OF the large caliber guns already mounted in partial completion of the project of coast defense as determined by the "Endicott Board", ninety-three are 12-inch, one hundred and nineteen are 10-inch, and ninety-three are 8-inch.

There are certain conditions as to position of armament, range, and target that must determine the gun necessary to meet given conditions. There can be no question as to a change in the most important condition—the target—between the date of sitting of the "Endicott Board" and the present time.

The battleships of Great Britain which were rated first-class from 1885 to 1895 are now rated as second-class, and, with the great advance made since 1900 commencing in England, for instance, with the Duncan or the London class and continuing in the King Edward VII. class, the ships of 1885 to 1895 will hereafter be rated as third-class, and the first-class Majestic type will soon become second-class. (Jane's notation.)[*]

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[*] As one of the most notable features in the progress of naval construction is the continued growth in the size of battleships and armored cruisers, it is interesting to turn to the new edition just published of F. T. Jane's volume "All the World's Fighting Ships," in which he has embodied the classification of the warships of the world.

To the big class of battleships he has assigned the classification "A1.". It is a significant fact that among the first class Powers, Italy, Germany, and Austria-Hungary are not represented in this class, but the other chief Powers have a number of these mailed leviathans in hand. The United States and Great Britain are leading in the "A1" battleships. Mr. Jane points out there are at present in course of construction for Great Britain ten, France six, Russia six, United States eleven and Japan two.—ED.

And not in England alone has this advancement been in progress. France has the République and five sister ships, practically the same, considering the armor opposing entrance of projectiles, as the Edward VII. class; Germany with the Wittelsbach class and the Kaiser class completed, is keeping well up with this advance. All of these mobile forts have belt protection of the equivalent of 9 to 12 inches of Krupp, and further protection to vitals designed to defeat the projectile from the highest power gun.

I may again safely take England as an example showing improved defensive qualities in the target since the project of coast defense as to caliber of high powered guns was determined. In 1891 and 1892 the Royal Sovereigns were rated as first-class with the old compound armor; in 1895-6 the Majestic class, nine ships, appear with steel (Harvey) armor, not the Harvey-nickel or Krupp, the belt amidships equal to about 6 inches of Krupp; in 1898 the Formidable class was launched with 9 inches of Harvey-nickel belt armor equal to 7½ inches of Krupp; in 1901 the Duncan class with about the same protection; following this came the London class, five ships, with 9-inch Krupp belt and the equivalent of 3 inches of Krupp as protection to vitals; and last the King Edward VII. class, three completed and five more building, with 9 inches of Krupp belt, 12-inch barbettes, and with protection to vitals of the equivalent of 14 inches of Krupp.

I have endeavored to describe the great and improved defensive features of the maneuvering forts that would immediately, upon a declaration of hostilities, menace some portion of our coast, and seek to run by the outer defenses of some important harbor, or force an entrance thereto: What caliber guns shall be brought to the defense of the outer harbor? Those that *might* answer the purpose, under the most favorable conditions to the guns, or one that promises, under all conditions, to inflict the maximum material damage to the attacking fleet in the shortest period of time?

I do not propose to enter into a discussion of the use of medium or small caliber guns. I believe the 6-inch ordnance gun is generally accepted as the ideal weapon for the work it would be called upon to perform in the defense of any position. The use of smaller caliber guns can only be determined by local conditions that vary with the position to be protected, but local conditions do not enter into the question of outer defense of our harbors; and while, for strategic reasons, Portland would be more important to England, for instance, than some harbor further south, and Boston and New York would offer more attractions to an enemy than a harbor at a smaller sea port, still, in the question of caliber of guns to be mounted, the aim should be the destruction of the best armored ships that could attack the position, whether it be of great or relatively less importance.

The question then presents itself, what gun may be depended upon, or is most likely to effect the destruction sought—we assume the installation of the 6-inch rapid-fire gun for use against unarmored cruisers or the secondary armor of battleships and cruisers, and to discourage any reconnaissance of, or any offensive operations against, the outer mine field. Rapidity of fire, high muzzle velocity, ease of maneuvering and weight of projectile places this gun in a class by itself, superior to either the 8-inch above or the 5-inch and 4.7-inch below.

Without taking up the question of the battleship or cruiser as a horizontal target, which should be discussed in connection with mortar fire,—the question of the ship as a vertical target remains. Why should we have three guns of different calibers, two of which may not be, at all times, capable of doing the work expected of them through inherent lack of energy, while one at least can only fail through errors of position finding and maneuvering? Why should we mount any more 8-inch or 10-inch guns, except possibly in a very few positions, not enough to affect the argument as to the adoption of a one type gun of large caliber?

I believe the government would not consider the question of a few thousand dollars additional in the first cost of emplacing a gun that would, as near as possible, guarantee protection, as against those that would insure protection only under *certain limitations* of range and target. If the enemy would agree to send only a cruiser squadron against a given position, 8-inch guns for water-line attack, with the assistance of the 6-inch guns, would probably give a good account of themselves; if the enemy would send in its second-class battleships only, the 10-inch guns, with the assistance of the 6-inch batteries, would doubtless be equal to repelling any attack that might be made, conditions being equally favorable to batteries and ships.

But an admiral will send his first-class line-of-battleships against a fortified position, he will keep at the most unfavorable angles from the heaviest armament or he will run past at the highest speed commensurate with safety to his ships, remaining in the zone of effective fire the shortest possible time. The *raison d'etre* of the 8-inch gun under present conditions is not apparent; it appears to me to be wholly obsolete, and occupying advantageous positions which it is unable to fill through inherent inefficiency. Large caliber guns are designed to fire projectiles which will perforate the main vertical armor of battleships and armored cruisers—such large caliber guns as will not meet this requirement, through lack of energy to perforate the improved or heavier defensive armor of the target, should at once give place to a gun which will, as near as possible, fulfil the mission for which it was designed.

A ship must approach within 1000 yards of an 8-inch gun before 8 inches of Krupp may be successfully attacked. It is the weakest gun in the service; compare it with some of the others, considering at what range each will perforate Krupp armor the thickness of the caliber of the gun.

GUN	ARMOR	Range in yards	Service M.V.
		at	f.s.
6-inch	6″ Krupp	3500 to 4000	2600 to 3000
8-inch	8″ Krupp	1000	2200
10-inch	10″ Krupp	2250	2250
12-inch	12″ Krupp	3650	2250

Any first-class battleship must approach to within 3500 yards before her secondary armor of 5 inches to 6 inches of Krupp may be successfully attacked by an 8-inch battery, while barbettes, turrets, conning-tower, air ducts, machinery, and all essentials to efficient offense would remain practically unaffected. In the ranges mentioned I have given the projectile the advantage of normal impact.

All of the foregoing applies in a general way to the 10-inch gun as well as to the 8-inch, although the former has some efficiency for the purpose originally designed while the 8-inch has practically none. At 3500 yards range 9 inches of Krupp may be successfully attacked with normal impact by the 10-inch projectile, but normal impact at this range would be the exception, not the rule; from 3000 yards to 1000 yards the projectile would probably defeat armor of from 9 inches to 11 inches of Krupp, and there the value of the 10-inch gun against main vertical armor practically ceases, while the barbettes, bulkheads, main conning-towers, belt amidships, all guns of a caliber sufficient to inflict material damage to coast batteries and all machinery essential to the successful maneuvering of the ships would remain intact, even at the extreme short range of 1000 yards. More than all this is the vital question of the length of time a battleship is in the zone of effective fire during one phase (a run past) of a naval attack of a harbor. For a reconnaissance in force a first-class battleship squadron could approach within 4000 yards of 8-inch batteries with no danger to its secondary (6-inch) armor, or the guns protected by same, and in a full attack of forts or in the phase of "run past," as said before, no essential of the ships would be materially injured at 1000 yards, so during no instant of time is the ship in the zone of effective fire from an 8-inch gun as regards the main vertical armor protecting machinery, or the armored turrets, barbettes, etc.

The same squadron would come into the zone of effective fire of 10-inch batteries where say 9 inches of Krupp could be successfully attacked, if impact were normal, at 3500 yards. Assuming that the batteries were placed within 2000 yards of the channel entrance to the harbor, an unusual proximity due to the fixed rules for the location of heavy armament, the ship would be in the zone of effective fire, assuming a speed of ten miles per hour, for only five minutes, but during that time the ship would be hit repeatedly. Shot and shell would perforate her secondary armor, intermediate and secondary guns would be destroyed, lower deck and belt forward and aft might be perforated, but would all that stop the ship? The machinery would be intact, the flotation might be reduced, but, with its 14 to 18 water-tight compartments, it probably would not be seriously impaired, the guns of the main battery would still be effective, and assuming the destruction of barricades, mines, etc., the harbor would be in possession of the fleet.

Under the same conditions how would the same squadron fare in the several phases of an attack upon a position and harbor defended by 12-inch batteries? At 10,000 yards armor piercing shells weighing 1000 pounds will perforate the 6-inch Krupp secondary armor and burst into fragments destructive to secondary batteries and the personnel; at 7500 yards 9-inch belt armor will be perforated by the 12-inch A.P. shot, (4000 yards greater range than the 10-inch will perforate the same armor) and the 12-inch carries in 1000 pounds of metal as against the 575 pounds of the 10-inch. At 6000 yards the 12-inch defeats 10 inches of Krupp, at 5000 yards, 11 inches, at 3650 yards, 12 inches. At this range (3650 yards and less) all belt armor, bulkheads, barbettes, turrets, hoods, and conning-towers are at the mercy of the 12-inch gun; the vitals of the best battleship in commission are protected by the equivalent of about 14 inches of Krupp, but one 12-inch A.P. shot at a range beyond the harbor entrance will crash through it all, and, bursting, destroy the machinery that gives it life.

While the 10-inch projectile acknowledges defeat against armor of 11.3 inches at 1000 yards, the 12-inch projectile perforates this thickness at five times that range; while the fire of the 10-inch gun might be said to be effective against battleships at 3500 yards and less, the 12-inch gun is effective at 7500 yards, and becomes *annihilating* at 3650 yards and less; while the 10-inch gun has the battleship in the zone of its effective fire during a run past for five minutes only, or from 3500 yards range to 2000 yards, the 12-inch gun has the same target in the zone of its effective and destructive fire for eighteen minutes or from 7500 yards to 2000 yards—and the question of speed of target, and inferior limit of range or location of armament with respect to the channel, will not affect the time factor relatively.

It has been claimed that an 8-inch or even a 10-inch can be fired at much shorter intervals than a 12-inch gun; according to the provisional drill regulations the loading interval for the 12-inch is 30 to 35 seconds, the tripping interval is 10 seconds; for the 10-inch, loading interval 25 to 30 seconds, tripping interval 8 seconds; for the 8-inch, loading interval 20 to 25 seconds, and the tripping interval 6 seconds. Adding 10 seconds to the above time for each gun as a factor of safety the 8-inch will fire 7 shots in five minutes, the 10-inch 6 shots and the 12-inch 5 shots; even allowing that the 8-inch shots will be 25 per cent as effective as the 12-inch, and the 10-inch, 50 per cent as effective, which they are not at any range, the claim of more rapid-fire for the 8- and 10-inch gun amounts to little, and can not be made at all when the question of the relative length of time the target will be in the zone of effective fire of each gun is considered.

Even the 12-inch gun, of model previous to 1900, is none too effective when we consider that a fleet must come within a range of 4000 yards before an armor-piercing shot can perforate the defensive *essentials* of the first-class battleships. Consider the varied tactics that can be employed by a fleet commander. He has the choice of position to be attacked, he has the choice of time of attack, he may be able to maneuver at unfavorable angles from the heaviest armament, and to some extent at varying speed over an irregular course until he comes within the zone of destructive fire, as distinguished from mere effective fire, when he would endeavor to run past at the highest speed consistent with safety to his vessels. He would have, possibly, ships of small value in advance disguised as battleships if he came in line ahead; these would doubtless attract at least part of the fire, and he would thus escape a concentration of fire that might otherwise be destructive. While it might be dangerous for him to come in while a fog was on, there are degrees of haziness that would make range-finding difficult, and identification of the target still more so, and yet would not preclude safe navigation under a pilot who was familiar with the channels. All of the above leads up to the obvious necessity of having every shot that does hit count, and count for the greatest amount of *material* damage possible.

To say that wherever there are 8- and 10-inch guns there is usually a 12-inch battery is, to me, no argument. The theory of indicating the battleships for the 12-inch, and the cruisers for the 10-inch, and firing at the water-line or upper works is excellent, and would be practical under favorable conditions, but it is a foregone conclusion that we are not going to be allowed favorable conditions. We have to accept the duel when it is offered, the admiral has the choice of weather, time, position and weapons, we are a fixed target, he is a moving one. The 12-inch gun fires A.P. shot and shell, and could doubtless fire torpedo shell at reduced muzzle velocity. It will do all that the 8-inch or 10-inch guns can possibly accomplish, and would triumph in the decisive moment where they must of necessity meet defeat.

The Secretary of the Navy in his annual report says: "The lessons of the war in the East thus far are the same as those of the Spanish war with respect to the relative value and uses of battleships, torpedo boats and destroyers. Weight of metal, heavy guns, and hard hitting whether at long or short range still do the most effective work. The day of the battleship is not over, and the sphere of the lighter vessels, while important, is auxiliary only."

That paragraph tells the whole story. . "Weight of metal, heavy guns, and hard hitting" is equally applicable to army ordnance; and if the day of the battleship is not over, it will be made more effective offensively and defensively than it is to-day. Already a move is being made in this direction, for it is reported that "the present proposition of the general board (Navy) as to battery is that the new battleships shall carry at least four 12-inch guns in turrets, and as many other heavy guns of not less than 10-inch caliber as it may be possible, omitting entirely the intermediate battery, and leaving the secondary battery unprotected by armor, while smoke pipes, air ducts, etc., are to be protected if possible as far as the upper decks by heavy armor."

It should be remembered that the report says "*at least* four 12-inch." More would be mounted if the ships could stand it, and further the fighting range of a naval engagement is short; so the fact that some 10-inch guns are to be mounted on board these ships is no argument in favor of them on land. There is to be no intermediate battery, nothing between the heaviest guns for which they can provide a mount, and the rapid-fire secondary battery.

The completion of the torpedo defense, the general installation of position-finding equipment, and the increase in the personnel sufficient to furnish one full relief of artillerymen to man all the batteries are the most urgent needs of our coast defense; but it is none to early to decide upon the gradual elimination of such heavy guns as will not be fully equal to the destruction of the essentials of the best battleships that any nation could bring before our harbors.

I saw at the Watertown Arsenal a few days ago a 12-inch gun of improved model mounted on a disappearing carriage, model 1901. This gun is expected to give 2600 f.s. muzzle velocity.* That is, I believe, the one gun of large caliber needed in our coast defense, and the further mounting of 8- and 10-inch guns should, in my opinion, be discontinued, or at least all new emplacements should be constructed with gun centers sufficiently far apart that 12-inch guns may be substituted for any 8-inch or 10-inch guns that may be temporarily emplaced; the day of these guns for outer harbor defense is about over—if indeed it has not already passed.

NOTE.—Captain Howell's paper was submitted through military channels for permission to publish it, and the following endorsements appear on the original manuscript:

3rd Endorsement.
Headquarters Department of the East,
Governors Island, N. Y., January 5, 1905.

Respectfully forwarded to the Adjutant General, Atlantic Division, recommending that authority be granted for its publication. It is a valuable and forcible paper upon a subject of present and vital importance.

(Signed) F. D. GRANT,
Brig. Genl., U.S.A., Comdg.

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* A.P. shot from this gun M.V. 2600 f.s. should perforate 12.6 inches of Krupp plate at about 6000 yards with normal impact. Artillery School formula for perforation, capped projectiles.

5th Endorsement.
Headquarters Atlantic Division.
Artillery Inspector's Office,
Governors Island, N. Y., January 12, 1905.

Respectfully returned to the Adjutant General, Atlantic Division.

The reasoning of Captain Howell is considered sound and his paper well presented.

General Totten of the Engineers laid it down as a fundamental coast defense proposition that the most powerful guns possible should be mounted in our forts, to the end that the greatest margin of advantage in attack might be enjoyed.

The line of argument of Captain Howell taken in connection with the principle of General Totten would point to the 16-inch gun as the only truly effective gun against modern battleship armor *at all ranges*. A 16-inch A.P. shot is the only projectile that we can with certainty send into the interior of battleships at ranges beyond 4000 yards. Such a projectile would enter through belt or turret armor up to the extreme limits of effective artillery fire. Why should we not take the advantages offered by our largest type armor piercer?

It is recommended that this paper be forwarded to the War Department, recommending publication.

(Signed) E. M. WEAVER,
Major, Artillery Corps,
Artillery Inspector.

8th Endorsement.
War Department, Office of the Chief of Artillery,
Washington, January 24, 1905.

Respectfully returned to the Military Secretary, recommending that permission be given to publish this paper. It deserves the commendation it has received from the Commanding General, Department of the East.

The Chief of Artillery regrets that our coast armament has not been limited to 12-inch, 6-inch, and 3-inch guns.

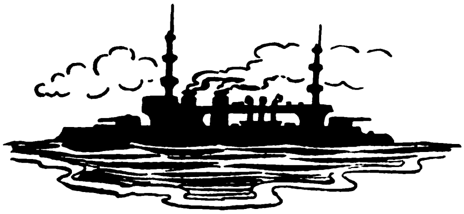
(Signed) J. P. STORY,
Brig. Genl., Chief of Artillery.

10th Endorsement.
War Department, The Military Secretary's Office,
Washington, January 28, 1905.

Respectfully returned to the Commanding General, Atlantic Division, Governors Island, New York.

The Chief of Staff has no objection to the publication of this paper.

By direction of the Chief of Staff,
(Signed) HENRY P. MCCAIN, Asst. Adjt. Genl.



AMMUNITION FOR CANNON*

CAPTAIN THALES L. AMES, ORDNANCE DEPARTMENT, U.S.A.

SMOKELESS POWDER.

THE last decade has witnessed remarkable progress in the development of smokeless powder, progress which has quite kept pace with the development of guns, which, in recent years, in the change from smooth bore to rifled cannon, has been marked. All the credit for the present advance can by no means be claimed for the last decade, for, at its beginning, great progress had been made, the beginning dating back many years.

The discovery that the action of nitric acid on such substances as cotton and glycerine produced smokeless explosives many times stronger than black powder was the beginning, a desire to use these in small arms and cannon was the incentive for experiment, which finally resulted in the development of the present powders.

Neither guncotton nor nitroglycerine in their natural states was suitable for propelling charges in guns, both being too violent in their action. An attempt was made, however, to use nitrocellulose, but nitroglycerine had the additional disadvantages of being a liquid and not readily adapted to such use.

A very important advance, shortly after nitrocellulose was first known, was the discovery, in 1847, that it was soluble in a mixture of ether alcohol, the solution, collodion, being used for surgical purposes. Further use of this property was made as early as 1860 in the manufacture of celluloid, and during the succeeding years other solvents for nitrocellulose were found. After solution, the evaporation of the solvent left a tough, horny colloid.

Difficulty had been encountered in obtaining nitrocellulose sufficiently purified to render it stable, and it appeared that on this account any extensive use of it was impossible. It lacked purification from the fact that during the process of nitration the fine capillary tubes of the cotton fiber were filled with the

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nitrating acid, and the washing to which it was subjected later for purification, failed to remove it. This acid was capable of reacting farther upon the nitrocellulose starting decomposition, which, once under way, progressed rapidly. An improvement on this process of manufacture was patented by Abel in 1865, which almost completely removed this objection to its use, although many years appear to have passed before full advantage was taken of the invention.

The improvement consisted in pulping the nitrocellulose before washing it, the fibers being cut into very short lengths, permitting the removal, by the water, of the acid remaining in the capillary tubes of the fibers.

The inconvenience of using a liquid explosive led to a search for means of overcoming this disadvantage of nitroglycerine. Nobel found that certain porous substances were able to absorb a large percentage of nitroglycerine, and hold it indefinitely without leaking. He also found that, when thus absorbed, it was much less sensitive to shock, and that it would burn without exploding. As a result of his experiments, he announced his discovery of dynamite in 1866. One disadvantage resulting from the absorbent material being inert, was that the new explosive had less energy per unit of weight than pure nitroglycerine and less than at the time seemed desirable. To overcome this objection, Nobel finding that a nitrocellulose of low nitration was soluble in nitroglycerine when heated, and that the mixture when cold was a stiff jelly-like mass, in 1875 patented explosive gelatine, which had all the good properties of the dynamites already referred to, and the advantage of being more powerful, weight for weight, than nitroglycerine even. His patent also covered its manufacture without heating the nitroglycerine by use of a solvent which would dissolve the nitrocellulose without warming, then mixing with the nitroglycerine and evaporating the solvent.

One of the first powders for use in arms, in the manufacture of which advantage was taken of the solubility of nitrocellulose, was brought out in 1882, and was known has E. C. Powder. It was composed of pulped nitrocellulose and nitrates formed into grains which were moistened with either and dried. The ether partially dissolved the grains and left them coated with a hard, dense skin of collodion. Several similar powders followed, among which were Vieille's Poudre B, in 1886, and Poudre BN, shortly after, both manufactured and used by the French Government for military purposes.

From the known properties of this explosive gelatine, and from those of nitrocellulose powder already manufactured, Nobel conceived the the idea of modifying explosive gelatine, so that it would be suitable for use in arms, and in 1888 patented ballistite, using 40% of nitrocellulose in it, as compared with 7% in explosive gelatine. These proportions were changed, a year later, to 50% nitrocellulose and 50% nitroglycerine. A solvent may be used, or gelatinization may be effected, by using moist nitrocellulose, warming the nitroglycerine and adding warm water. Results obtained with this powder were very satisfactory, and it was immediately used quite extensively, especially in Italy, where it has continued in use up to the present time.

The year following the announcement of ballistite by Nobel, Abel and Dewar, in England, patented cordite, which was composed of nitroglycerine combined with nearly the same percentage of nitrocellulose (38%) as was used by Nobel in ballistite. There was this difference, however, Nobel used a nitrocellulose of low nitrogen content, which was soluble in nitroglycerine, while Abel and Dewar used one containing a high percentage of nitrogen which was insoluble in nitroglycerine, using acetone as a solvent. They also used a small percentage of some substance, as vaseline, as a deterrent. This powder has been used extensively from that time up to as recently as 1902, when modified cordite was adopted, in which the relative percentage of the ingredients was changed to 65% of nitrocellulose, 30% of nitroglycerine and 5% of vaseline.

A number of smokeless powders containing nitrocellulose, or nitroglycerine and nitrocellulose, these either alone or with substances added as deterrents or to promote the keeping qualities of the powder, were brought forward and tested during the next few years. Among these was indurite, developed by Professor C. E. Munroe at the United States Torpedo Station, and patented by him in the United States in 1893. This was a pure nitrocellulose powder, using guncotton or a nitrocellulose of high nitration only. Its gelatinization was effected by mono-nitro-benzene. It was tested extensively by the navy, and gave very satisfactory ballistic results.

Another powder, developed during this period, and patented in 1893 by Messrs. Maxim and Schupphaus, which gave satisfactory ballistic results, was one composed of about 90% of nitrocellulose of high nitration and 10% of nitroglycerine.

It is thus seen that from the present point of view, great progress had been made in the solution of the question of a proper smokeless powder, at the beginning of the last decade.

Nitroglycerine powder containing from 10 to 50% of nitrocellulose of a varied degree of nitration and with and without deterrents and preservatives, had been manufactured and tested, as had also pure nitrocellulose powders, and nitrocellulose powders to which nitrates had been added.

Conditions, however, had not progressed sufficiently in the United States for immediate advantage to be taken of the progress made. There appears to have been a general distrust of the stability of these powders, due probably to the general impression, common a number of years previous to this time, and with good reason, as to the stability of nitrocellulose and also doubtless to the fact that samples on hand showed unmistakable signs of active decomposition, such as has been witnessed in more recent years with similar smokeless powders.

As information on such subjects was kept carefully guarded, each manufacturer had to pioneer the way for himself. Considerable time elapsed after an order was given before a sample could be furnished, due to the time required for manufacture, and to the general lack of experience and reliable data to guide the manufactures in producing samples; several might have to be manufactured before one, having a granulation suited to the gun desired, could be produced. Progress, therefore, was necessarily slow.

Experiments were first made in the United States with smokeless powders for small arms for military purposes about 1890, and in the next and following years, samples were tested in the field and seacoast guns. All promising samples obtainable were tested, and among these werethe French BN, German smokeless, Navy smokeless, cordite, Troisdorf, Leonard, Peyton, Maxim-Schupphaus, DuPont and Rotteweil. A part of these contained 50% or more of nitroglycerine, part between 20 and 30% and one as low as 10%, while several had no nitroglycerine, being pure or nearly pure nitrocellulose powders. The nitrocellulose powders here referred to were either mixtures of nitrocellulose of high and low nitration, or of high nitration alone, as the Navy Department indurite, and all differed from the one finally adopted, which was a pure nitrocellulose powder of about 12.44% nitration.

After exhaustive tests, the conclusion was reached, in 1897, that powders containing from 10 to 40% of nitroglycerine, the other ingredient being nitrocellulose having from 13 to 10% of nitrogen, depending upon the percentage of nitroglycerine, were best suited for use in army cannon, and further tests concluded during the next few months resulted in the adoption of a powder designated as NN (12.25), by which was meant a nitrocellulose nitroglycerine powder, 25% being nitroglycerine, the remainder being nitrocellulose of 12% nitration. It is to be noted that this is almost exactly the same composition as that recently adopted in England after most careful investigation.

Owing to excessive pressures having been obtained from several lots of this powder in different guns, with corresponding damage to the guns, its manufacture was discontinued in March, 1899. The excessive pressures referred to were obtained, some with the single-perforated and some with the multiple-perforated cylindrical grains. In one case the powder contained but 10% of nitroglycerine.

The cause at the time assigned for the high pressures with this powder was brittleness, due to which it was believed that the grain broke up when subjected to high pressure, thereby greatly increasing the burning surface and the corresponding evolution of gases.

While examination made at that time showed the grains to be very brittle, experience gained in recent years with nitrocellulose powder has led to the belief that the excessive pressures obtained were not produced by the powder breaking up, but by the powder having a low critical pressure for the gun, due to brittleness, by its being a comparatively quick powder for the gun, and to the projectile being delayed in its forward motion, due to a large or unusually hard band or some similar cause; the high pressure being the result of the natural laws of burning, under the conditions existing in the gun.

The U. S. Navy had long enjoyed exceptional advantages in the investigation of smokeless powder, having early established an experimental plant for its manufacture at the Naval Torpedo Station, Newport, R. I. Here, under the able direction of naval officers and with the assistance of skilled chemists, experimental work was started on smokeless powder in 1888, and continued during the following years until a satisfactory powder was obtained. One of the first powders to be developed there was indurite, a pure nitrocellulose of high nitration, previously mentioned as patented in 1893 by Professor C. E. Munroe. A nitrocellulose powder containing nitrates was also experimented with extensively in 1895, but on account of its lack of stability, work on it was stopped.

The navy while testing samples of nitroglycerine powders obtained from manufacturers, did not look with favor upon such, and constantly bent its efforts to the production of a nitrocellulose powder.

Extensive experiments were made during the next two years with blends of nitrocellulose of different degrees of nitration. The properties of colloids produced by different solvents were investigated. Hydrocellulose was also experimented with extensively. The degree of nitration of cellulose under various conditions, physical and chemical, was examined and as a result a nitrocellulose of comparatively high nitration, completely soluble in ether and alcohol, was obtained, which formed a tough colloid, was smokeless, gave indications of high stability when carefully made, and when manufactured into powder, gave good ballistic results.

This powder, which was almost immediately adopted for service by the navy, and its manufacture undertaken on a large scale by private manufacturers, was of pure nitrocellulose of 12.44% nitration (later increased to 12.65), and 99% soluble in ether alcohol. This same composition had been adopted some years earlier by Russia for manufacture into smokeless powder. Lieutenant (now Commander) J. B. Bernadou, U. S. Navy, is mentioned as entitled to special credit in connection with the development of this powder.

Considerable quantities were on hand and could have been supplied for use during the Spanish-American War, but as only a part of the different caliber guns had been provided for, little, if any, was sent out. Immediately thereafter, ships were completely fitted out with it as opportunity occurred, and it has been manufactured exclusively for navy cannon up to the present time.

A further advantage now enjoyed by the navy is a large plant for the manufacture of smokeless powder at Indian Head, Md., the first appropriation for which was obtained in 1898. Experimental work at the Naval Torpedo Station is still carried on.

Nitrocellulose powder adopted by the army.—When the nitroglycerine powder adopted by the army gave irregular and high pressures, which resulted in the discontinuance of its manufacture in March, 1899, the navy had already adopted the nitrocellulose powder referred to, and had subjected it to numerous tests. As the army was badly in need of a satisfactory smokeless powder at once, and as the nitrocellulose powder adopted by the navy, appeared to fill the requirements, it was immediately adopted for army use also.

It was known that this powder was not quite as strong, pound for pound, as the nitroglycerine powder previously used, but, otherwise, it was believed to have all its good qualities as well as some not possessed by it.

Nitrocellulose powder was first manufactured for army use under the same specifications as were used by the navy, but as years passed, while both still called for practically the same chemical composition in the finished product, each prescribed a slightly different method of purification and different stability tests for both nitrocellulose and finished powder.

Present status of nitrocellulose smokeless powder.—For several years all moved smoothly for the nitrocellulose powder, and large quantities were purchased by both branches of the service, and excellent results were obtained uniformly with it; but, nearly two years ago during some experimental firing, in which velocities and pressures were taken, with a lot of nitrocellulose powder which had been in store for several years, it was found that the results given above a certain pressure did not correspond to the charges used, but were very irregular. Similar results having been obtained with other lots, a re-test of many of the earlier lots delivered was undertaken.

One conclusion reached from these re-tests was that all lots when fired, have what may be called a critical pressure, that is, a pressure above which the velocities and pressures do not increase regularly with the charge, often showing for charges corresponding to critical pressures no increase in pressure from those previously obtained with smaller charges, and for greater charges, irregular pressures and sometimes dangerously high ones.

For most of the lots tested the critical pressure was found to be between 35,000 and 40,000 pounds per square inch, while, for some, regular results were obtained as high as 45,000 pounds.

Various causes have been assigned to account for the existence of a critical pressure point and for the resulting variations. Among these is the brittleness of the colloid, and tests thus far made indicate almost to a certainty that this is an important factor, due apparently to an increased rate of burning as a function of the pressure and not to the breaking up of the grain. The cause of the brittleness of the grains has also been investigated, and is believed to have been determined.

A second cause is the form of grain now commonly used by both services—the multi-perforated grain, about 2½ times its diameter in length. From its form it burns on an increasing surface. The gases given off, therefore, are an increasing function of the thickness of powder burned, and as the thickness of powder burned is a function of the pressure, the form may contribute, if other conditions are favorable, to produce high pressures. Conditions would be favorable if a powder had a high initial burning area for the gun in which it was used, and the projectile used had a slightly larger or harder band offering an increased resistance, as there would be a corresponding rapid evolution of gases with corresponding pressures before the projectile could take up sufficient velocity to make the space passed through great enough to keep conditions normal in its rear.

The form of the grain cannot be said to be the cause of high pressures, but may contribute, if other conditions are favorable for them.

A second conclusion was that nitrocellulose powders, as they had been manufactured and delivered, tended to increase slightly in ballistic force on storage. A slightly smaller charge would give the same velocity and pressure as had been given previously by a larger charge. A natural explanation of this was that the slight quickening was due to some change in moisture and solvent from that originally contained, but investigations made did not show this to be so in every case.

As a result of the re-tests, effort is being made to secure a colloid which will not have critical pressures below 45,000 or 50,000 pounds, and experiments are under way using flat strips and single-perforated grains with a view to the adoption of one or the other, if found to give greater uniformity than the multi-perforated. Failing to obtain a nitrocellulose powder giving uniform results for all pressures below 45,000 pounds, powders of other compositions will be tried.

Nitroglycerine and nitrocellulose powders.—The relative force of explosives may be taken as proportional to the product of the quantity of heat produced by the volume of gases given off.

Table 1 has been published previously as showing the relative force of nitroglycerine and nitrocellulose, and from it an estimate can be made of the relative force of their various combinations.

From Table 1, it is seen that the heat produced by nitroglycerine is practically twice that from nitrocellulose, while on the other hand, the volume of gas produced by nitrocellulose is the greater, but not nearly enough to make up for the difference in heat. Nitroglyerine, therefore, has much the greater force. While great force is desirable in a powder, it is in the case of nitroglycerine powders accompanied by an injurious action on the gun—erosion— which takes place to a greater or less extent with all powders, but is unusally great with nitroglycerine powders on account of the relatively large quantity of heat produced by its combustion.

TABLE 1.

Substances.	Quantity of heat.	Volume of gas.	Relative force (heat by gas)
Nitroglycerine	145	71	10 300
High-grade guncotton	93	86	8 000
Low-grade guncotton	71	93	6 600

With nitrocellulose powders a larger volume of comparatively cool gas is produced, and very good ballistic results are obtained, and results just as high as are obtained with nitroglycerine powders can be obtained if guns having sufficiently large powder chambers are built and correspondingly large charges are used, the erosion still being much less than would result from the use of nitroglycerine powders producing equal velocities. For the same gun, using the same maximum pressure, higher ballistic results can be obtained with nitroglycerine powder than with nitrocellulose, but with greater erosion. As the percentage of nitrogen in nitrocellulose varies, so the volumes of gas and heat per unit weight vary, the volume being a maximum for a nitrocellulose powder containg 12.44% of nitrogen. This, coupled with the fact that this nitrocellulose was in every other way found suitable for manufacture into smokeless powder, led to its adoption by the U. S. Navy.

By using a powder containing 25% of nitroglycerine, the erosion is reduced to a point considered unobjectionable by many, and the force of the powder is still noticeably above that of pure nitrocellulose powder having 12.65% of nitrogen. This is the powder first adopted for use in army cannon, but the manufacture of which was shortly discontinued. At this time, it appears that the fault was probably more in the methods of manufacture than in the composition, and that with proper care and methods a most satisfactory powder might be produced.

This conclusion is supported by the fact that the English Government, after extensive experiments, adopted in 1902 a modified cordite, composed of 65% of nitrocellulose, 30% of nitroglycerine, and 5% of vaseline. The nitroglycerine not only adds force to the powder, but prevents brittleness. The vaseline also prevents brittleness, and moderates the high temperature produced by the nitroglycerine, thereby decreasing erosion.

Pure nitrocellulose powders, as stated previously, are known to change slightly during storage, due to gradual change in solvent and moisture contained, and to other causes not well understood. During manufacture the solvent is reduced to about 4%, and although several weeks in the dry-house will not change this appreciably, the powder loses it very gradually when stored, slightly changing in ballistic value.

It is understood that powder containing nitroglycerine is entirely free from this defect, as no difficulty is experienced in entirely eliminating the solvent used. If manufactured and stored properly, it can be kept indefinitely without change. Little reliable information, however, is at hand by which to judge this point. Nitroglycerine when present in nitrocellulose powders facilitates the working of them, less pressure being required to run the colloid through the presses, but on account of the danger attending the use of nitroglycerine, powder makers prefer to manufacture nitrocellulose powder.

Stability and other tests.—The progress of the last decade consists not alone in the selection of a smokeless powder, but in great improvement in the stability of the powders produced, as measured by the stability tests in use.

The nitrocellulose is subjected to prolonged steaming or boiling which removes more thoroughly any free acid which may be present, and is also believed to remove, by decomposition, the traces of cellulose of low nitration, which are known to be much less stable than those of higher nitration.

For many years the only test applied to nitrocellulose and finished powder was the Abel test, which detects with great sensitiveness the presence of acid, either that remaining from nitration or that produced by decomposition. This test is still prescribed for nitrocellulose.

The new tests, several of which have been adopted recently, measure with more or less accuracy the rate of decomposition of nitrocellulose or powder during a considerable length of time, the sample being kept at a high temperature. Of these the German test and the Ordnance Department 115° cent. test, at present, form part of the specifications for army powder.

The German test is at 135° cent., and uses litmus paper. Three points in the test are noted: First, the complete reddening of the paper; second, the appearance of brown fumes (N_2O_4); and third, the explosion of the sample.

The most recent test adopted is the Ordnance Department 115° cent. test. It is applied to powder only, to the grains in their natural state, and consists in heating the sample for eight hours each day for six days, and determining from day to day, the loss in weight. The total loss of weight for this time must not be greater thas 8 per cent. Several advantages are claimed for the test, the more important being simplicity, a temperature sufficiently low to indicate clearly differences in powders of different stabilities, and the fact that it shows at any time, the total loss in weight due to decomposition.

These tests are based upon the following assumptions: First, that heating an explosive causes decomposition, the rate of which increases with the temperature; and second, that the rates of decomposition of explosives at temperatures above normal are an indication of what their relative behavior will be at normal temperatures. While the last principle is doubtless correct, sufficient data are not yet available to construct the stability curve of powders at normal temperature, measured in years, as a function of their rate of decomposition at high temperatures, nor is there any knowledge as yet as to what the form of this curve will be.

Another test, to determine the physical condition of powder, has been placed in the specifications recently and is known as the compression test. In it a grain of powder, equal in length to its diameter, is compressed between two parallel surfaces until cracks appear in the surface of the powder· A good powder should stand 50% compression before these cracks appear. The use of this test will insure obtaining powders having colloids of more uniform toughness, and it is expected that the critical pressure for powders showing high compression tests will be raised uniformly.

The granulation of smokeless powders.—From theoretical considerations, which were confirmed by experiment, the late Captain S. E. Stuart, Ordnance Department, U. S. Army, selected the seven-perforated cylindrical grain as the best form for obtaining high ballistic efficiency, and this form was used for the nitroglycerine powder first adopted for service. This same form was also selected by the navy when the present service powder was adopted, and both branches of the service have continued to use it almost exclusively up to the present time.

Since the irregular results with nitrocellulose powder have been attributed in part to the form of grain used, this subject is receiving further attention.

Smokeless powder grains, under the conditions existing in a gun, burn by parallel surfaces, that is, burn at a uniform rate over the entire surface of the grain. If the ratio of the initial burning area and any subsequent burning area for the various forms of grains is considered, it is found that this ratio varies, not only for the different forms of grain, but also for the same form of grain, as the burning progresses.

For the seven-perforated grain, the area is increasing up to the point where the burning surfaces become tangent and the grain disintegrates, at which point about 85% of the grain is consumed. The maximum percentage of increase in the burning surface of the seven-perforated grain varies as the relative dimensions of the grains are changed. Thus, if the length is kept constant while the ratio of the diameter of the grain divided by the diameter of the holes is increased, the maximum burning area will be increased, and similarly, if the diameters of the grain and of the holes are kept constant, as the length of the grain is increased, the maximum burning area will again increase.

For the usual form of seven-perforated grain, the maximum increase in surface is about 37 per cent. For the single-perforated strip and similar grains, the area is decreasing, though it may be, depending upon the relative dimensions, but slowly. For the single-perforated grain, it may be made near unity by making the perforation of large diameter, the walls thin and the length comparatively great.

Theoretically, the multi-perforated grain appears to have advantages, due to the fact that the initial burning surface of a charge can be made low. When the gun is fired, the rate of evolution of the gases, therefore, is low at first when the movement of the projectile is very slow, and increases as the powder burns until the maximum pressure is reached, and beyond until the web is consumed, which probably occurs almost immediately after the maximum pressure is reached. Beyond this the pressure drops off rapidly, but there has been a comparatively long interval of sustained high pressure at the breech due to the burning on an increasing surface. With this form of grain the bulk of the powder is burned very early in the travel of the projectile through the bore, and works expansively throughout the remaining length, giving the powder a high efficiency.

The single-perforated grain burns on nearly a constant surface throughout the length of the bore, and therefore a greater volume of gas is given off in the chase of the gun and correspondingly high pressures are maintained here, although, due to burning on a constant surface, there is a less sustained high pressure at the breech.

Theoretically, the single-perforated grain should give greater uniformity than the multi-perforated when slightly abnormal conditions of loading are encountered. Tests are to be undertaken shortly to settle this point, and also the relative ballistic efficiency of the single and multi-perforated grain.

Due to the fact that smokeless powders require a specially designed form of grain for each gun, and to the accumulation of many data relating to this subject, a clearer idea of the laws governing can be obtained than was before possible.

In designing grains of powder for all service guns, the California Powder Works, for quite a number of years, has used very successfully the ratio of the area of the grain divided by its volume, assuming that the pressure in any gun varies directly with this ratio.

Later it was shown that the thickness of the web, or the least dimension of the grain, could be substituted for τ in Sarrau's formulas for pressure and velocity, and satisfactory results obtained, and also, that similar results were obtained when the reciprocal of the ratio already referred to was used for τ. Or, since the ratio of the area of a grain to its volume is the same as the ratio of the area of a pound of the same powder to its volume, both the pressure and velocity vary with the burning area per pound.

Recently a special study has been made of the relative advantages of the various forms of grain, taking into consideration the initial surface and the rate at which this surface changes as the burning progresses, and as a result the tests of different forms of grains are to be made. A thorough study is being made of the laws governing the rate of burning of powder throughout the length of the bore, which promises most interesting results. This study is based upon the area of powder burned at any instant, and the law of burning as a function of the pressure.

Up to the present time the dimensions of grains required to give the ballistic requirements in the various guns have not been prescribed, and as a result considerable variation exists in the dimensions of grains supplied by different manufacturers for the same gun, with a corresponding variation in the weight of charge to give standard velocities and pressures. It is now proposed to prescribe the exact dimensions of all grains, allowing proper working tolerances, with the expectation that much greater uniformity in charge will result with powder delivered by different manufacturers, and, with thorough blending and careful storage, it may result in having but a single weight of charge for each gun.

Black powder priming charge.—The most satisfactory results are obtained with smokeless powders when a priming charge of black rifle powder is used, the quantity being sufficient to raise the temperature and pressure in the powder chamber high enough so that the powder grains are ignited over their entire surface instantly. Without a priming charge, hangfires, misfires and irregular results are apt to occur. For nitrocellulose powder the weight of the priming charge is about 2.6% of the weight of the smokeless charge, while for nitroglycerine powder about 1% is sufficient.

In fixed ammunition, the powder is placed in the case loose, the igniting charge being made up into two disks, using crinoline, one disk being placed in rear of the powder next the primer in the case, and the other in front of the powder. When the 110-grain primer, referred to later, is used in the case, it takes the place of the rear igniter of black powder.

For guns not using fixed ammunition, the powder is made up into cartridges, using raw silk for bags. The tops and bottoms of the bags are made double, the priming charge of black powder being quilted between. Where the charge is too large to handle in one section, more than one is used, each being made as already described.

Storage cases.—Charges of smokeless powder were supplied to the seacoast fortifications, first, in lined wooden boxes; later, in zinc cases with balata washers and screw tops, and more recently, in corrugated-iron storage cases, the covers of which are soldered on. This care is considered nncessary to prevent change in the smokeless powder, due to loss of volatiles, also to protect the priming charge from moisture.

Smokeless powder as now delivered in bulk by munufacturers, is placed in well-made zinc-lined boxes having only a small outlet, which is sealed by a soft rubber gasket, made so that it can be easily renewed if deterioration takes place.

FUZES AND PRIMERS.

No subject connected with ammunition has received more attention during the last decade than that of fuzes, and satisfactory progress has been made. The object sought has been to secure a fuze which will be certain in its action under the various conditions met with in service, and which at the same time will be perfectly safe in transportation and handling, and under all other conditions met with prior to being fired.

Percussion fuzes.—To be certain that a percussion fuze will be safe up to the moment when fired, and sure in its action on impact, requires that some change shall take place in the fuze between the time when it is loaded in the gun and the time when impact takes place. This change is called arming, the firing pin being prepared to deliver a blow at impact, which will ignite the priming composition.

The majority of the fuzes used, up to the present time, have been armed by the inertia of a part of the fuze, which will be designated as the arming unit, at the time the projectile is taking up its velocity in the gun, overcoming the resistance which previously made the fuze safe and by its movement at this time, making it possible for the firing pin to deliver a blow at impact, which will set off the fuze. In all such fuzes, the force making the fuze safe, or the resistance to arming, must be less in each case than the force required to transmit the maximum acceleration of the projectile to the arming unit, to insure the arming of the fuze.

Having determined the resistance to arming necessary to make service fuzes perfectly safe under all possible conditions, whether a fuze, having this resistance, can be used for all guns will depend upon whether the maximum acceleration of the projectile in each particular gun is sufficient to insure arming.

Both theory and practice have proven clearly that fuzes with this method of arming cannot be made sufficiently safe for present guns of low power, as it has been found that if they are made sensitive enough to arm, they will be armed by shocks received incident to handling and transportation. One fuze of this type, known as the ring-resistance, has been adopted for service during the present decade, and is still used almost exclusively in service, but will be replaced shortly by those of the new type.

When it was demonstrated clearly that ring-resistance fuzes could not be made with a satisfactory factor of safety when used in guns of low power, it was recognized that the difficulty was inherent in all fuzes arming in this way, and experiments were undertaken with fuzes armed by the rotation of the projectile. These were known as centrifugal fuzes, and while not a new type, do not appear to have been given the consideration to which they were entitled. Recently this fuze has been much improved and extensively tested, and is considered a safe type for use in guns of all calibers.

As adopted for service, it differs from those previously used only in the arming unit, which is cylindrical in shape and cut in halves along its axis. The cavity in the fuze, in which the arming unit or plunger is placed, is large enough to permit a slight outward movement of the halves, sufficient to turn the firing pin which is secured to them, from a position entirely within the plunger with the point turned nearly at right angles to the plunger's axis, to a position projecting in front of the plunger and with the point in prolongation of the axis. The halves of the arming unit are held in the unarmed position by a spring, which when arming takes place, due to the outward motion of the halves, undergoes further compression. The initial compression of the spring is adjusted to require the desired number of revolutions of the projectile before arming can take place. The outward motion of the halves is limited to that required for arming, which takes place before they are in contact with the interior walls of the fuze, so that the forward motion of the plunger at impact is not hindered by friction which might arise from this cause.

Fuzes armed by the acceleration of the projectile in the gun might also be armed by being dropped or by severe jolting, the forces producing arming, acting in the same manner in either case; while in fuzes armed by the rotation of the projectile, forces resulting from drops or jolts do not act directly to produce arming, and should there be any tendency for the halves to separate, experience has shown that the spring holding them together can be given sufficient initial tension to make the fuze safe under all conditions, and yet arm and remain armed until impact, in guns giving the least angular velocity to projectiles.

As centrifugal fuzes are safer, theoretically, than those armed by the acceleration of the projectile, and as experiment and experience have shown that they are amply safe when suited for use in all guns, these fuzes have been adopted for use in nearly all service projectiles. Their general use serves also to simplify the question of manufacture and supply.

Delayed-action fuzes.—Nearly all fuzes are provided with a delayed-action element which, with armor-piercing projectiles, permits them to pass through the armor before bursting takes place, and for shells fired in the open it permits the shell to rise after impact to a sufficient height to make the fragments effective over a larger area than would result from the shell bursting on the ground.

Time fuzes.—In the combination time and percussion fuze the percussion element is exactly the same as one or the other of those already mentioned. Time is measured by the burning of a specially prepared train of powder, the length to be burned and therefore the time to elapse before the bursting charge of the shell is reached, being capable of adjustment. The time train is ignited when the gun is fired, by a plunger and primer very similar to that used in the percussion fuze armed by the acceleration of the projectile, except that in the time fuze the motion of the plunger, which corresponds to arming in the ordinary fuze, ignites the priming composition, which immediately ignites the time train. In time fuzes in use until recently, the time train was contained in the time-train cone, and extended several times around it. This cone was hollow and formed the interior walls of the fuze, and enveloping it was the cone cover, which had the position of the time train beneath marked on it, and was graduated in seconds and parts of a second.

To set this fuze a punch was used which made a hole entirely through the cone cover, time train, and cone at any desired point, and the flame from the priming pellet, coming through this hole, ignited the train.

An improvement on this fuze has been introduced recently, in which the time train is contained in two disks, the planes of which are perpendicular to the axis of the fuze, and which extend to its outer surface. The time train lies in a groove in each of these disks and forms a complete circle except at one point in each where, for a short interval, the groove has not been cut. When assembled the upper disk is fixed and the lower one movable. The zero point is marked on the body of the fuze below the lower disk, which is graduated in seconds or yards. When set at the zero mark, the flame burns directly through and reaches the bursting charge in the shell. When the lower disk is revolved any distance, as 20°, the flame must burn that distance in the upper ring and back the same distance in the lower ring, taking a corresponding time to reach the bursting charge. The communication from the interior of the fuze to the upper ring, and from the upper ring to the lower, is just at the point where the break in the upper and lower trains takes place, so that these trains always burn from one end only. All that is necessary to set the fuze is to revolve the lower disk until the division indicating the desired range is opposite the zero mark.

A simple fuze setter has been designed which, having been set for the desired range, may be placed over the fuze, and engaging in the movable ring, may be turned in either direction until it comes up against a stop on the fuze proper, when the desired setting will have been given, the fuze being held stationary while the movable ring is turned.

Primers.—The field guns now in service use non-obturating friction primers, but when these guns are replaced by the new model using fixed ammunition, all primers in service will be of the obturating type, obturation being secured by the expansion of the thin walls of the primer against the walls of the primer seat. Guns using fixed ammunition use percussion primers almost exclusively, and in guns not using fixed ammunition, friction or electric friction-primers are used. In these latter guns, sub-caliber ammunition requires a special primer, one which will receive the flame from the regular primer used in the gun and transmit it to the propelling charge.

The older form of obturating primer was secured in its seat by screw-threads, considerable time being required to replace a fired primer. In the present models, the threads are omitted, the primer being held in its seat by the firing mechanism, which automatically ejects the fired primer when the firing mechanism is raised for the insertion of new primer. This improvement tends to increase the rapidity of fire of the gun.

Mercuric fulminate is no longer used as the priming composition in fuzes and primers, on account of its injurious action on the metal of the containing cup. Its place has been taken a composition made up of sulphur, sulphide of antimony, chlorate of potash, and ground glass, the relative proportions of the ingredients varying slightly, depending upon the particular use to which it is to be put.

Ordinarily a primer contains, besides the priming composition, only a sufficient quantity of mealed powder to communicate the flame to the propelling charge, or priming charge, if there be one.

For nearly all fixed ammunition, a primer is now manufactured, having a larger amount of mealed powder, enabling it to take the place of the rear igniting charge of black powder; this is known as the 110-grain primer.

PROJECTILES.

The use of cast-iron spherical projectiles dates back almost as far as the use of cannon, and with but one important change—the use of shell filled with powder or other inflammable material—has continued for centuries.

With the adoption of armored vessels, more powerful projectiles were required, and experiments were made with elongated ones of both cast-iron and steel. At first projectiles from 1½ to 2 calibers in length were used, one end being flat and the other hemispherical; the pointed or ogival form however, showing its superiority in competitive tests, was soon adopted. The radius of the ogive was at first made equal to the diameter or caliber of the projectile; later this radius was increased to two calibers, which is still largely used.

At first projectiles of chilled cast-iron were preferred, but finally the superiority of the steel was acknowleged.

Steel shells of a design very similar to those used at present were first manufactured about fifteen years ago. A small number of cast-steel projectiles have been manufactured and tested, but forged steel projectiles, specially treated, are now generally acknowledged to be the most effective against armor.

There has been constantly, a healthy competition between projectiles and armor. By improved methods of treatment, forged-steel projectiles in use at the beginning of the present decade, were able to attack successfully the Harveyized plate, being experimented with at that time. They were outmatched, however, by the Krupp face-hardened plate, which very shortly displaced the Harveyized plate. But at this time the most notable improvement in projectiles during this period was perfected and again established an equality. This improvement consisted in placing, over the point of the projectile, a cap of soft steel. By its use the efficiency of projectiles has been increased from 15 to 20% or the efficiency of armor plate decreased correspondingly. Experiments have shown that the best results are obtained with a cap of soft steel, having sufficient volume and strength to offer considerable resistance before breaking up, and plastic enough to permit of deformation before rupture.

Capped projectiles are most effective when used against face-hardened plates, and to understand their advantage when thus used, it is necessary to understand the theory of the greater resistance offered by these plates.

The hardened surface of the plate offers very great resistance to penetration as well as great resistance to bending, and as a result of these qualities the shock due to the impact of a projectile is transmitted to a large area of the back part of the plate, and great resistance is brought to bear to stop it without penetration. If the projectile has sufficient energy to bend the hard face, thus backed up to its elastic limit, and break it, the resistance after that is only local. Now, as to the action of the cap which meets the face of the plate at a high velocity, and dishes or bends it to its elastic limit; the projectile, during this time, is forcing its way through the cap, destroying it, and it reaches the plate only to find the hard face bent to its elastic limit and breaking up; then the projectile, still intact, has conditions to cope with only slightly different from those met in an armor-plate without a hard face. The cap appears to ease the shock of the projectile against the hard face, this face being partly or largely disposed of while the projectile is piercing the cap.

Another explanation of the action of the cap in assisting in penetration, is that the heat, generated while the projectile is penetrating the cap, is taken up by the plate at the point of impact, and its hard face so modified that its resistance to penetration is lessened. The cap also increases the effective angle measured with the normal to the plate, at which armor-piercing projectiles can be fired at plates without glancing off.

Until recently the acceptance tests of projectiles required them to penetrate the plate at a given velocity, all the parts of the projectile, if it broke up, passing through the plate. The specifications now require the projectile to pass through the plate and be in a condition for effective burst, and manufacturers appear to have no difficulty in meeting this condition.

Base covers.—The premature bursting of shells in guns having been traced with certainty to the penetration of the powder gases from the propelling charge into the interior of the shell around the threads of the base plug or fuze, a copper disk has been provided for all steel shells using high explosives, to prevent accidents from this cause. An undercut groove is turned in the base of the shell, outside of the threads referred to, in which the base cover is secured by a lead-filling strip, making a joint through which the powder gases do not penetrate.

Steel projectiles will be used extensively hereafter in guns of small caliber. Rapid-fire seacoast guns will have, for use against light armor, a projectile very similar in design to the armor-piercing projectiles used in larger guns, while mountain and field guns will have a thin-walled shell, having less penetrative power, but capable of carrying a large charge of high explosive, for use against earthworks and for breaching walls. Both projectiles will be made of steel of a good quality, but will not be expected to receive much treatment. Manufacturers usually punch and draw these projectiles to very nearly their finished dimensions.

Projectiles of new design.—Several projectiles varying somewhat from the standard types, or having special features, have been proposed and deserve special mention. The object of the various improvements, generally speaking, has been to increase the interior cavity without decreasing the penetrative qualities. This object was accomplished in the Davis projectile by drilling several holes, symmetrically placed about the axis of the projectile, in the forward end of the interior cavity. thereby increasing its volume without decreasing materially its penetrative power.

Projectiles fired against plates usually fail, or show weakness, near the bourrelet, as made evident by upsetting or by an increased diameter. This is due to the heavy base and walls advancing on the point when the projectile is suddenly stopped by coming in contact with the plate. The Bethlehem Steel Company has endeavored to correct this defect by decreasing materially the weight of the base, and by strengthening the walls against deformation by interior longitudinal ribs. They expect to obtain the same penetration with this projectile as with the standard, with a considerable increase in the volume of the interior cavity.

At present each of the guns of larger caliber is supplied with two classes of armor-piercing projectiles; shell with a large interior cavity and small penetrative power, and shot with a small cavity and greater penetrative power. It is believed by some that better results would be obtained by having but one armor-piercing projectile for each gun, having capacity for a bursting charge between the present shot and shell, the object being to simplify the supply, it being held that with high explosives the larger bursting charge is not essential. To meet this demand, the Firth Sterling Company has designed 5 and 6-inch projectiles, having capacities for bursting charges nearly midway between the present armor-piercing shot and shell, and having the same penetration as the standard shot.

They have given particular attention to the form of their projectile, one feature being that the body of the projectile in rear of the band is reduced until its diameter is less than that of the band seat, only sufficient metal being left immediately in rear of the band to support it when taking the rifling. Two objects are accomplished by this: the base is made lighter, and more important, as explained by the company, the small quantity of metal in rear of the band will shear off when the projectile passes through armor-plate, freeing the band from the projectile, rather than rupturing the projectile along lines joining the interior cavity with the band seat, which often occurs in projectiles of the usual design. The 6-inch shells of this design have been tested frequently, with excellent results, and the 5-inch shells promise to be as satisfactory.

Notwithstanding the great improvement in armor-plate, steel-capped projectiles, as at present manufactured, meet them on terms of as great equality as have existed at any time during the decade.

Shrapnel.—Present plans contemplate the use of shrapnel in all mountain, field and siege guns, except one-pounders, and in all seacoast guns up to 6 inches in caliber, and when it is understood that three-fourths of the ammunition for mountain and field guns is to be shrapnel, the other fourth being high explosive shell, and that shrapnel will also be used extensively in siege and seacoast guns, their great importance may be appreciated.

In the past there appears to have been uncertainty as to whether the bursting charge should be located at the front or rear of the case. At present the practice is to locate this charge always at the rear, and make it large enough to increase the velocity of the balls 200 feet per second at bursting.

Another important requirement of shrapnel, as at present manufactured, is that the case shall not be ruptured, due to the pressure in it from the bursting charge.

These conditions convert shrapnel into small cannon, which with their ammunition complete, are thrown into the vicinity of the enemy, where the powder charge is set off, throwing the balls forward at an increased velocity.

Shrapnel are commonly furnished with a point combination fuze which is connected with the bursting charge at the base of the case by a central channel, the middle part of the case around this channel being occupied by the balls. The space about the balls is filled usually by some smoke-producing compound as mono-nitro-napthalene, which assists in marking clearly the point of bursting.

The size or weight of balls to be used in shrapnel is an important consideration, both from the point of their efficiency against the targets at which fired, and the most economical use of the space in the shrapnel provided for them. In a well designed shrapnel, the balls should make up slightly more than 50% of its weight.

Lead balls are commonly used, but experiments have been undertaken recently with steel balls, having in view the penetration of the shields used on field carriages.

It is generally assumed that a bullet with 58 foot-pounds energy will disable a man, and one with 287 foot-pounds, a horse, and knowing the initial velocity, the weight of the complete shrapnel, and that of the balls, the danger space after bursting, for both men and horses, can be determined; or assuming the danger space desired at any range, the conditions necessary to give it can be computed.

As time fuzes, which are generally used in shrapnel, can be set to burst at zero, shrapnel will in future replace canister for close-range firing, the slight increase in expense being more than counter-balanced by the simplification of the supply, which will result from reducing by one the kinds of projectiles to be carried.

Fixed ammunition and cartridge cases.—No change relating to ammunition has been more marked than that from loose to fixed.

At the beginning of the decade fixed ammunition was used in guns of only the smallest caliber, and these were more or less experimental, but owing to the greater rapidity of fire which could be secured by its use, and to the fact that no special gas check need be provided in the gun, and to the simplification of supply, complete rounds always being together, it is now used almost exclusively in all guns up to 4 inches in caliber. Cartridge cases are also used in the 4.7 and 6-inch guns, although the projectile is not fixed in the case.

The methods used in the manufacture of cartridge cases have been greatly improved, the largest size being now drawn and formed from brass disks, in a manner very similar to that used for the small-arms cartridges.

HIGH EXPLOSIVES.

The advantage to be derived from using shells filled with a bursting charge of high explosive was early recognized, and experiments undertaken in 1883 had for their object the securing of an explosive which would stand the shock of being fired from the guns then in use. More recent tests have been made to obtain one which will not explode on impact with armor, this latter shock being much more severe.

At the beginning of the present decade a number of explosives had been tested for safety in firing, the most satisfactory one of which was guncotton having a large percentage of water present. Between this time and 1896, a number were tested without obtaining satisfactory results; among these were terrorite, rackarock, mono-nitro-napthalene and jovite. In 1897-98, extensive experiments were made with guncotton, and with even greater success than before, due to a detonating fuze devised by Lieutenant, now Captain, W. S. Peirce, Ordnance Department, U. S. A. Thorite was experimented with extensively in 1899 and 1900, with the result that it was not considered suitable for use as a bursting charge for shell, due to its highly hygroscopic properties, its deterioration in storage, and to its failure to detonate uniformly, also to the fact that much more promising explosives were available for test.

In the test of high explosives, need was felt for some simple means of determining the relative sensitiveness of the various explosives submitted for test. To meet this there was designed a testing machine for this purpose, consisting of two hard steel pistons surrounded by a closely-fitting sleeve. The sample to be tested is put between the ends of the two pistons surrounded by the sleeve, and arranged so that a weight may fall from any desired height and strike one of the pistons, the other being held securely. The sample to be tested is placed between the pistons in the form of a small flat disk. The test is known as the impact test. Results obtained with this test have been confirmed by numerous firing tests; therefore, it provides a simple way of determining whether any proposed explosive is deserving of more extensive tests.

As a result of preliminary tests in 1900, the conclusion was reached that high explosives were available from which satisfactory ones for service could be chosen. Also, that a safe and efficient detonating fuze was available, which would stand both the shock of discharge and the penetration of armor without premature explosion. This fuze was a slight modification of the one previously used with guncotton. The conclusion was also reached that projectiles having a base plug or fuze must have a base cover of continuous metal, effectually covering every joint, to prevent the entrance of the powder gases into the shell cavity.

The explosives which were under trial and which were regarded with favor, included the following:

1.—Rendrock Powder Company's No. 400;
2.—Picric acid;
3.—Maximite, 10% and 25% grades (submitted by Mr. Hudson Maxim of Brooklyn, N. Y.);
4.—Explosive D.
5.—Guncotton pellets, about 15% moisture and loaded in a wax matrix.

These explosives were subjected to a series of tests to determine their relative values as bursting charges for shells, after the determination of their relative force (by calculation); specific gravity; density of loading; ease of supply; method of loading; safety in manufacture; stability; hygroscopicity, and action on metals. They were all subjected to the impact test, which they passed satisfactorily.

To determine which was the least sensitive to shock when loaded in shells, due to impact on armor-plate, six-pound steel shells were loaded with the various explosives, and fired against Carnegie tempered (nickel-steel) plates, 1, 1.5, 2, and 3 inches thick. The six-pounder projectiles were used, not only on account of their comparatively small cost, but because of the great severity of the shock on the bursting charge in these shells at impact against 3-inch plates. In these tests, rendrock No. 400 and picric acid failed to penetrate the 1-inch plate without explosion. Guncotton passed the 1 and 1.5-inch plates, but failed on the 2-inch. The two grades of maximite and explosive D passed the 1, 1.5, and 2-inch plates, and also a 3-inch mild-steel plate.

The results of their test against the 3-inch tempered-steel plate are shown in Table 2.

TABLE 2.

Shell charge.	Number of rounds.	Thickness of plate in inches.	Action of shell.
Velocity, 1920 ft. per sec., 10 per cent Maximite	1	3	Struck squarely and point passed 4.5 in. beyond front face of plate. Shell broken and fragments rebounded, leaving clean hole. Explosive ignited, as shown by cloud of smoke.
25 per cent Maximite	1	3	Point penetrated about 4.25 in.; shell rebounded 110 ft., badly set up; no explosion.
Explosive D	2	3	One with same penetration as preceding, and one striking somewhat obliquely, penetrated about 3 in.; both broken. Explosive formed cloud of powder; not ignited.
Velocity, 1970 ft. per sec., 25 per cent Maximite	1	3	Badly upset and broken on plate; cup-shaped hole about 1.5 in. deep; explosive ignited, as shown by cloud of smoke.
Explosive D	1	3	Same as preceding, except 1.7 in. deep. Explosive formed cloud of powder; not ignited.

As a result of these tests the conclusion was reached that had the shells been capable of penetrating the plate, none of the explosives would have been set off by the shock of impact, but as explosive D was not ignited in any of the rounds, it was considered less sensitive to shock than the two grades of maximite, which were considered equal.

These experiments were continued by firing projectiles of larger caliber, up to and including 12-inch charged with more than 50 pounds of both maximite and explosive D, against armor-plate up to and including 12-inch face-hardened plate, and in every case satisfactory results were obtained. As a result of these tests, both of these explosives were adopted for service.

The progress made in the development of fuzes and high explosives has been to a very considerable extent due to the efforts of Captain B. W. Dunn, Ordnance Department, U.S.A.

A number of experiments were made in 1899 and the following years with a projectile designed especially to carry a large bursting charge of high explosive, such as explosive gelatine.

This projectile, known as the Isham shell, had for the 12-inch caliber the same general form as the torpedo shell. It was made of cast-steel with diaphragms extending radially from a central column, dividing the shell cavity from point to base into ten annular compartments, the object being to reduce the danger of explosion, due to the compression and friction of a long column at discharge. Mr. Isham claimed that with his shell, explosives which were too sensitive to be fired in the ordinary shell could be fired from service rifles, also that the weakness of his shell was more than counter-balanced by the greater force of the explosion over that secured by the less sensitive explosives ordinarily used.

The experiments conducted thus far have not confirmed the claims of the inventor.

COMPRESSION OF STEEL BY WIRE-DRAWING DURING SOLIDIFICATION IN THE INGOT MOULD*

HARMET PROCESS

THE object of compression of steel during the process of solidification is to prevent as far as possible the formation of those defects that are found in ingots allowed to cool undisturbed.

Dealing with the steel within the ingot mould, this, though it may be of the finest quality while in the liquid state, can completely change its character during the passage into the ingot mould unless particular attention is bestowed upon the conditions and circumstances which accompany the solidification with the object of combating the defects which tend to develop there. The cooling process in fact exposes the metal to the injurious effect of three forces—contraction, crystallization, liquation—all of which change the qualities which are essential to commercial steel. In the first place, therefore, endeavor will be made to show how these forces act on the metal in the different conditions under which it is allowed to solidify. In order the better to define the period of time which it is desired to investigate, it may be assumed that the metal passes from the liquid to the solid and cold state in two phases. The first corresponds to the period of the liquid state within the ingot mould at about 2000° to the moment of stripping the ingot at about 700°. The second one corresponds to the period spent in cooling from 700° to the temperature of the atmosphere.

During the first of these two phases the steel poured into an ingot mould may either (1) be left to shrink freely; or (2) be subjected to compression by the Whitworth system; or (3) subjected to compression by wire-drawing by the Harmet system.

These are the three cases to be examined. Other minor operations may be neglected, since they fall within either of

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* We are indebted to Captain E. L. Zalinski, U.S.A. (Retired) for the data and material on which this article is based.—ED.

these categories. But before studying successively any of these it should be remarked that the liquid steel, immediately on being poured into the mould, forms a solid crust owing to contact with the cold walls. This increases in thickness, rapidly forming a shell which assumes the shape of a vase filled with liquid metal (see Fig. 1).

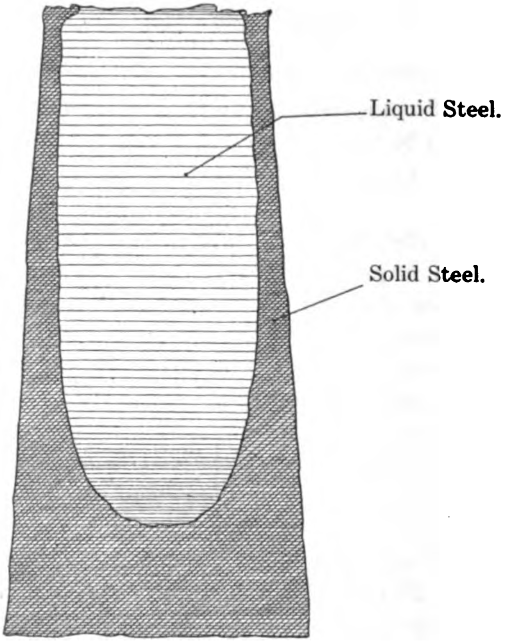

Fig. 1.

The almost instantaneous shrinkage of this shell causes the separation of the ingot from immediate contact with the mould, and a minute or two after casting it settles firmly on the bottom, no longer supporting itself against the walls of the ingot mould. It is at this moment that the process of compression should intervene, and it is essential to have recourse to this if it is desired to preserve the steel from the defects which are liable to cause deterioration. In the first place, however, the behavior of the metal must be considered, if allowed to cool undisturbed.

(1) *Contraction.*—The form of the solid shell as regards its external dimensions is determined from the time of the formation of the outer crust. The greater part of the contraction has already taken place, but there still remains the internal liquid

mass, of which the volume is greatly modified by shrinkage. Little by little, during cooling, this liquid mass becomes plastic and attaches itself progressively to the first shell, adding to its thickness. In the interior is left a hollow corresponding to the volume of the shrinkage.

The cold ingot, when divided through its vertical axis (see Fig. 2), exposes to view a large cavity in the upper part due to the flow of metal, which, as long as it is liquid, continues to descend by its own weight to fill up the hollows left in the lower part due to shrinkage. Besides this a hollow space is formed in the center itself after solidification, on account of the failure of the supply of liquid metal to fill the new cavities.

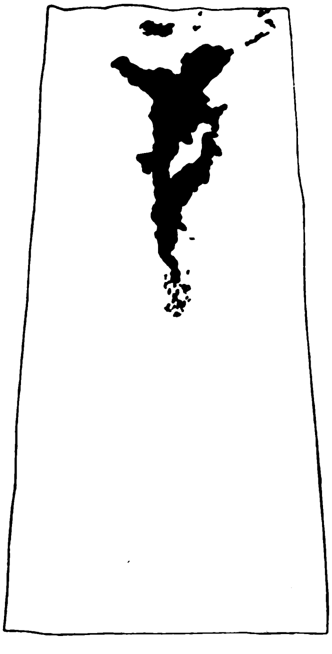

Fig. 2.

This defect in the metal extends along the axis, visible to the naked eye, throughout the whole of the upper half of the ingot. In the second lower half, recourse must be had to the microscope in order to detect the porosities which exist in the center, and the tiny cracks or fissures which permeate the whole of the solid mass. The microscope brings out these defects, but to explain their formation it is necessary to study more closely the complex phenomena which accompany contraction.

When the lower part of the ingot is solidified throughout its whole thickness, and as soon as the descent of the upper layers of liquid metal is interrupted, the shrinkage, proceeding as the cooling continues, sets up within the metal injurious stresses which are the cause of much mischief.

At the end of the first phase of cooling, that is, at the moment of stripping the ingot, when at 700°, an ingot left to cool undisturbed, will exhibit minute cracks throughout its length, and these will extend in the same manner throughout the whole mass of metal. The defect is still more aggravated by the further shrinkage which must still continue in cooling from 700 to atmospheric temperature, if this takes place within the ingot mould; but in most cases the heavy ingots are sent on to the mills when they reach the temperature of 700°. Thus the contraction in steel left undisturbed in the mould is productive of two kinds of serious defects: firstly, of pipe, cavities or porosities about the center, while the metal is still liquid or in a plastic condition; and secondly, stresses, cracks, fissures, and even porosities throughout the whole mass which, nevertheless, to the naked eye appears compact and perfectly sound.

Crystallization.—The steel in solidifying crystalizes in the form of an interlacing dendritic structure upon the internal surface of the pipe, in regular needles on the external surface of the ingot, or in polyhedric grains within the central mass. These crystals have little cohesion between themselves, and when stresses due to contraction within the metal are set up, these meet with but low resistance and cracking occurs easily. The polyhedric crystals often form groups divided by planes analogous to cleavage planes, and the fracture of a large ingot exhibits facets which resemble those of spiegel. These constitute the weak points, which require subsequently to be strengthened by forging process in order to obtain the necessary toughness in the finished product. This crystallization of the steel is promoted by any step taken to delay the solidification, such as lining the upper part of the mould with refractory material, and also by the contraction of the ingot, which, when left to itself, separates from the cold walls of the mould.

Liquation.—The metalloids which enter into the composition of the steel have a tendency to separate from the iron by liquation. The carbon is the most mobile, being attracted in turn towards the more fluid parts, finally concentrating in those where solidification last takes place; that is, in the head of the ingot when left to cool undisturbed, and particularly if the solidification is delayed by the use of a refractory-lined mould.

Attempts have been made, when leaving the ingot to cool by itself, to prevent the formation of pipe by placing on the top of the ingot a cover of refractory material intended to preserve the heat and keep the steel liquid for a longer time in the upper part of the ingot, which serves as a reservoir to supply the lower part. All that is gained by this is, not the avoidance of pipe, which is proportionate to the shrinkage of the steel, the volume of the cavity remaining the same in any case, but the raising of it or the concentrating of it at a somewhat higher level. The ingot remains porous along its center, but the cavities here are not so large.

This method of covering the ingot, by which the hardening of the metal in the upper part is delayed, is unfortunately attended with the inconvenience that it develops a coarse crystallization and especially tends to promote liquation by attracting to the upper part, when kept liquid for a longer time, the carbon, which rises in proportion as solidification proceeds in the lower part, and thus has more time in which to travel upwards. It thus results that a steel, though absolutely perfect while in the liquid state, is permeated with defects when, after undisturbed cooling in the ingot mould, it is taken out at a red heat (about 700°) to be dealt with further in the mills. The upper portion is affected with pipe, the whole mass is seamed with cracks, torn by the internal stresses, and cleft by crystallization, while the composition is rendered irregular by liquation.

In this state the metal may be regarded as useless, and the mechanical treatment by rolling or forging has to be relied on to correct as far as possible the defects which, through ignorance, were allowed to occur during solidification. The upper, unserviceable end, must be cropped, the cracks and fissures have to be rewelded, the stresses relieved, and the crystallization broken up and reduced to a fine state. But notwithstanding the application of the various means to effect these improvements, the liquation will remain unaltered and many defects will continue in existence, only to be discovered later in the tests on specimens undertaken after finishing the material.

Instead, then, of remedying defects which have been permitted to form within a metal perfect on leaving the furnace, it would certainly be preferable to prevent, or at least to palliate them, during the process of solidification. This is effected by compression by wire-drawing, which is now about to be discussed. Among the defects occurring in steel during cooling, no reference has been made to the blow-holes due to the gases liberated by the metal, for the reason that the elimination of these ought to be effected in the furnace. It is equally unnecessary to note the surface defects, such as flaws and cold drops. These are due to the want of care in the actual casting, and are not attributable to the ingot mould. They can, moreover, be avoided by bottom-casting.

(2) *Static compression.*—Before the introduction of compressing steel by wire-drawing, several attempts were made to compress the metal within the mould, but all depended in principle on applying a static pressure on top of the ingot, instead of bringing it to bear, as in the wire-drawing method, upon the bottom, which, being of a dynamic kind, performs effective work. Compression with a static pressure acting on the top of the ingot is the principle involved in the Whitworth process.

In spite of the great force of the pressure applied in the latter process, the effect of it extends only to the exterior of the ingot, which in cooling rapidly forms a crust with the rigidity of a column, and thus arrests the force applied and protects the whole of the central part against this pressure from above. The ingot is, moreover, depressed in the centre, and though the pipe has not exactly the form which it would have had if left to cool freely, yet it still effects the centre throughout a great part of its height. The method may answer for hollow pieces which have a raised centre, but is ineffective for solid bodies such as armor plates.

The central mass of the ingot being moreover relieved from compression, as is proved by the presence of cavities in the center, the fluid steel is left to itself and in consequence becomes affected by the injurious influence of liquation and coarse crystallization. The effect of this compression therefore accentuates rather than alleviates the strains, cracks, and internal fissures which are observable in steel left to cool undisturbed. The compression by static pressure, applied to the top of the ingot, appears thus to be an imperfect method for preventing the defects which tend to develop during solidification. It is otherwise with the method of compression by wire-drawing, the energy of which effectually prevents the formation of these defects.

(3) *Dynamic compression.*—It should be mentioned that

the main object of compression by wire-drawing is not so much to remedy the defects of the metal, as rather to forestall their development. The elimination of minor defects is left to the subsequent mechanical operations of rolling and forging. But before it is possible to prevent the formation of defects, the causes to which these are due must be carefully studied, and if it is found impossible to avoid them they can at least be dealt with in such a manner as to render them as little injurious as possible. It will be seen from the foregoing that all defects originating within the ingot mould are due, firstly, to the contraction which produces the pipe, the porosities about the center line, and the cracks and fissures throughout the whole mass. Secondly, they are to be attributed to the retardation in cooling which promotes the formation of large crystals with cleavages, and the liquation of the carbon.

Dealing with the first point, the contraction or shrinkage of the material during cooling follows a natural law which must pursue its course. If this is injurious in the cases under discussion it is on account of the fact that the outer shell of the ingot is permanently fixed, and the subsequent shrinkage of the central mass cannot therefore take place without leaving hollows in the form of pipe, porosities, or cracks. If this external shell is forced inwards upon the central mass, and compelled to follow the shrinking movement, or even to close in at a rate somewhat quicker than that at which the volume diminishes, the formation of cavities and internal faults will be avoided. This is exactly the result attained by compression by wire-drawing.

In order to combat efficaciously the effect of shrinkage, the compression of steel by wire-drawing must be applied to the whole surface of the ingot, restricting or diminishing its volume by closing inwards upon the central mass as shrinking proceeds. This entails the performance of work, work which constitutes the underlying principle of the process, and the value of which is proportionate to the total contraction of the mass upon which it acts. The amount of contraction per unit of volume or of weight is constant for one kind of steel of definite character. But it varies in the case of different kinds of steel. The work necessary to counteract the effect of this contraction per unit of weight will consequently be a constant amount for each kind of steel. Starting from this point, the work necessary to compress by wire-drawing any kind of ingot will be proportionate to the weight of the ingot.

With regard to the defects of the second category, the liquation and formation of coarse crystals with cleavages are due to retardation in cooling. It is impossible to overcome these defects completely, since instantaneous solidification is out of the question. But for the following reasons their occurrence may be sensibly diminished by compression by wire-drawing, introduced primarily to counteract contraction. :—

(*a*) The ingot mould in which compression is carried out not only consists of a great mass of metal which rapidly absorbs a quantity of heat, but it is kept in constant contact with the metal to be cooled by the gradual advancement of the ingot under pressure from below.

(*b*) In a liquid body which contracts or undergoes reduction of volume in passing into the solid state, pressure hastens the transition. This results in shortening the time, and at the same time a diminution in the crystallization and of the liquation is effected.

(*c*) The molecular movement, which, owing to pressure, takes place throughout the mass, also tends to effect a diminution in the crystallization and of the liquation.

(*d*) Finally, another circumstance which in general tends to hasten the cooling and diminish crystallization and liquation (contrary to the effect of a refractory-lined mould) is the gradual advancement of the head of the ingot into the cold portion of the mould. In fact the ingot under pressure is forced upwards into contact with that part of the mould which has not yet been subjected to the influence of the hot metal, and these surfaces being still quite cold, effectually tend to cool the head of the ingot and avert liquation. This circumstance accounts for the small amount of liquation found in ingots compressed by wire-drawing.

The above considerations indicate the necessity of not allowing ingots to contract freely during cooling, especially those from which it is desired to manufacture products of superior qualities. They show the advantage of compression and define exactly how the process should be applied. Further advantages also accrue from the compression by wire-drawing, which favorably affect the quality of the metal, and prevent waste of any part of the ingot.

It is now proposed to study the best methods for carrying out this compression by wire-drawing, and to illustrate the principal advantages which may be attained.

It has been shown that the injurious influence of shrinkage begins to make itself felt immediately on pouring the metal into the mould, and if a vertical section was made through the metal, a vessel of the form shown in Fig. 1 would be obtained, composed of a solid but extremely thin shell already separated from contact with the mould owing to lateral contraction, and filled with a heavy liquid, the weight of which tends to burst the shell, producing cracks through which it finds a vent. It is at this instant that pressure should be applied to the vessel from below for the purpose of supporting the weak shell by thrusting it against the cool walls of the conical mould. The shell is then forced upwards in the cone and closes in upon the central mass in proportion as the hollows tend to form within, due to shrinkage. Further, by hastening the solidification the coarse crystallization with cleavages is counteracted, and the tendency of the carbon to accumulate in the upper part of the ingot is lessened. This is also effected by forcing the metal into intimate contact with the thick ingot mould, and especially by causing it to advance gradually towards the cold parts of the walls.

Such is the operation of compression by wire-drawing, which, by leaving exposed the upper portion of the ingot and applying pressure to the base, causes it to rise in the conical mould as though being forced through a draw-plate. The solid crust shown in Fig. 1 doubles inwards, driving the internal metal upwards, the action being similar to that of the pressure of the hand upon a rubber ball, and by this means the formation of cavities are avoided, which occur if the metal is left to contract freely. The pressure upon the base, or the rate of advancement within the mould, is so controlled as to keep the shell constantly full without overflowing. The speed is regulated according to the rate of contraction, exceeding the latter slightly, in order to maintain every portion of the ingot under a state of continuous pressure, but a tensile stress never occurs in any portion. The conical form, which is essential for producing lateral stricture in proportion as the ingot advances, increases the power of the press by producing a wedge-like action.

This compression by wire-drawing being applied to the metal immediately after casting, and placing the whole mass under pressure without causing any tensile strain, entirely prevents the formation of internal cracks from the first moment it is brought into action. It also preserves the absolute solidity of the ingot without pipe or cavities about the center, produces a fine crystallization without cleavage planes, greatly reduces liquation, and generally improves the physical properties owing to the effect being similar to that of forging. Finally, on taking a vertical section through the axis, the compressed ingot presents the shape and appearance shown in Fig. 1, Plate I., whereas without compression the same metal would have resembled the ingot shown in Fig. 2, Plate I.

A study of one of the mechanical installations adopted at the steelworks of Saint-Etienne, in order to effect the compression by wire-drawing, will give a clear idea of all the others. A few brief details of one of the presses of 1200 tons for 5 to 6 ton ingots may be of interest.

Two tie-bolts of forged steel (1 and 2 in Fig. 3,) hold apart an upper and lower cross-piece (marked 3 and 4). These tie-bolts are hollow, and the central hole of the one serves as a pipe to conduct the water to the press,* this being led from the distribution valve through the passage 5 and again from the tie-bolt to the hydraulic cylinder by the lower passage 6. Through the central opening in the other tie-bolt are led two small cords having their lower ends attached to the ram of the press. Thence they pass up through the hollow bolt over two pulleys, 8 and 9. From the second pulley onwards the ropes separate, one being led over the pulley 10 to an indicator within sight of the operator, where it actuates a pointer which traces the curve indicating the speed of ascent of the piston. The other is carried to the accumulator and governs the regulating-valve, stopping the press automatically if the operator is inattentive or passes the desired point.

The cast-iron cross-piece 3 carries attached to it a plate 12, which is vertically adjustable, and serves as an abutment against which the top of the mould rests during compression. The stripping cylinder 13, with a double-acting piston, is also carried on the upper cross-piece. The lower cast-iron cross-piece 4 has attached to it, first, the two supports 14, which serve to strengthen the whole arrangement; secondly, the forged steel cylinder 15 and the actual piston 16, which carries the ram 17 extending upwards, both of these latter being also of forged steel. The intermediate cast-iron cross-piece 18 performs the service of guide to the ram 17. The operator is accommodated on a platform within reach of the starting-valve 19 and the indicator 11. The quantity of water required is very little, and can be supplied by an accumulator of small size, which regulates the pressure and controls the small pumps which feed it.

The compression is effected between the ram 17 and the plate of abutment 12 attached to the upper cross-piece. The steel which has to undergo compression is contained within its mould 27, and is brought up to the press on a small trolley 20, a track being provided for this purpose.

Car for ingot mould.—The car 20 (see Fig. 4) is of cast-iron, and the axles of the wheels are of extra strength to withstand the shock of the stripper which is added to the weight of the ingot and mould. The car

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* In future it is recommended to lead the water in from below the level of the ground, to avoid the throttling of the piston (16) in its descent.

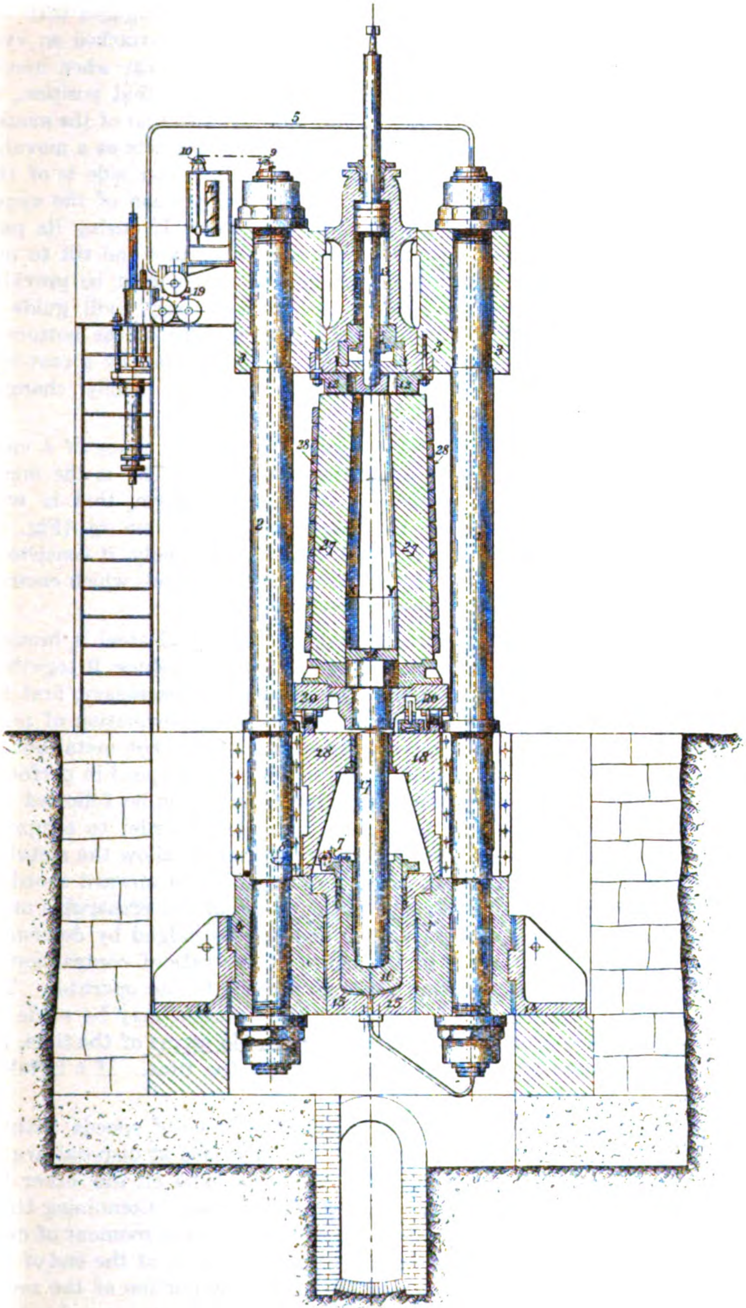

Fig. 3

is moved by means of a pawl carried on a rack 23, which engages with the ribs cast underneath the body of the car. At one end is attached an eye-piece in which is inserted a conical pin for stopping the car when immediately beneath the press, and for fixing it immovably in that position, so that the center line of the press corresponds exactly with that of the mould, the ingot, and the bottom of the mould. This latter (25) acts as a movable plunger within the mould during compression. The under side is of the special form and between it and the circumferential portion of the upper surface of the ram 17 is allowed a play of 1 millimeter. If during its passage upwards into the mould it should deviate from its axis and tilt to one side—an unlikely event, but the occurrence of which must be provided against—the ram of the press, pushing at one side only, will guide it back to the perpendicular course. The upper surface of the bottom is protected against the action of the steel during pouring by a cast-iron disc 26, 30-60 millimeters in thickness, which may be easily changed when worn out.

Ingot moulds.—The ingot mould is formed in the first place of a cast-iron casing 27 consisting either of one or several parts. This is the mould proper, the interior near the base being cylindrical in form, that is with vertical walls. Then towards the top, beginning at the line *xy* (Fig. 4), the form becomes conical with a taper of 1 in 30. Secondly, it consists of one or even two series of hoops 28 of cast and rolled steel, which encircle the mould and hold the several sections firmly together.

When the car with the mould containing the liquid steel is brought beneath the press, it remains to compress the ingot, crushing it together, and wire-drawing it, meantime taking the precautions necessary, first for keeping the ingot from flowing over and preventing the formation of pipe, and secondly, for avoiding the excessive spurting of the hot metal out of the mould which causes a waste and is due to too great a speed in performing the operation. The contraction of the ingot must then be followed up, and the rate of this should even be slightly exceeded in order to compress the core of the ingot, but care must be exercised not to allow the metal to flow over the edge of the outer shell. As regards the upward speed of advance which is most suitable to give to the piston of the press, this must vary according to the rate of contraction, and can be judged by determining first the successive values of the curve of the rate of contraction in terms of the time. This will then serve as a guide to the operator. The determination of the curve of the rate of contraction may be made by determining the rate of advancement of the piston in terms of the time, for $s = vt$, where s is the space, v the velocity, and t the time. If t is taken as the unit of time, then $s = v$.

In attempting to establish theoretically this curve of speeds without first taking into account the wire-drawing, the only data at disposal are on the one hand the total contraction of the steel, and on the other the approximate time necessary for the cooling of the metal. Combining these and taking as basis the initial volume v of the ingot at the moment of casting, it may be determined what will be its least volume v_1 at the end of any period of time, for example five minutes. Again, the portion of the mould occupied by the ingot (always at the moment of casting) also was of volume v, but at the end of the time this volume increased in consequence of expansion to v_2. The difference $v_2 - v_1$ represents at the end of the time

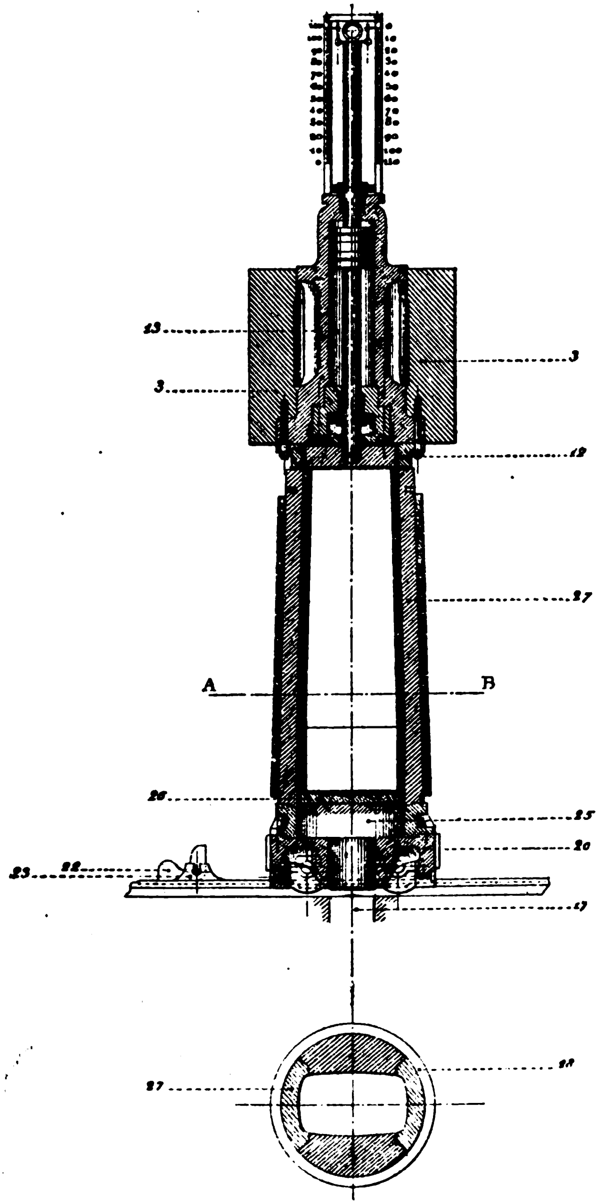

Fig. 4.

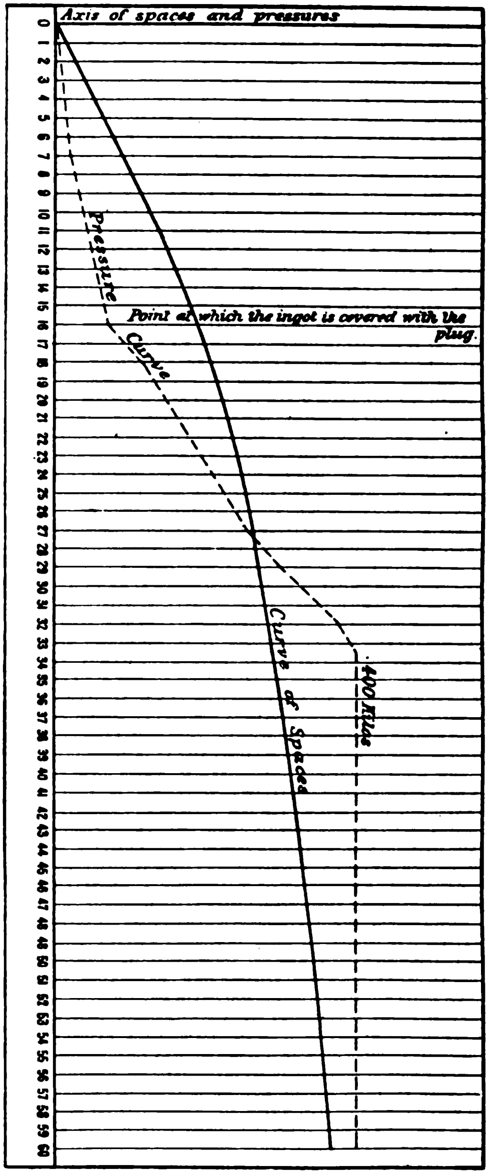

Fig. 5. Type of curve for an ingot of 2 tons.

the space which would exist between the walls of the mould and the ingot resting on the bottom, if the latter had remained solid without forming any pipe. In order then to enable the compression to preserve the solidity of the ingot without forming an internal cavity, the press must have risen vertically at the end of time through a space equal to the diminution of the volume of the cone of the mould corresponding exactly to $v_2 - v_1$. In this manner one interval of advancement of the piston is determined, and in consequence one point of the required curve is obtained. A series of calculations, if it were possible to make them, would permit the construction of the complete theoretical curve corresponding to the shrinkage and to the cavity, without taking account of wire-drawing. To include the latter condition it would be necessary to accelerate the speeds.

But the data are of too vague a nature to admit of tracing a definite curve in this manner, and if plotted, such a curve could only be considered as approximate and would require correction immediately in accordance with the results obtained, for neither the exact temperature of the metal nor that of the mould can be determined at the end of a fixed period of time.

An approximate curve having then been established as rationally as possible, several operations were carried out with the press. The first ingots were divided longitudinally through the vertical center-line, and after each compressing operation the curve was modified according to the results of the experiment. Each type of mould was found to have its distinct curve, which when once traced on the cylinder of the indicator permits the exact regulating of the upward speed of the press. Fig. 5 represents the curve of the ingot of two tons, being ordinary 30 carbon steel, cast in the octagonal moulds of the Saint-Etienne steelworks.

The indicator (see Fig. 6) consists of a cylindrical drum 29 revolving on a vertical axis by means of clockwork 30. This carries a roll of paper on which is previously traced the curve of the upward speed of the piston. A pencil-holder 31 slides vertically upon the guide 32, the pencil being gently pressed against the paper by a light spring. The cord is attached at one end to the piston of the press and passes through the tie-bolt 2, over the guide pulleys 8, 9, 10, the other end being fastened to the pencil-holder, which is thus caused to traverse vertically the same distance as the piston. A spring coil and drum 33 keep the cord under tension.

For perfect compression the curve traced by the pencil in its vertical movement while the cylinder revolves by clockwork should appear superimposed upon the normal curve determined by experiment.

After the preliminary trials as described above, it was found that the conduct of the operation could be simplified in regard to the determination of the curve of speeds, and also by the automatic control of the press. Instead of taking an approximate curve for the investigation and following it while controlling the press by hand and then dividing the ingot to see if it is sound, it is much more simple to remove the stripping cylinder and substitute a mirror at an angle of 45 degrees, which reflects the surface of the ingot within the mould during the whole time that it is under compression. By watching the mirror it is possible to control the press with perfect ease and to regulate its speed, keeping the ingot full of metal to the brim, with just a tendency to overflow. From a first trial is obtained in this manner an absolutely sound ingot. The top is not quite so smooth

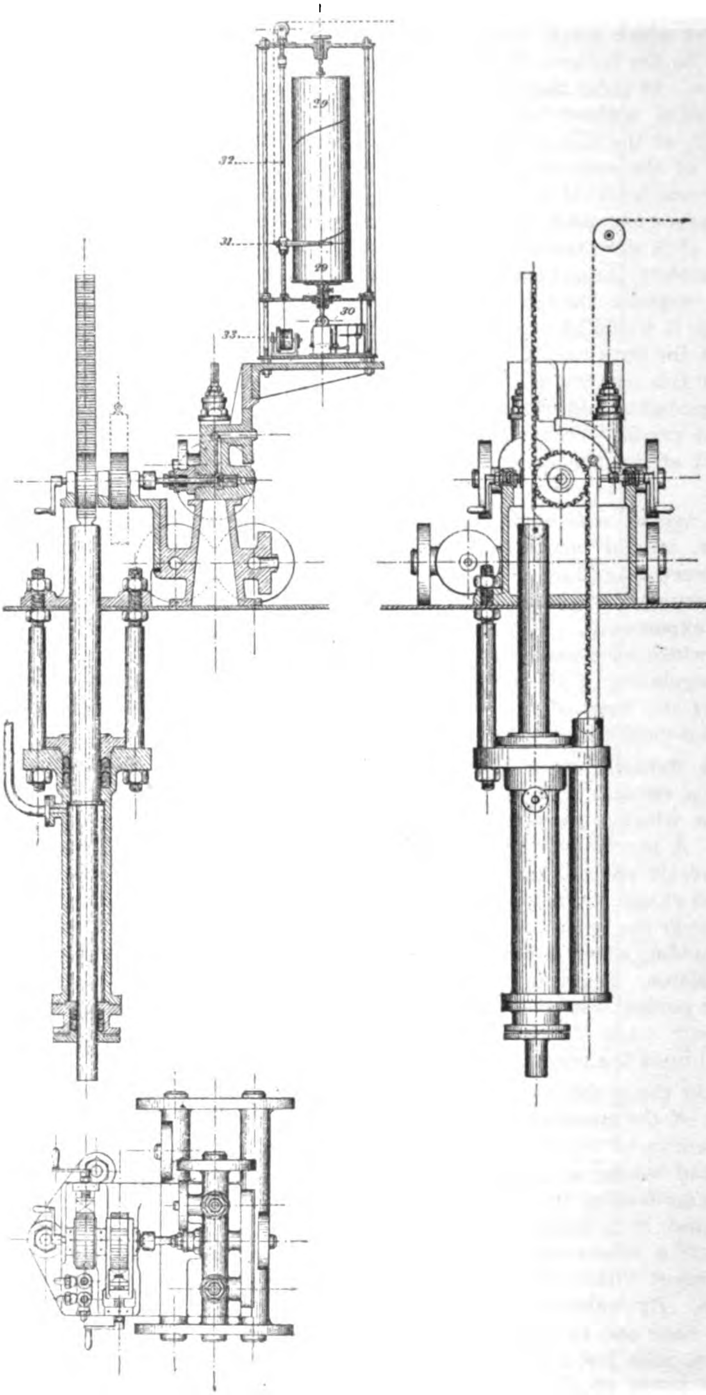

Fig. 6.

as if the piston of the stripper had rested on it, and the stripping must be effected elsewhere, but this is a matter of no great difficulty. During compression with the aid of the mirror, the pencil of the indicator has traced on the white paper a curve of speed of the press, and for the succeeding operations with the same mould it is only necessary to follow the same curve.

The dimensions and power of the press and the accessory controlling apparatus vary with the weight of the ingots to be compressed. A certain definite relationship should exist between the presses, the moulds, and the ingots. Hence a complete commercial installation comprises a series of several installations all designed and constructed according to the same type, but varying in dimensions and power according to the weight of the ingots to be produced.

RESULTS OBTAINED.

Two kinds of results are to be considered: commercial or economical results, and scientific or physical results. The latter more particularly interest the artillery service but there is no reason for not noting the former, for the utilization of the scientific results would not be possible if the commercial results of the process did not allow of delivering the compressed metal at a cost sensibly comparable to that of the uncompressed metal. Otherwise the process described would have but hardly more than a theoretical interest and its application would be limited to altogether special purposes where the question of cost is of secondary importance.

COMMERCIAL OR ECONOMICAL RESULTS.

(*1*) *Increase in the Proportion of Useful Ingot Metal.*

In the first place the economy in metal or the better utilization of the material is clearly shown in Figs. 1 and 2 Plate I., which give illustrations of ingots both compressed and uncompressed. When the steel is not compressed it is necessary to cut off from the upper part of the ingot about 30 or 40 per cent. of the length, in order to reach the sound portion towards the base, which appears to the naked eye almost compact. The advisability of removing a still greater waste piece is revealed by the aid of a lens or the microscope.

When steel is compressed by wire-drawing it is sufficient if 4 per cent. is cut off the upper part of the ingot.

An impartial examination of numerous ingots divided sectionally at the steelworks of Saint-Etienne, proves clearly that the waste at the head of an ingot is 25 per cent. less in the case of compressed steel than with uncompressed steel cast in iron moulds without refractory lining. On comparing compressed steel with that cast in refractory-lined moulds, the difference in waste would be slightly less, but for the lining to have any effect it must extend some distance below the top of the ingot, and consequently that portion covered with sand must afterwards be removed, which causes considerable wastage. Besides this the lining is expensive, and tends to aggravate liquation. As an important technical result it may be assumed that a mean saving of 25 per cent. in ingot metal is effected.

(2) *Increased Capacity of Existing Plant.*

As a result of the above, in an existing works of which the various buildings and mechanical appliances are well arranged, compression by wire-drawing increases the productive capacity by 25 per cent., and in consequence also increases the relative value of the works by 25 per cent.

In constructing new works, for the manufacture of armor plate for instance, the adoption of compression enables the same weight of finished products to be turned out, but with a reduction in the mechanical equipment, furnaces, and plant of 25 per cent. as compared with an ordinary works of the same capacity of output.

(3) *Reduction of Forging in Converting the Ingot into the Finished Product.*

Compression by wire-drawing not only eliminates the defects due to contraction, but effects a forging of the metal, thus lessening the subsequent labor to attain the same result.

The homogeneity of the compressed metal is as perfect as can be desired both in the upper and lower part of the ingot, but, on the other hand, the uncompressed metal presents irregularities and extreme weakness even in those parts of the ingot which are ordinarily available for consumption, as indeed is shown by the results of all the tests carried out.

Tests on rough ingots.—After cutting to waste a piece equal to 5 per cent. of a compressed ingot all the portions adjacent to the cut surface exhibit a marked superiority of quality as compared with that of ordinary ingot steel after cropping to waste 28 per cent., this being the percentage of waste insisted on by the French Government and by the great Railway Companies. Table I. gives results of tests on sections from rough ingots, in which the core part is included. An examination of these results shows:—

A. That in the material of a compressed ingot adjacent to the waste piece equal to 5 per cent. of the total metal the mean result of the three tensile tests was :—

Limit of Elasticity.	Stress producing Rupture.	Elongation per cent.
73.5 kg. per sq. mm.	78.40 kg. per sq. mm.	6.83

And three bars subjected to an impact test withstood an average of fourteen blows each from a drop-hammer weighing 18 kg., falling from a height of 2.1 meters.

B. That in the case of an uncompressed ingot after cutting off 28 per cent. of the whole metal, all the tensile and impact tests failed to give any result at all.

Again, on comparing the results in Table II. of tests on steels which had undergone two workings,* and also those of Table III. of tests on steels subjected to four workings,* it will be observed that the superiority of the compressed steel is nearly as marked as in the former case.

Tests on forged steels.—A single forging operation or one working is sufficient for compressed steel, since the effect of compression is analogous to a forging operation upon the whole mass. The metal therefore retains much fewer internal stresses than are retained by ordinary steel in its soundest portions.

Comparing the results of impact tests given in Table II., carried out on steels which had undergone two workings, with those given in Table III. with steels subjected to four workings, it will be observed in the portions taken from the upper part where the waste had been cut off: That in the case of the compressed ingot with 5 per cent. of waste, after two workings, all the bars withstood twenty blows, and after four workings all the bars also withstood twenty blows. Two workings are therefore as effective as four as far as satisfying the conditions of French specifications is concerned.

In the case of ingots cast in refractory-lined moulds, and with a wastage of 28 per cent., the results of impact after two workings showed that fracture occurred with the fifth blow, the second blow, and the sixth blow respectively. But after four workings all the bars were good. The effect of two forgings or workings is, therefore, inferior to that of four in the case of uncompressed ingots cast in refractory-lined moulds.

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* The expression "two workings" means a forging operation which reduces the the cross-section of the ingot by one-half. "Four workings" indicates one which reduces the section by three-quarters.

For the ingot cast in plain moulds, the waste being 28 per cent., the results of the impact test were :—

In the case of the metal subjected to two forgings, all the bars were broken at the first blow. After four forgings all the bars were good. In this case also the effect of two forgings is inferior to that of four. The tensile tests give indications of a similar tendency, though less clearly defined in character.

PHYSICAL RESULTS.

(1) *Compactness Conferred by Wire-Drawing.*

Before proceeding to examine any other technical results, it may be shown here how the influence of compression affects the body of the metal during solidification, and how it finally renders the metal absolutely sound. Small ingots of about 120 kg. were compressed during five, six, seven, eight, nine, and ten minutes respectively, and were then left to contract freely.

After five or six minutes the metal was still liquid, or at least pasty about the center at the time the action of the press was interrupted. The subsequent contraction took place, to the injury of the part not yet solidified, and it yielded to the tension, leaving cavities, which however diminish in size as the time more nearly approximates to that necessary for solidification. At the end of eight minutes solidification is complete, and this period corresponds, for the ingot of 120 kg., to what was before termed the first phase of cooling. If this were taken to the mills immediately on leaving the press, and there treated mechanically, it would give a perfect metal. If, on the contrary, it is allowed to cool after these eight minutes of compression, the ingot remains solid, since the metal is no longer mobile. Cavities can no longer be formed, but the metal is cracked by the shrinkage subsequent to compression, and the cracks are easily discernible. The lowest limit for the compression of ingots of 120 kg. is therefore eight minutes, the compression leaving them free at the moment that solidification is complete, and while the metal is still weak. At the end of nine minutes no defect is apparent to the naked eye, notwithstanding the shrinkage which continued after compressing. If in regular practice, in the manufacture of crucible steels for instance, the ingots were allowed to cool to the temperature of the atmosphere, a compression of nine minutes would then be found to be almost sufficient.

Still, in order not to risk coming too near the limit, a compression of ten minutes' duration ought to be allowed for ingots of 120 kg. with moulds of low cooling power. Absolute soundness of metal would then be assured; but even then it would be preferable to work it immediately on leaving the press and not allow it to cool. A compression of eight minutes' duration is however sufficient if the ingot while hot is stripped and sent to the rolling mills. For crucible steel the time necessary for compression is less than for open-hearth steel, since the pouring is much slower. The influence of compression by wire-drawing on the cooling is noteworthy, as this takes place almost evenly from top to bottom, the head cooling about as rapidly as the base, a condition which favors the chemical homogeneity of the metal.

(2) *Physical Homogeneity in the Center of the Ingots.*

The compactness resulting from compression extends throughout the whole mass, and gives a sound metal, thoroughly homogeneous, in the very center of the ingot. This result is shown by fractures made on bars of 10×10 centimeters (4×4 inches) taken from the central portion of two ingots, one of which was compressed and the other not compressed. The uncompressed ingot was first forged and a piece equal to 28 per cent. of the weight was cropped off the upper end; the lower part was then drilled, the core part being cut out in the form of a round bar of 50 mm. in diameter. The compressed ingot was in the rough state, having neither been forged nor rolled, and was entire. A similar round bar was drilled out of the core of this latter, and the fractures of these two round bars were compared. Dark patches appeared on the two upper specimens from the compressed ingot, but these were in reality merely shadows, and the two fractures did not reveal any cavity. In the case of the uncompressed ingot, however, the first seven pieces, reckoning from the upper end of the ingot, were defective in the center, in spite of having had cropped off a piece equal to 28 per cent. of the weight.

A compact metal, free from defects in the very core, is undeniably the best for every kind of manufacture, since forging or rolling always has a tendency to strain the core of the metal, a tendency which is aggravated by the defects already existing. Thus all armor-plates show about the center of their thickness a plane of fatigue, which becomes a plane of rupture if the rough ingots show central cavities developed during rolling. In all ingot steel, cast freely without compression, the core exhibits from top to bottom (apart from the pipe) a defective material full of porosities due to contraction. Etching with acid brings out at once the defects which are not directly visible.

An examination made of numerous fractures of forgings shows that such fractures generally start from such "streaks" or shrinkage cavities and everything tends to prove that they are attributable to the weakness of the metal at these points. Since the compression of steel by wire-drawing obviates the defects which occur in the core of ingots, forgings of compressed steel will offer more resistance than those from uncompressed metal under the same conditions of shape and stress.

(3) *Diminution of the Liquation. Improvement of the Metal from the Point of View of Chemical Homogeneity.*

The more perfect homogeneity noticeable in compressed ingots has already been explained. The analyses given in Table V. show the comparative homogeneity of two ingots taken from the same charge for the purpose of investigation, which were respectively compressed, and cast in a plain mould. These ingots were divided sectionally through the vertical axis, and the analyses show the composition of the metal at those points marked with a number.

The homogeneity is notably superior in the compressed steel, although the sample No. 15 was taken at the extreme limit towards the upper end, at a much higher point than in the case of the other one. The improvement would be still more marked in the case of very heavy ingots of large cross-section.

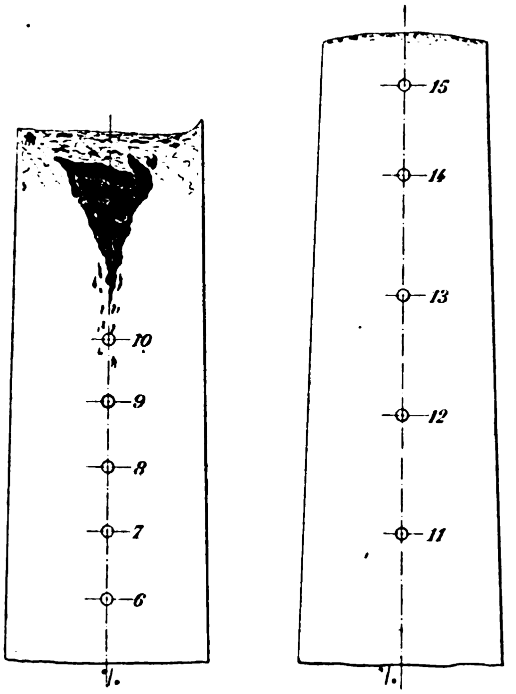
(4) *Improvement of the Metal from the Point of View of Mechanical Tests.*

In order to show this improvement in different conditions of the metal, there are given in the following tables comparative tests on rough ingots, on ingots that had received two workings, and on ingots that had been given four workings; and then, in the fourth table, comparative tests on the natural metal and on metal that had been tempered and annealed. In each case the two ingots were of the same weight and of the same charge.

For the tests in the first three tables, a waste of 5 per cent. was cut from the top of the compressed ingots and of 28 per cent. from the uncompressed ingots. In each ingot a block containing the axis was cut out. The sketches accompanying

TABLE V.—TESTS OF ROUGH INGOTS.

(Analyses taken along the center.)



Steel cast in plain mould.
Weight = 1210 kg.

Compressed steel,
Weight = 1340 kg.

	Per Cent.				Per Cent.		
6	C = 0.40	S = 0.008	P = 0.023	11	C = 0.40	S = 0.008	P = 0.023
7	C = 0.40	S = 0.007	P = 0.023	12	C = 0.41	S = 0.008	P = 0.024
8	C = 0.41	S = 0.007	P = 0.024	13	C = 0.42	S = 0.009	P = 0.023
9	C = 0.45	S = 0.010	P = 0.024	14	C = 0.42	S = 0.009	P = 0.025
10	C = 0.45	S = 0.010	P = 0.025	15	C = 0.41	S = 0.009	P = 0.023

the tables show the location of the test specimens and how they were taken.

From a study of the four tables it is clearly seen that the compressed metal possesses qualities very superior to those of the uncompressed metal. These qualities can be noted in all conditions of the metal (Tables II. and III.) ; even after four workings the difference in favor of the compressed metal is very great.

The qualities due to compression are brought out in a particularly striking manner in Table IV., by the action of tempering. In the compressed metal this treatment by increasing the homogeneity, increases the elastic limit, the tenacity and especially the elongation. In the uncompressed metal, it develops defects since it renders the specimens unfit for test and diminishes the elongation.

The fact that tempering accentuates the faults of the uncompressed metal and, on the other hand, improves the compressed metal, enables us to conclude with certainty that the latter contains almost no incipient fissures and no internal stresses that tempering releases by producing fractures and fissures. A study of the fractures in Table I. leads to the same conclusion.[*]

(5) *Improvement of the Molecular State of the Steel.*

The compressed ingot presents to the eye a grain of a visibly finer structure, and the large cleavages no longer exist ; but the only results which it is possible to produce here are those revealed by microphotography.

The photographs, Figs. 1 and 2, Plate II., represent the structure of two small ingots. The natural metal shows a fissure of considerable extent.

The photographs, Figs. 3 to 14 Plate III., show the structure, at a magnification of 80, of two ingots of the same charge,

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[*] The letters A, B, C, D, F, G, H, J, K, in the fracture column refer to a classification currently used in France to denote the various aspects presented by the fracture. :

A—fibrous fracture exhibiting a surface entirely cupped.
B—fibrous fracture, on the surface of which the cupped part is incomplete.
C—horizontal fracture, fibrous center surrounded by ring of very fine crystals.
D—fibrous, not quite horizontal, with lines across somewhat akin to woody fibre in appearance.
F—smooth diagonal fibrous fracture, inclined at about 45° to axis of test piece.
G—fairly smooth fibrous fracture, V-shaped, showing a bright line in the angle,
H—finely crystalline, bright, horizontal fracture, slight flaw on surface, contraction of area small.
J—very finely crystalline, dull, horizontal fracture; very little contraction of area.
K—fracture showing large bright crystals, horizontal, with scarcely any contraction at all.

A is considered a perfect fracture, and the others follow in the order of the letters, each succeeding one being worse than that preceding. Fractures designated by two letters present the characteristics of each type indicated by the respective letters.

and the sketches, Figs. 1 and 2, indicate the position in the ingots from which the specimens were taken.

In general the constituents ferrite and pearlite show in their disposition a greater degree of homogeneity in the case of the compressed ingot. Moreover, a more minute examination of the uncompressed ingot, Fig. 11, reveals a large band of ferrite traversed by a small crack of microscopic size, which in the further course of operations would form an obstacle to prevent the uniting of the pearlite on either side of it. Thus an artificial cleavage would occur at this point in the rolled or forged piece, which would prove more or less troublesome according to the direction of the stress to which the metal is subsequently subjected.

In Fig. 14, showing the structure of an uncompressed ingot, a similar occurrence may be observed. Here the elements are grouped in dendritic formation, with a double crack penetrating the ferrite and enclosing a pearlite band towards the center of the figure. These cracks constitute a starting-point for rupture, and the unexpected failure of steel in use is often due to them.

In the photomicrographs of the uncompressed ingot, on the other hand, the dendritic structure, and above all the cracks and cleavages, are absent.

APPLICATIONS.

The Harmet process is employed commercially on a large scale at the steelworks of Saint-Etienne, and results obtained are most satisfactory. The compressed metal has been used with success for armor-plates, projectiles, crank-shafts, etc. Due to the marked qualities of the compressed metal, the process should be of particular value in the case of gun forgings.

In recent years there have been recurring accidents in bursting of guns in firing. The guns were most carefully constructed, from the best structural steel obtainable in the United States. This steel was tested most fully at every step of manufacture, and was only accepted when it met, in the physical tests, a very high standard of requirements. In endeavoring to determine the reasons for the occasional shortcomings, investigations were made in 1901, both as to what might be designated the intimate structure of the steel when in the ingot and after forging. The board on test of metals dissected two steel ingots, the being of carbon-steel and one nickel-steel. These ingots were found full of small inferior cavities, resulting from the continual contractions of the metal when passing from the fluid to the solid state. There was also a considerable piping in the interior of the ingots. (See Plates IV., V., VI., VII.).

Notable variations in chemical constituents in different parts of the ingots were found to exist. This was caused by liquation and segregation, the occurrence of which appeared to be unavoidable in all methods in use. No amount of forging could eliminate the interior cavities referred to. They were simply "squeezed" together and lengthened by the act of forging. There being no adhesion in these flattened cavities, they are necessarily elements of weakness.

Streaks in gun forgings.—The term "streak" has been applied to the local appearance of gun forgings in process of machining, referring to differences in color or the lack of continuity of the metal as commonly witnessed in more or less well-defined lines or paths which are found to follow a direction parallel to the axes of the forgings. According to their color they are designated as light streaks or dark streaks, and they may be present separately or associated in the same forging. They are not found evenly distributed, being more numerous in some zones than in others, and frequently present in groups in the general localities where they occur. Their dimensions range from the fraction of an inch to upward of 4 feet in length, penetrating at times one-half inch or more below the surface. In terms of their other dimensions they are comparatively narrow in width.

Their presence is made manifest when the metal is machined, and greater or less prominence may be given their development by varying the conditions pertaining to the machine tool in respect to the depth of cut and feed employed. Streaks are not introduced by the operation of machining, but their presence is thus made known. Different etching solutions will aid in bringing the streaks clearly into view. Etching is not essential for this purpose in a microscopic sense, but assists ordinary vision in discerning a streaked state.

Direct experiments in the forge shop upon unstreaked steel have not resulted in the production of streaks of the type under consideration. A careful examination of streaked metal frequently shows the presence of short, interrupted dark lines, which are actually seams, places in which the continuity of the metal is wanting.

The association of seams with streaks leads to the inference that they may have a common origin, and apparently the time of their formation is restricted to the period when the metal is in the ingot.

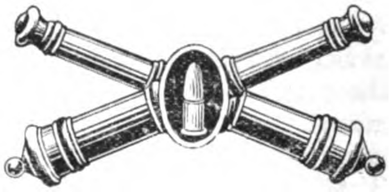
The shapes of ingot cavities, when such exist, are changed by the subsequent operation of forging. The walls may be brought into contact, a partial or complete welding effected, and the junction of such parts extended materially beyond their original lengths as the forging is drawn under the hammer. The tensile properties under stresses applied parallel to the direction of such extended junctions are not generally modified thereby, but loads applied normal to them may be expected to show deficiency in ultimate strength and elongation. These remarks are based upon the behavior of certain streaked forgings subjected to tangential stresses; that is, normal to the general direction of the streaks.

So far as known the presence of streaks is attended with loss in tensile strength and elongation. Their magnitude, whether singly or in groups, and whether they are lines or welded or nearly welded metal or actual seams will have a bearing on the gravity of the defect, as well as the relative proportions and the positions of the plain and streaked metal in the finished forging.

Investigations on this subject were made by the Ordnance Department, U. S. A., in 1902. Some rings, analogous to the rings forged for guns were turned down. "Streaks" were found in many places, and it was obviously the result of the shrinkage cavities previously mentioned. Where these occurred the metal structure was necessarily weak. This was shown more fully when the rings were subjected to hydraulic pressure until they burst. The lines of breakage were where the streaks were most in evidence.

It is claimed for the Harmet process that it presents the economic advantage in that a larger proportion of the ingot is acceptable for gun, armor and other forgings admitting only of perfect metal. It is to be tested in this country, the Ordnance Department having ordered from abroad a 10-ton ingot for trial. The French government now accepts the Harmet process steel ingots with five per cent. of wastage, instead of twenty-eight demanded for the uncompressed steel ingots, and there is further economy, as it is found that the Harmet steel, with but two forgings, gives as good results in impact tests as the uncompressed steel gives in four forgings.

Summarizing, the claim for steel made by the Harmet process is: that it is more perfect in its physical structure, free from shrinkage cavities and piping; much more uniform in its chemical composition; gives twenty-five per cent. more available metal in the ingots produced, and requires a much smaller amount of forging to secure the best results. The process is used at Cammels' in England and Beardmore's works at Glasgow where there is an installation for wire-drawing 20 to 40-ton ingots for armor-plates. It is also now being installed by John Brown and Company and Firths, whilst other establishments are preparing to use it. It is in successful operation at the Oberbilk Works at Dusseldorf. It is, however, conspicuously absent in the steel establishments of the United States.



Harmet Process
for Steel.

PLATE I.

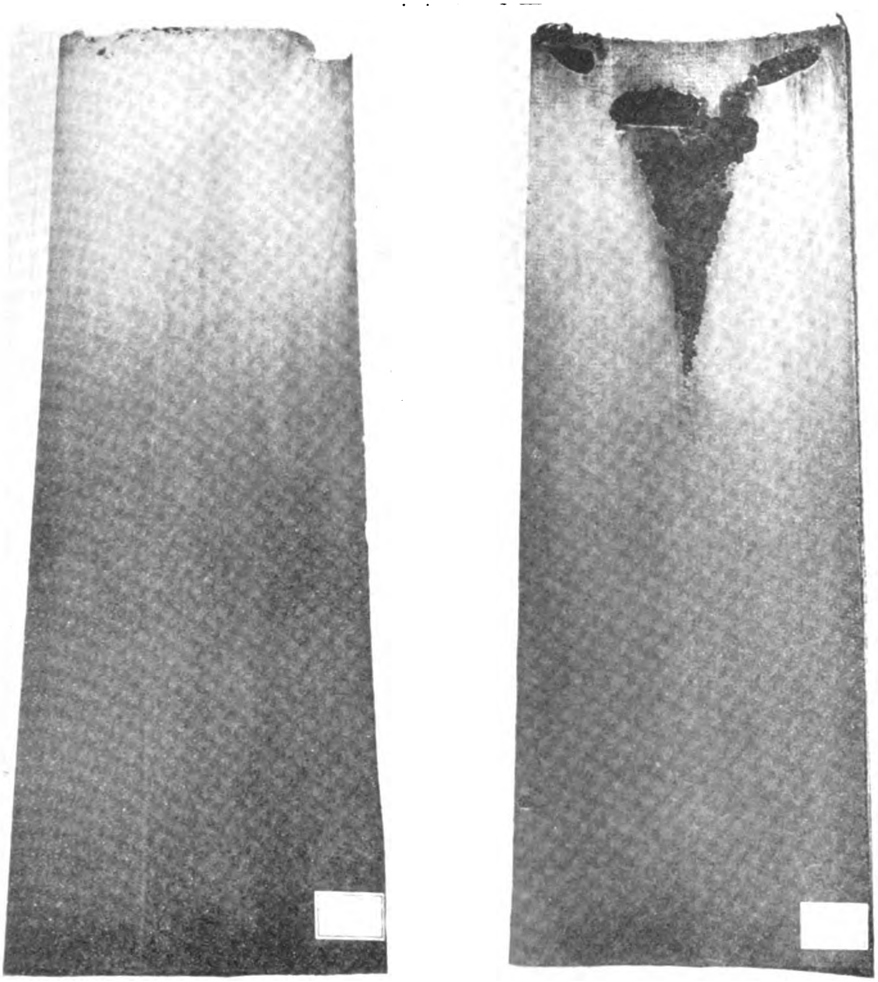


FIG. 1. Compressed Ingot.

FIG. 2. Uncompressed Ingot.

Longitudinal section by plane through axis of ingot.

PLATE II.

FIG. 1. Non-compressed metal (fissured).
Small ingot. Magnification 80.

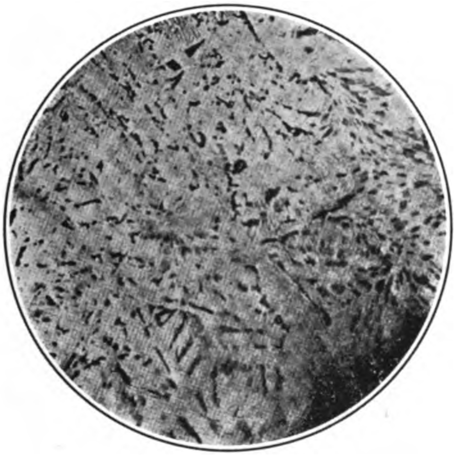


FIG. 2. Compressed metal. Small ingot.
Magnification 80.

Harmet Process for Steel.

PLATE III.

Metal (fissured).

ressed Metal.

ressed Metal.

Metal (fissured).

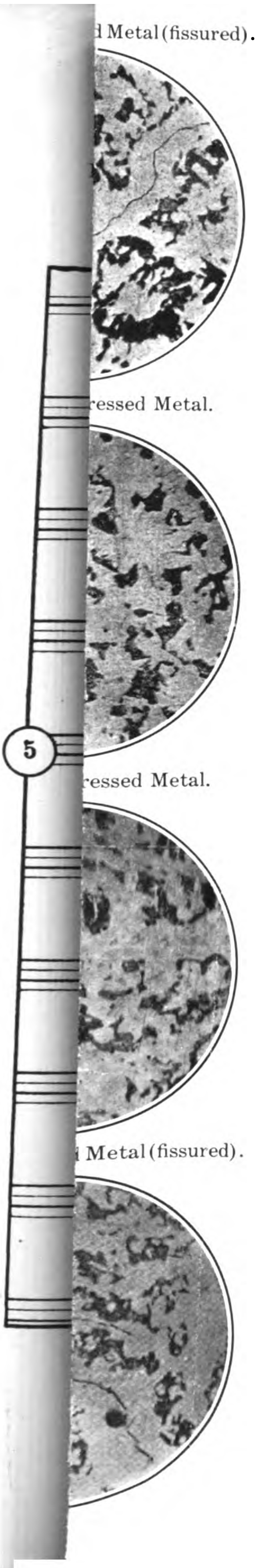


FIG. 2. Uncompressed Ingot.

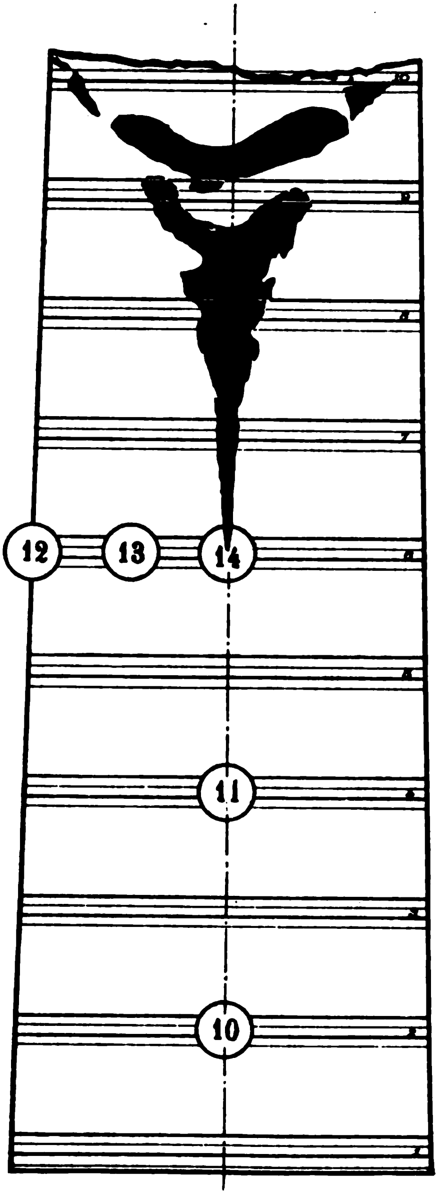
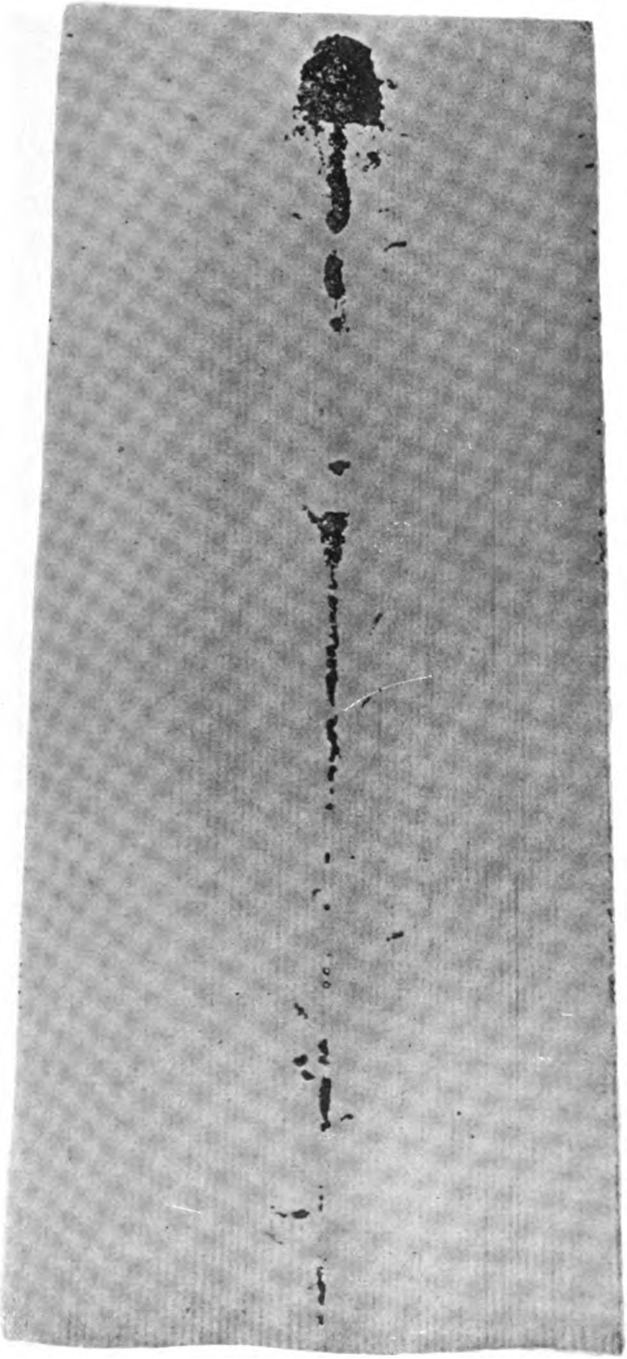
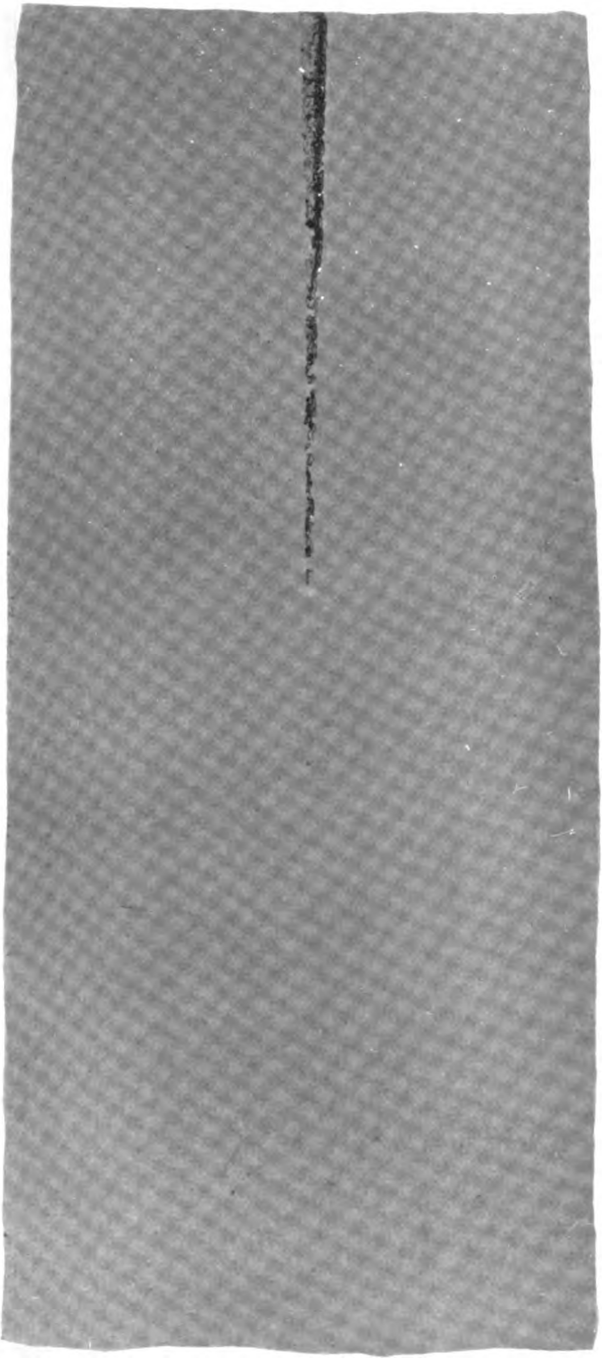


PLATE IV.



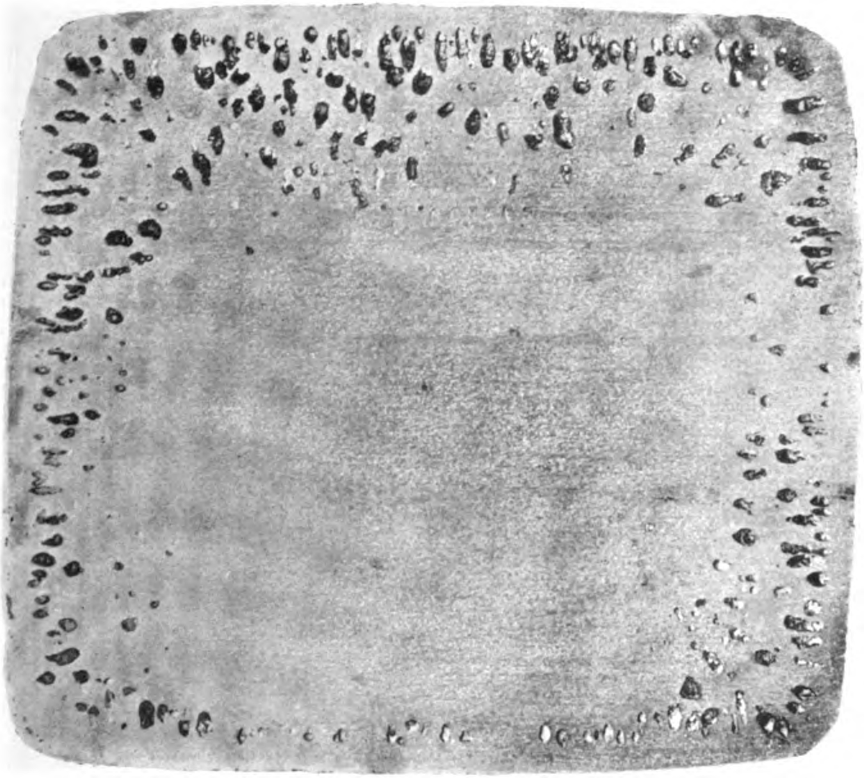
Carbon Steel Ingot (uncompressed)
Longitudinal section, middle of length of ingot.

PLATE V.



Nickel Steel Ingot (uncompressed)
Longitudinal section, middle of length of ingot.

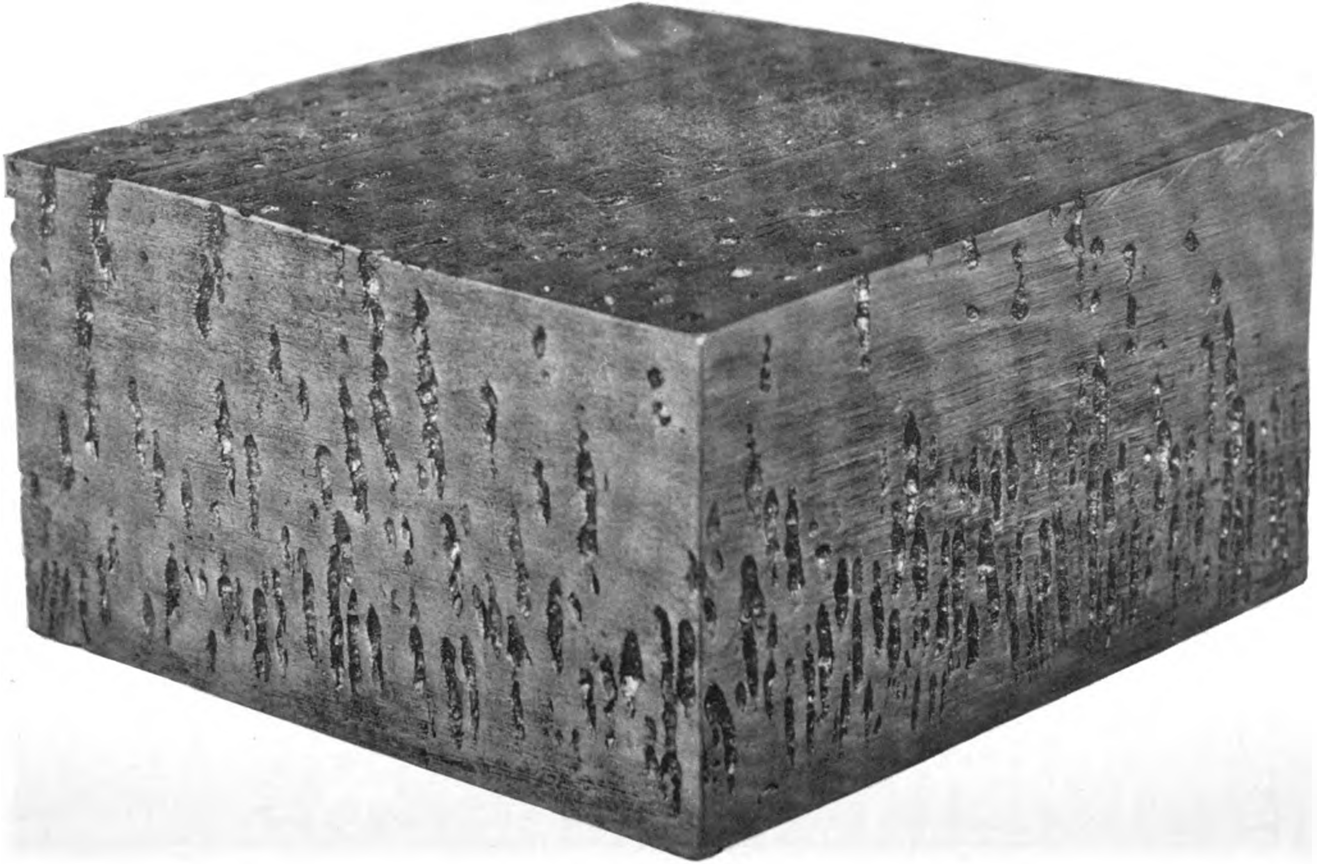
PLATE VI.



Carbon Steel Ingot (uncompressed)
Test specimen, 16½ inches from bottom.

Harmet Process for Steel.

PLATE VII.



Nickel Steel Ingot (uncompressed) Test specimen. Appearance as taken from ingot.

DOUBLE INTERPOLATION IN TABLE II. OF INGALLS' BALLISTIC TABLES.

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Instructor of Ordnance and Gunnery, U. S. Military Academy

THE formulas for double interpolation, Table II., given on page 16 of the "Handbook of Problems in Exterior Ballistics, Artillery Circular N, series of 1893," and in the introduction to the Ballistic Tables, are not sufficiently accurate for use, in many cases; and are in fact rarely used in the solution of ballistic problems. There are two reasons for this: the first, the lack of accuracy of the formulas; the second, the loss of time involved in the selection of the proper formula for use. The lack of accuracy in the formulas is due to the omission of the terms involving the second differences. The loss of time in selection is due to the fact that the formulas as written are not sufficiently general, and different formulas must be used for the same function in different parts of the table. If therefore we supply the missing terms and, at the same time, put the formulas in more general terms, the resulting formulas will not be subject to either of the above criticisms, and it is fair to expect that they will be more useful.

All the functions of the table being functions of two independent variables, V and Z, a particular value of any one of them, as for instance of the function A, may be graphically represented by the length of a line drawn perpendicular to the plane containing the axes of V and Z. In the figure the axis of V is horizontal, the axis of Z vertical, the origin of coordinates being somewhere to the left of and above the figure. Taking any value of A from the table, and calling the corresponding values of V and Z, V_0 and Z_0, from a point on the plane corresponding to these values lay off on a line drawn perpendicular to the plane the length f_0 equal to the value of the function. Draw V_0V_2 of a length, h, corresponding to the difference between the two values of V given in the caption of the table. Draw $Z_0Z_2 = 100$. From V_2 draw a perpendicular to the plane and lay off on it the length of the function taken from the next table for the same value, Z_0. From Z_2 lay off the next value of A in the original table, and from a point at a distance of 100 under V_2 lay off the next value of A in the succeeding table. Join the ends of the functions as shown. The solid enclosed by the lines thus drawn contains all the values of A contained between two successive tabular values of both Z and V. Now if we cut the solid first by a plane through V in the figure, and next by a plane through Z in the figure, the intersection, f, of the two planes will be the value

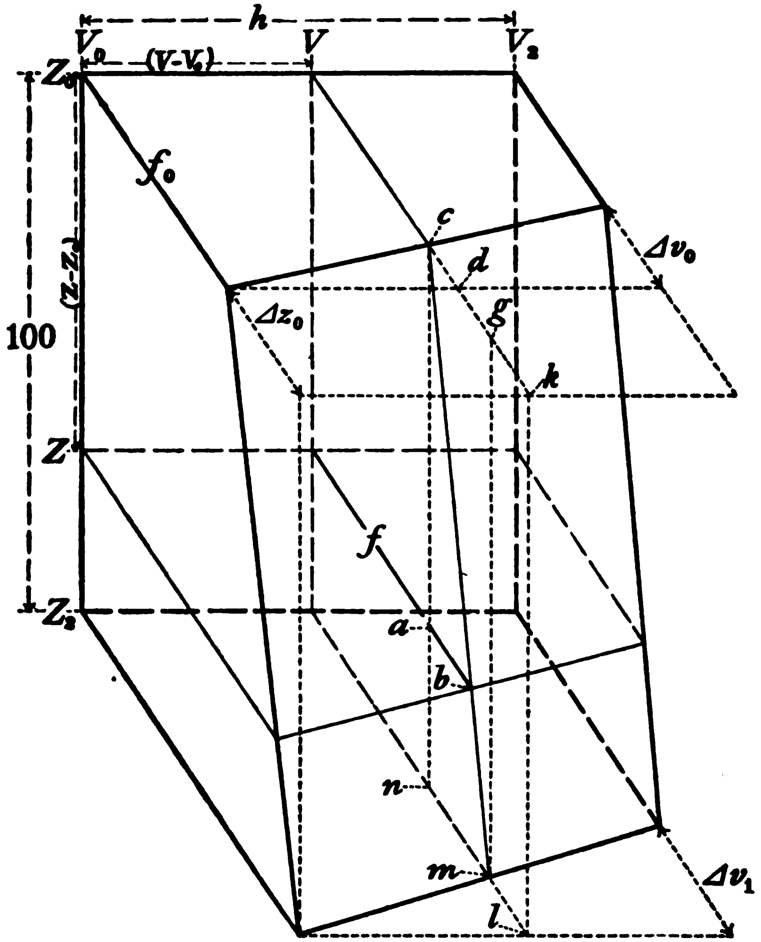

Fig. 1.

of the function for the particular values V and Z between the tabular values.

By means of the dotted lines, $\triangle z_0$, $\triangle v_0$ and $\triangle v_1$ are shown; $\triangle v_1$ being the value of $\triangle v$ immediately under $\triangle v_0$ in the table. The purpose of the other lines will appear.

From the figure,

$$f = f_0 - cd + ab \qquad cd = \frac{V - V_0}{h} \triangle v_0$$

$$f = f_0 - \frac{V-V_0}{h} \triangle v_0 + ab \qquad ab = \frac{Z-Z_0}{100}\, m\,n = \frac{Z-Z_0}{100}\,(nl - ml)$$

$$nl = ck = \triangle z_0 + \frac{V-V_0}{h} \triangle v_0$$

$$ml = \frac{V-V_0}{h} \triangle v_1$$

$$ab = \frac{Z-Z_0}{100} \left\{ \triangle z_0 - (\triangle v_1 - \triangle v_0) \frac{V-V_0}{h} \right\}$$

$$f = f_0 - \frac{V-V_0}{h} \triangle v_0 + \frac{Z-Z_0}{100} \left\{ \triangle z_0 - (\triangle v_1 - \triangle v_0) \frac{V-V_0}{h} \right\}$$

Since the function of A diminishes with V and increases with Z we will indicate this by writing $f^{(-V)}_{(+Z)}$ for f. Performing the operation indicated in the second member, and rearranging the terms, the formula takes the form :

$$f^{(-V)}_{(+Z)} = f_0 + \frac{Z-Z_0}{100} \triangle z_0 - \frac{V-V_0}{h} \triangle v_0 - \frac{Z-Z_0}{100} \cdot \frac{V-V_0}{h} (\triangle v_1 - \triangle v_0)$$

By properly changing the signs, formulas are obtained for those functions that vary differently. Solving the above for V and then for Z, the resulting formulas give the value of V or Z when the value of the function and Z or V are given.

DOUBLE INTERPOLATION FORMULAS—BALLISTIC TABLE II.

f = non-tabular value of any function corresponding to the non-tabular values V and Z.

f_0 = tabular value of function corresponding to tabular values V_0 and Z_0 *always less than* V *and* Z.

h = difference between velocities given in caption of table.

$\triangle v_0$ and $\triangle z_0$ = tabular differences for f_0.

$\triangle v_1$ = tabular difference next following $\triangle v_0$ in same table.

$f^{(-V)}_{(+Z)}$ indicates that function decreases as V increases and increases as Z increases.

Use the following formulas for the functions A, A′, B, T′, log C′, and D′ throughout the table. They also apply for some values of the functions A″ and log B′ when V>2500.

$$f^{(-v)}_{(+z)} = f_0 + \frac{Z-Z_0}{100}\Delta z_0 - \frac{V-V_0}{h}\Delta v_0 - \frac{Z-Z_0}{100}\cdot\frac{V-V_0}{h}(\Delta v_1 - \Delta v_0)$$

$$V = V_0 + \frac{\left(f_0 + \frac{Z-Z_0}{100}\Delta z_0\right) - f}{\Delta v_0 + (\Delta v_1 - \Delta v_0)\frac{Z-Z_0}{100}}h$$

$$Z = Z_0 + \frac{f - \left(f_0 - \frac{V-V_0}{h}\Delta v_0\right)}{\Delta z_0 - (\Delta v_1 - \Delta v_0)\frac{V-V_0}{h}}100$$

Use the following formulas for the functions A″ and log B′ when V<2500, and for some values beyond that point.

$$f^{(+v)}_{(+z)} = f_0 + \frac{Z-Z_0}{100}\Delta z_0 + \frac{V-V_0}{h}\Delta v_0 + \frac{Z-Z_0}{100}\cdot\frac{V-V_0}{h}(\Delta v_1 - \Delta v_0)$$

$$V = V_0 + \frac{f - \left(f_0 + \frac{Z-Z_0}{100}\Delta z_0\right)}{\Delta v_0 + (\Delta v_1 - \Delta v_0)\frac{Z-Z_0}{100}}h$$

$$Z = Z_0 + \frac{f - \left(f_0 + \frac{V-V_0}{h}\Delta v_0\right)}{\Delta z_0 + (\Delta v_1 - \Delta v_0)\frac{V-V_0}{h}}100$$

Use the following formulas for the function u.

$$f^{(+v)}_{(-z)} = f_0 - \frac{Z-Z_0}{100}\Delta z_0 + \frac{V-V_0}{h}\Delta v_0 - \frac{Z-Z_0}{100}\cdot\frac{V-V_0}{h}(\Delta v_0 - \Delta v_1)$$

$$V = V_0 + \frac{f - \left(f_0 - \frac{Z-Z_0}{100}\Delta z_0\right)}{\Delta v_0 - (\Delta v_0 - \Delta v_1)\frac{Z-Z_0}{100}}h$$

$$Z = Z_0 + \frac{f_0 + \left(f_0 + \frac{V-V_0}{h}\Delta v_0\right) - f}{\Delta z_0 + (\Delta v_0 - \Delta v_1)\frac{V-V_0}{h}}100$$

Inspect the tables to determine how the function varies with V and Z, and select the proper group of formulas.

Exercise great care in the use of the plus and minus signs.

The above formulas are accurate, and though they appear complicated they are in reality quite simple, and readily become fixed in the mind. They possess the advantage of containing quantities that all appear on one page of the tables, so that if one remembers how the function varies there will be no necessity of turning the page. In the recent addition to the ballistic tables the proper sign appears in each column of differences. It is to be hoped that this change will be made in any future reprint of the first edition. The desired information will then be found, with the data, on a single page.

The f formulas in each group are particularly simple, and when their construction is observed they may be readily written out with little effort of memory. Regarding these formulas, it will be observed that the correction for Z is first applied to the tabular value of the function, with the sign that indicates the manner of the variation of the function with Z. The correction for V is similarly applied, the sign being indicated by the manner of variation of the function with V. The last term contains the product of the fractional parts of the two preceding terms, and its sign is positive if the signs of these two terms are similar, and negative if they are dissimilar.

In the formulas as written the difference between $\triangle v_1$ and $\triangle v_0$ is usually positive, and attention need be given to the sign of this difference only when dealing with the functions log B′ and log C′.

The use of these double interpolation formulas will obviate the necessity of resorting to the method of solving problems laid down on page 46 of the Handbook of Problems, where it is written: "when, as in this example, the given muzzle velocity falls between two tabular velocities, it is more accurate to compute the required elements for each of the limiting velocities and then determine the elements by proportion." This method is cumbersome, is not accurate, as will be shown, and requires more than twice as much time for the solution of the problem as will be required for an accurate solution by means of the formulas above.

Perhaps this can best be shown by solving the problem on page 46 of the Handbook with the help of the above formulas.

The value of V is 1951 $\qquad \log C' = 5.04696$

$$Z = 2900 + \frac{50469.6 - (50442 - .02 \times 224)}{44 + .02} 100 = 2972.9$$

$$\begin{array}{r@{\;=\;}l}
\log X & 4.19271\\
\log Z & \underline{3.47318}\\
\log C & 0.71953\\
\log C_2 & \underline{0.71933}\\
\log C_2/C & 9.99980\\
\log \sin 2\varphi & 9.23967\\
\log C & \underline{0.71953}\\
\log A & 8.52014\\
A & 0.03312 = a'_0
\end{array}$$

$$\frac{Z-Z_0}{100} = \frac{331.2-(311-.02\times 15)}{26-2\times .02} = \frac{20.5}{26}$$

$$A'' = 798 + 0 + \frac{20.5}{26}\,57 = 843$$

$$\begin{array}{r@{\;=\;}l}
\log A'' & 2.92583\\
\log C & 0.71953\\
\log \tan \varphi & \underline{8.94195}\\
\log y_0 & 2.58731\\
\text{const. } \log & \underline{5.01765}\\
\log\ (\log f) & \underline{7.60496}\\
\log f & 0.00403\\
\log C_2/C & \underline{9.99980}\\
\log \beta c & 0.00383\\
\beta c & 1.0089\\
\log C & 0.71953
\end{array}$$

The value of βc is the same as that obtained in the Handbook. The value of log C obtained in the Handbook is 0.71964, making C equal 5.2437. Log C obtained above makes C = 5.2424, the correct value, since $\frac{X}{Z} = \frac{15585}{2972.9} = 5.2424$.

In the above solution another advantage in the use of the interpolation formulas is made evident, namely: the ease with which the correct value of one function may be obtained when an interpolated value of another function and a value of V or Z are the arguments.

It will be observed in the interpolation formulas for V and

Z that the fractional coefficients of h and 100, in the second members of the equations, are the values of $\frac{V-V_0}{h}$ and of $\frac{Z-Z_0}{100}$. In a case of this kind, it is therefore necessary to calculate only the fractional part in the second member of the formula applicable to the function used as an argument, and substitute this value for $\frac{V-V_0}{h}$ or for $\frac{Z-Z_0}{100}$, as the problem may require, in the formula applicable to the function sought.

U.S.M.A., West Point, N.Y.,
February 11, 1905.

PROFESSIONAL NOTES

PROGRESS IN WAR MATERIAL 1904

In the three years that have passed by since the campaign in South Africa, ample time has been afforded to re-arm our field artillery. Nevertheless, with the exception of the twelve batteries which have been furnished with the German quick-firing 15-pounder, the whole of our field and horse artillery batteries are at this moment provided with weapons which are inferior in handiness, range, rapidity of fire, and accuracy to those of most of the European Powers—and Japan. It is true that orders have been given out within the past few weeks for 107 batteries of field guns—seventeen batteries for the horse artillery and ninety for the field artillery—642 guns in all, being at the rate of six guns per battery, or going back to the old scale of equipment again, a most salutary arrangement.

It is also quite true that a certain number of coast batteries have been partially re-armed, and the work that has been accomplished in this direction during the past year and a half noticeably has furnished a substantial increment to the permanent defenses of the United Kingdom and of our coaling stations, as well as towards the strength of Hongkong, New Zealand, Bombay, &c. But expenditure upon the last two places is met locally, so our armament estimates are recouped as regards these items, and, indeed, many others of similar character.

Let us, however, dwell for a moment upon what has been done, rather than upon what has been left undone. Unquestionably the efficiency of our siege train and batteries of position has been raised to a high standard. The new guns and carriages, or mountings, are of the most powerful and trustworthy type; and a remarkable contrast to the siege equipment of the German army, the smallest 12-centimetre howitzer of which requires six horses to drag the gun and limber, the ammunition wagon being still more cumbrous. Moreover, the 10-pounder jointed screw mountain gun, which has just been issued for hill service, has proved a very useful weapon in Thibet, and will doubtless be increased in caliber for future hill warfare. The latest 6-inch Mark III. quick-firing gun of 7 tons, which occupies the position of the antiquated 7-inch and 9-inch muzzle loaders, in all of the lately re-armed coast batteries, has an initial velocity of 2154 f.s., and an extreme range of 10,900 yards. The latest 9.2-inch, Mark X. gun, which is practically a quick-firer, is of 46.66 calibers in length, and has a muzzle velocity of 2800 f.s. Its perforation of Krupp steel at 3000 yards is 10 inches—with an uncapped projectile. The cap would increase the perforation about 25 per cent. Most of the 9.2-inch guns have been mounted this year.

Perhaps in subsidiary elements of war material the greatest progress has been made on shore during 1904. The system of position finding by night has been brought to a very high degree of perfection by means of an improved arrangement for searchlight details. The large and important positions in our coast fortresses, which have several groups of guns, each worked by their own position finder, are now fitted with three separate searchlights. One of these has a fixed beam, stretching across the estuary or roadstead, through which an enemy must pass in approaching the fortress, thus indicating the exact locality of a hostile vessel for a moment, which is at once covered by a second, or fighting light, and then kept in the beam as it approaches the defending batteries; the third light is for prospecting outside of the fixed beam, and for giving notice of the approach of the enemy, whilst still at a considerable distance. The movable searchlights are so arranged with a see-saw apparatus guiding the sweep of the beam in front, that, as they revolve, they clear the site of friendly works, and do not expose them to the observation of the foe. Whilst this illumination of the hostile vessels is in progress, the control of the position finders keeps the guns of the various batteries ever laid upon them; and actually, in some cases—where automatic hydraulic gear is employed to elevate and train—following the path of the ships as they approach. It is needless to say that night attacks are those which require the most skilful forms of defense. In the daytime a trial shot or two will be of as much service very often as a position finder. Singularly enough, the exact site of a searchlight in the darkness is very difficult to spot. The fort or position which contains the projector is not illuminated by the light itself. So the working of searchlights does not help the enemy. It was, indeed, made abundantly clear, during the searchlight experiments which were conducted in the summer of 1904, while torpedo boat attacks were made upon the large naval ports at night, that the highest speed was unavailing to enable those vessels to evade their exposure to the continuous beams of the fighting lights and to avert their inevitable destruction by the countless groups of 12-pounder and Hotchkiss guns which bristle around the openings to all of these ports.

Let us turn now to the development of naval war material. The Mark IX. 12-inch, steel-wired 50-ton gun, 496.6 inches in total length, of 40 calibers, is now an accomplished fact upon vessels of the King Edward VII. type; and, as each of these huge battleships approaches completion, the four 12-inch wired guns are to be found lying upon skids in the naval ordnance yards, waiting for the ships—not ships for the guns, as was the case in 1887. When it is considered that each of these weapons takes three years to build, it is clear that the naval artillery authorities have not been backward in their warlike preparations for the past year or two. For let us bear in mind that, whatever may be the ordnance tables published by manufacturers, and the flights of fancy for the future from across the Atlantic, the King Edward VII. type is far and away the most powerful type of battleship actually afloat; and the Mark IX. 12-inch and Mark X. 9.2-inch wire guns upon that type are the most powerful ordnance hitherto mounted as service weapons. It is the practice of other naval powers to talk of experimental weapons as though they were illustrative of service armament. We do not. The 12-inch gun has a muzzle velocity of 2750 f.s., developing an energy of 44,622 foot-tons, with a penetrative force of 15¼ inches into Krupp cemented steel at a distance of 3000 yards. This is with an uncapped projectile. With a capped projectile of armor-piercing character, having a small internal capacity of about 2½ per cent of the entire weight, the penetration would be 18 inches into Krupp cemented steel plates at 3000 yards. As it is doubtful whether battleships will be again loaded with armor plates of this prodigious thickness, it seems unnecessary, for the present at least, to aim at increased penetrative power. The same argument holds good with the 9.2-inch and 6-inch guns. The gun, with its improved muzzle velocity and penetration has beaten the armor plate, provided that the velocity is well over 1800 f.s., the degree required to develop the usefulness of the soft metal cap; so we may stand easy for a time. Expert writers in some of last year's annuals have severely criticised our last mounted 12-inch guns, because they are only of 40 calibers, and assumed to be inferior in range to other visionary weapons intended for foreign Powers. It is remarkable how quickly experience gained is lost sight of. It is only from ten to fifteen years ago that both France and Great Britain built a number of heavy guns which were so unduly elongated that they drooped during practice with battering charges. Yet we are urged to repeat this unhappy and expensive experiment.

The discussion of the gun naturally leads us to that of the armor which it is designated to attack. We are indebted to Messrs. John Brown and Co., Limited, of the Atlas Works, Sheffield, for much valuable information on this head, showing recent progress in the improvement of armor plates. Krupp cemented plates are still the most advanced form of thick armor plate protection, although it is unusual to apply cementation to plates of 4-inch and under in thickness. We say this last with a certain amount of reservation, for as we shall see, the Hadfield Company appears to have made this year a specially hardened 6-inch plate which breaks up 6-inch armor-piercing shells, and it could probably repeat the process of manufacture with a 4-inch plate. The steel for Krupp cemented plates—and indeed for all the special plates which are now being made—has a high tensile strength, approaching 50 tons per square inch, and contains small proportions of nickel, chromium and manganese. Cementation, or carburising, is carried out in the same manner as was the practice observed in the Harvey process; that is to say, animal charcoal is placed between the faces of two plates laid together, face to face, which are run into a furnace with a bogie bottom, and bricked up for two or three weeks, seven days being allowed for cooling. In this way the proportion of carbon in the face is increased, and the front is then capable of being hardened. Seven days are allowed for cooling, which has to be a most gradual process, in order to prevent the plates flying to pieces by cooling too quickly. In the final face-hardening the plate is subjected to heat graduated from the face to the back. After this heating the face is placed under a cold water douche, from a series of pipes pierced with holes and containing water at a high pressure, which sprays with such violence as to prevent the formation of bubbles of steam on the surface. Messrs. John Brown and Co. afford, as a recent instance of the strength of these Krupp cemented armor plates, an experiment made with one of 5.9 inches in thickness, supported by an oak backing and 1¼-inch skin plate. Four uncapped shots were fired with a 6-inch gun at energies of 2664 foot-tons, which would represent an average range for attack. In no case was penetration effected or even of an important character. The equivalent resistance of Krupp cemented steel to that of wrought iron is from 2.3 to 2.8. The armor plates now being placed upon the Britannia and the New Zealand are not trimmed and planed so extensively as was the case formerly by Admiralty instructions. Those near the water-line are made smooth so as not to create unnecessary friction, but the barbettes and turrets are left untouched upon the surface—a much less costly and more advisable plan. The less the skin surface is touched the better.

We must now turn to the question of projectiles. We have received from Messrs. Hadfield's Steel Foundry Company, Limited, much valuable and recent information on this head. That Company has had very important experience during the past year with its cast steel projectiles, none of which have undergone the forging process observed by other manufacturers. Hadfield's capped "Heclon" projectiles have given the following results, which are summarized from a long report: A 4.7-inch capped shell, with a striking velocity of 2100 f.s., perforated a 6-inch K.C. plate; a 6-inch capped shell, with striking velocity of 2000 f.s., perforated the same; a 7.5-inch shell, with velocity of 1980 f.s., perforated a 7-inch plate; a 9.2-inch shell, with velocity of 2023 f.s., perforated a 9-inch plate. These figures speak for themselves. All the shells had a bursting capacity of about 2½ per cent. They perforated the plates and oak backing, and were afterwards found in condition for bursting, several practically undeformed. The result of these experiments demonstrates, "without a peradventure," as they say in America, the value of cast steel of suitable quality for projectile manufacture, and the influence of the soft nose or cap.

The Hadfield Company has also made important strides in the improvement of 6-inch armor plates, these being also of cast steel of special character, and called "Era." A shield of this material six inches in thickness resisted a 4.7-inch armor-piercing shell fired at 2100 f.s. velocity, and a lyddite 6-inch shell fired at 2035 f.s. velocity, the striking energy being 2875 foot-tons. This measure of resistance was, we should say, quite unique.

Some naval officers in this country are disinclined to view favorably the capped projectile, as its usefulness is not maintained below 1800 f.s. velocity, and at sharp angles of inclination it does not act well. But we should say that its usefulness under normal circumstances far outweighs any defects that low velocities and oblique firing might create. The Hadfield Company has just executed a very extensive order for Spain for capped "Heclon" projectiles of large caliber—28, 24 and 14-centimetre—this being probably the first order for large caliber capped projectiles made commercially in this country. The execution has given entire satisfaction.

The Hotchkiss Ordnance Company, Limited, has made considerable progress during 1904 in the development of its own special types of ordnance. The latest Hotchkiss 6-pounder 57mm. 58-caliber high-power semi-automatic gun is a very remarkable weapon, and of greatly increased powers of range and accuracy. It appears to contain the fewest number of separate parts that could be made sufficient for the mechanism of a semi-automatic gun, and yet all these can be separated by hand. Its simplicity and lightness, yet extraordinary length, make it one of the most effective quick-firers that we have seen. It possesses the following advantages: Greatly increased rapidity of fire. No danger of hang-fire, the automatic opening of the breech not taking place until the gun has been fired. One man less in the gun crew.—*The Engineer.*

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NEW HORSE AND FIELD ARTILLERY EQUIPMENTS.—ENGLAND.

PARTICULARS AS TO WEIGHTS, ETC., OF 13-PDR. AND 18-PDR. Q.F. GUNS.

Particulars.		13-pounder.	18-pounder.
Muzzle velocity		1658 f.s.	1610 f.s.
Caliber		3 inches	3.3 inches
Weight		6 cwt.	9 cwt.
Breech mechanism		Swinging block	Swinging block
Rifling	Grooves, number	18	18
	Twist	Uniform	Uniform
Firing mechanism		Percussion	Percussion
Approximate weight of gun and carriage		cwt. qr. lb. 18 0 12	cwt. qr. lb. 23 3 3
Approximate weight of carriage limber		12 0 0	14 3 3
Approximate weight behind traces		30 0 12	38 2 6
No. of rounds in carriage limber		24	24
Approximate weight of wagon (filled)		cwt. qr. lb. 15 1 21	cwt. qr. lb. 19 1 14
Approximate weight of wagon limber (filled)		14 1 27	18 1 16
Approximate weight behind traces		29 3 20	37 3 2
No. of rounds in wagon limber		38	38
No. of rounds in wagon		38	38
Height to axis of gun from ground		3 ft. .86 in.	3 ft. .86 in.
Wheels	Track	5 ft. 2 in.	5 ft. 2 in.
	Height	4 ft. 8 in.	4 ft. 8 in.
Weight of projectile (filled and fuzed)		12½ lb.	18½ lb.
Ammunition		Fixed and fitted with percussion primer	Fixed and fitted with percussion primer

WAR OFFICE (A. 2),
February 6th, 1905.

—*Royal Engineers Journal.*

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TACTICAL EMPLOYMENT OF FIELD ARTILLERY

THE GERMAN METHOD AS COMPARED WITH THE FRENCH

When the principles of the *Reglement de manoeuvre de l'artillerie de campagne* of June 8, 1903, (Part I., pars. 614 to 685) on the tactical employment of the French field artillery are compared with similar principles of the German regulations (Part IV., pars. 270 to 377), there will be found concordant statements in several places where reference is not directly made to the new French material; while, on the other hand, or exactly in cases where it is a question of the new gun and its effect, entirely different conceptions on its employment are set forth. The reason for this is to be found in the characteristics of the new French material and in what the French claim for its properties.

Ammunition supply.—The French regulations advocate methods involving an enormous expenditure of ammunition, whereas we rightfully lay special stress upon the necessity of husbanding the available supply with the utmost care. "Rightfully" we say because, however liberally provided a battery may be, it is impossible to count upon the ammunition always being at hand at the right moment in the midst of the varying incidents of a battle.

The allowance of rounds per gun is greater in France than in Germany, but, owing to a battery in the former country having only four guns as against six in a German battery, the latter has a larger total supply of shell with it. The French carry 312 and the Germans 216 rounds per gun with the battery.

Employment of field artillery in general.—The great principle in Germany is to bring into action a number of guns superior to that of the enemy at the very beginning of an action, and to work these guns as soon as possible in "mass," i. e., under one controlling head.

In France, on the other hand, it is held that only sufficient guns should be employed to meet the immediate requirements of any particular case, great care being taken not to use more than are necessary. It is even considered right to make use of one section only of a battery under certain conditions. If two guns seem likely to attain the immediate object, the other section remain in action without firing. In certains cases the engagement of two different targets by the two sections is contemplated. The French regulations do not provide for detaching sections for particular purposes as is done in Germany, especially when working with cavalry.

Although in France the number of guns originally opening fire is thus regulated by the breadth of the target to be engaged, as many other guns as possible are held ready to come into play at short notice. These remain in "positions of readiness," either the "position d'attente" in which the guns are halted, limbered up, as close behind their probable position for action as is compatible with keeping under cover, or the "position de surveillance" in which the guns are unlimbered behind cover, ready at any moment to open fire.

Such "positions of readiness" are also recognized in Germany, especially for artillery in defense, but not, as in France, with the object of keeping a regular "reserve" of artillery. In the latter country the theory is that the guns first opening fire will, as a rule, at least "stagger" the enemy, and that the subsequent unmasking of a large force of previously concealed guns will complete his discomfiture.

But we are not convinced of the soundness of this theory. It does not seem right to keep a number of guns idle, which are practically in action, both because it is asking a great deal of the personnel of these idle batteries and because they must run the risk of having their position discovered and being overwhelmed or seriously damaged by hostile fire before they can reply to it. Nowadays artillery will open fire against any position or area which seems likely to have troops and especially guns on it, and particularly so if it is known that the opposing artillery is given to keeping a "reserve" of guns as in the case of the French. Discovery is of course more likely in the "position de surveillance" than in the "position d'attente," for in the former, according to the "reglement," directions of fire will be laid out if possible and other preparations made for opening fire at a moment's notice, operations which involve a risk of exposure.

Other conditions being equal, three batteries will take less time than one to put an enemy's battery out of action, and therefore it is better to use a superior number of guns at once if they are available. The German regulations say—"effect will be much increased by the simultaneous opening of an unexpected, carefully prearranged, and well maintained fire. Rapid and decisive results will be obtained by combining the fire of several batteries against one target and by increasing the rate of fire."

The reason for the adoption of the above mentioned methods by the French is to be found in the nature of their equipment, which makes changes in position and also changes of target after fire has once been opened, operations involving a considerable loss of time.

In Germany, batteries in the front line are as a rule kept silent only when it is necessary in order to prevent confusion in ranging owing to the difficulty of identifying bursting shell when several batteries are ranging on one target.

The French "reglement" considers rapidity in gaining effect as the characteristic of field artillery. This is to be obtained by a high rate of fire, the great effect of each shell, and by "surprise."

Although the rate of fire obtainable with the German gun is less than that of the French, the effect of a single round is as great with the former weapon as with the latter, whilst the mobility of the German gun is distinctly superior. This should enable it to compensate for its lower rate of fire by getting to work more quickly. The German regulation paces are, both for marching and for maneuvers, more rapid than the French, whilst in Germany less restriction is placed upon the use of the gallop.

As regards the methods of fire the French view is that there should be alternating intervals of rapid fire and silence, whilst the Germans advocate the use, in general, of a continuous steady fire, both in order to economize ammunition, and in order to spare the nerves of the gunners the strain of very rapid firing except in special cases.

Respecting choice of target, the French "reglement" recommends that the most easily seen should first be engaged, and next that which seems most likely to hinder the advance of the infantry. The German instructions advise as the first objective that which is most important in view of the tactical situation, which will generally be the enemy's artillery at first, as it would be obviously unsound to engage hostile infantry which could be clearly seen at a long range in preference to the enemy's artillery in action partially behind cover, which, if left alone, might do great damage against infantry later on.

Duties of artillery commanders.—The instructions in both countries under this head are generally similar. In France however, it is considered that the general commanding should as a rule give the order to open fire besides pointing out the place where he wants the guns first to come into action, whilst in Germany the moment the fire is to be opened is left for artillery commander to decide, unless the general commanding has particular reasons for wishing to fix it himself.

Selection of artillery positions.—In France the immediate situation appears to be the guiding factor in the choice of a position, whilst the German regulations lay more stress upon the general tactical situation and the ultimate object of the battle.

The French prefer guns in action so far behind a crest line that only the flashes of the guns can be seen from the front, the Germans favor a more forward position in which a man standing at the end of the trail can just see the target. This latter method enables the gun to keep on firing at an advancing target longer than is possible with the former. Considering that the French gun is heavy to move by hand, it would seem that the forward position would also suit it best, for time and probably men would be lost in running up in order to sweep the forward slopes.

The French "reglement" is not in favor of long lines of artillery as they are easily located, but it is diffcult to see how they can be avoided in view of the large number of guns now used.

In both countries the necessity of making the best use of the ground for concealment whilst coming into action is insisted upon.

The French "reglement" lays down that the whole front available should be made use of as far as is compatible with the provision of suitable positions for artillery commanders. Intervals are not however, to be reduced below the normal except when guns are acting in close support of the infantry attack in its final stages, when intervals may be diminished and even dispensed with altogether, whilst questions of cover and concealment must not be allowed at such times to interfere with the most vigorous support by the artillery. Whenever there is a pause in the fire the detachments should construct shelter for themselves with any materials available, particular attention being paid to filling up, with earthen parapets, the spaces between the gun shields and caisson and the ground.

In Germany also the whole available front is to be used, but in cases where a reinforcement of guns may be expected the intervals between units may be reduced in order to prevent the mixing up of batteries, etc., but intervals between guns are never to be reduced below ten paces, except in the pursuit. Artificial cover, also, is to be constructed when opportunity offers. This would naturally be done if pauses in the enemy's fire occurred, without any special instructions in the "reglement" being necessary. The Germans, however, do not contemplate making "fire pauses" until the enemy's fire ceases altogether, and cover would then be superfluous.

After discussing the above general principles the French "reglement" goes into more detail, but first of all lays stress upon the fact that the offensive alone can result in decisive successes, and that the action of artillery will therefore be considered in its various phases from the point of view of the offensive. A paragraph, of seven lines, deals with defensive action. The German regulations, aware of the fact that the defensive must be often adopted in any great campaign even by the side which keeps the "offensive" idea most in view, carefully consider the action of artillery in defending positions, and also devotes some space to its action in retreat, a subject which the French work dismisses in three lines.

Artillery with the advance guard.—According to the French "reglement," artillery with the advance guard should spread itself over the country as much as possible, apparently with the idea of deceiving the enemy as to its strength, coming into action as much as possible under cover and taking care to be ready for sudden attacks. It should never commit itself so far that it cannot withdraw at will from the engagement, and should frequently change position when it has gained its immediate object by its fire.

The German view, except as regards taking cover and being ready to resist attacks at close quarters, is very different.

According to the German treatise the commander of the advance guard artillery should keep his batteries well in hand. Wide dispersion with a view to deceiving the enemy is only advocated for defensive purposes, and it is considered that even under those circumstances an astute enemy will not be misled for long.

Another reason for keeping the advance guard artillery together is to leave room for the guns of the main body to come into action as they arrive without any mixing up of units. The artillery of the advanced guard should only at once engage the enemy's guns when such a course appears likely to be successful from an artillery point of view, but it must at the same time be prepared to sacrifice itself if necessary in order to protect its infantry or to cover the advance of the main body. In face of a superior force of guns it should as a rule await the arrival of the artillery of the main body in a covered position, ready to open fire with it on its coming up. As a matter of fact it will be practically impossible nowadays, in view of the great effect of modern artillery, for a battery, once under fire of opposing guns, to break off the contest at will and remove to another position, unless supported by the fire of other batteries. Although the French regulations seem to think such a course advisable and practicable, it is by no means clear how these frequent changes of position are to be carried out, or what advantages they confer in an advance guard action, especially in view of the inferior mobility of the French gun.

The artillery combat.—The French "reglement" lays down, as the first rule, that the opposing artillery should be subdued in the shortest possible time with the fewest guns that can achieve this object. The fire of all the guns should be concentrated upon a portion of the enemy's artillery line, whilst that portion is engaged upon some other target than one's own guns. The French work calls attention to the necessity of keeping a close watch on batteries which have been silenced lest they should re-open fire, and conversely, the duty of silenced guns to recommence firing as soon as possible. Batteries which have run out of ammunition are not to retire without orders from a superior officer. When the infantry assault is to be supported every gun that can possibly do so should join in the fire, at whatever risk. The French regulations provide for occasions upon which artillery will cease firing at intervals whilst the detachments seek cover, ready to re-open fire at a suitable moment. The German book only mentions such inaction in the case of artillery acting on the defensive, where, by the general's orders, guns may be kept under cover during the enemy's artillery preparation, but they must in any case open fire when the hostile infantry comes within range.

Change of position.—With regard to changes of position, the German and French points of view are different. The French consider the matter mainly from an artillery standpoint, whilst the Germans look more to the general tactical situation. According to the French, the advantage of remaining in one situation lies in the fact that familiarity with the surrounding country is obtained and it therefore becomes easier to change the fire rapidly from one target to another, whilst careful examination of the ground occupied or likely to be occupied by the enemy is rendered possible. The main disadvantage rests in the fact that the enemy will be at the same time becoming better acquainted with one's own position. A change of position will often be necessary when the circumstance which brought the guns into action at a particular point become altered.

In Germany stress is laid upon the fact that every change of position causes a break in the fire, and therefore such changes are disapproved of unless the tactical situation renders them necessary.

In France change of position by alternate units is recommended, as is also the case in Germany, but in the latter country it is the practice to commence an advance simultaneously unless one portion of the line can cover, with its fire, another portion as it moves forward; in retreating, also, the guns are often moved to the rear together to avoid the danger of the portion left behind being overwhelmed by the fire of the whole hostile artillery, were units retiring alternately. In both countries limbering up under cover and, in retirement, coming into the new position from the rear are advocated.

Preparation of the infantry attack.—In both countries the concentration of a very heavy artillery fire under one control upon the point or points of assault as the infantry approach the hostile position is advocated, a certain number of guns being told off to fire upon the enemy's artillery; but even if the latter should be reinforced the majority of the guns should endeavor to keep down the fire of the infantry. The French "reglement" lays down that this should be done without regard to cover for the guns or detachments, adding that the value of cover generally decreases as an action progresses; the German work does not acknowledge this latter point; it will by no means necessarily be the case, especially when the guns are on the move, for at close ranges the best possible use of ground must be made to avoid serious loss on the way. Neglect of cover may often tempt into renewed action hostile guns which may have ceased firing.

Action during the assault.—During the assault the French divide their artillery into two portions. One of these advances with the infantry to the closest ranges, whilst seeking what cover it can from the features of the ground, and trying particularly to occupy flanking positions from which fire can be kept up until the last possible moment, and counter attacks can be met. The other portion remains, as a rule, in its original position, and shells the hostile infantry as long as it can without endangering its own troops, afterwards firing upon the reserves. Should, however, the enemy's artillery resume activity, this portion at once brings every gun to bear upon it.

The German work recommends that only a few detached batteries or possibly brigades should advance with the infantry, mainly for moral support, as it is thought that most of the targets which these guns could engage could be equally well fired upon from the previous artillery position if this was well chosen at the outset. The greater part of the artillery will generally remain in its original position and concentrate its fire upon the enemy's infantry, not relinquishing this task even if the enemy's artillery should recommence firing.

In both countries the advanced batteries will at once move on to the enemy's position if the assault is successful, followed by the main body of the artillery, and every gun will be employed to prevent the retreating foe making fresh efforts at resistance. In case of failure of the assault, the artillery must at all costs cover the retirement of the infantry, it being considered no disgrace to lose guns whilst performing this duty.

Retreat.—The French "reglement" lays down that during a retreat the artillery should continually delay the pursuing enemy by sending successive sections into action against him, these sections being prepared to sacrifice themselves if the circumstances demand it. The German treatise distinguishes more clearly between the tasks of covering the first withdrawal of the army after an unsuccessful action, giving it time to get into march formation, etc., and the action of rear guard artillery, which is by no means to be of a self-immolating nature. On the contrary it should only remain in action long enough to cause the enemy to deploy, thus giving the main body the advantage of the time necessary for this deployment.

This procedure should be repeated wherever positions favorable for the purpose occur, the main point being that the guns should be able to effect their retirement from these positions as far as possible unobserved, i.e., they should be able to "sneak away." It would be a fatal error to prolong rear guard actions too much, as the retirement of the rear guard infantry is thereby dangerously delayed.

Artillery on the defensive.—The German work deals with this question far more thoroughly than the French, which confines itself to stating that every effort should be devoted to preparing good artillery positions, without occupying them until necessary, and to improving means of communication and approaches to these positions. Guns are not to open fire until the general commanding the force gives the word.

The German regulations mention the above points, and further recommends that, if the enemy's line or lines of advance are uncertain, the artillery should be kept concentrated, routes to all possible positions for action being examined and improved where necessary. If the direction of the enemy's approach is less doubtful, the guns may be kept limbered up, in rear of their probable positions in action (cf. the French "position d'attente"). If the line which the enemy will take is very nearly certain, batteries may be brought into action close in rear of the actual positions from which they will open fire (cf. the French "position de surveillance"). In this latter case it is recommended that the limbers should be kept close in rear of their guns until the latter are about to open fire, in order that the batteries may be limbered up at a moment's notice should a sudden change of position be rendered necessary by some unexpected move upon the part of the enemy. With due regard to the absolute concealment of the whereabouts of the guns all possible preparations for a rapid opening of fire should be made. The actual firing positions should be occupied before the hostile artillery comes into action. Artificial cover and screens should be prepared and every effort made to render the task of ranging difficult for the enemy's guns. Opening fire too early is to be carefully guarded against. —*Abstract of a paper by Major von Zwenger*, Militar-Wochenblatt, 114, 115, 116, 1904.

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RUSSIAN FIELD ARTILLERY AT THE BATTLE OF DA-THCI-TSIAO*

In all the articles relative to the battle of July 11/24 only a very brief summary has been given of this artillery duel which lasted fifteen hours and the whole weight of which was borne by the batteries of the 9th

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* This report of one of the principal actors in this battle, Lieut.-Col. Pachtchenko, was published in the Rousskii Invalid, numbers 236, 240 and 242 of 1904. This same Journal had already given in a previous number an account of an espisode in the artillery duel at Da-tchi-tsiao, which was very interesting, especially in regard to the consumption of ammunition. See JOURNAL U. S. ARTILLERY, November-December, 1904, p. 312.

artillery brigade of the East Siberian Rifles. And yet that day furnishes a number of lessons on the role of artillery in battle.

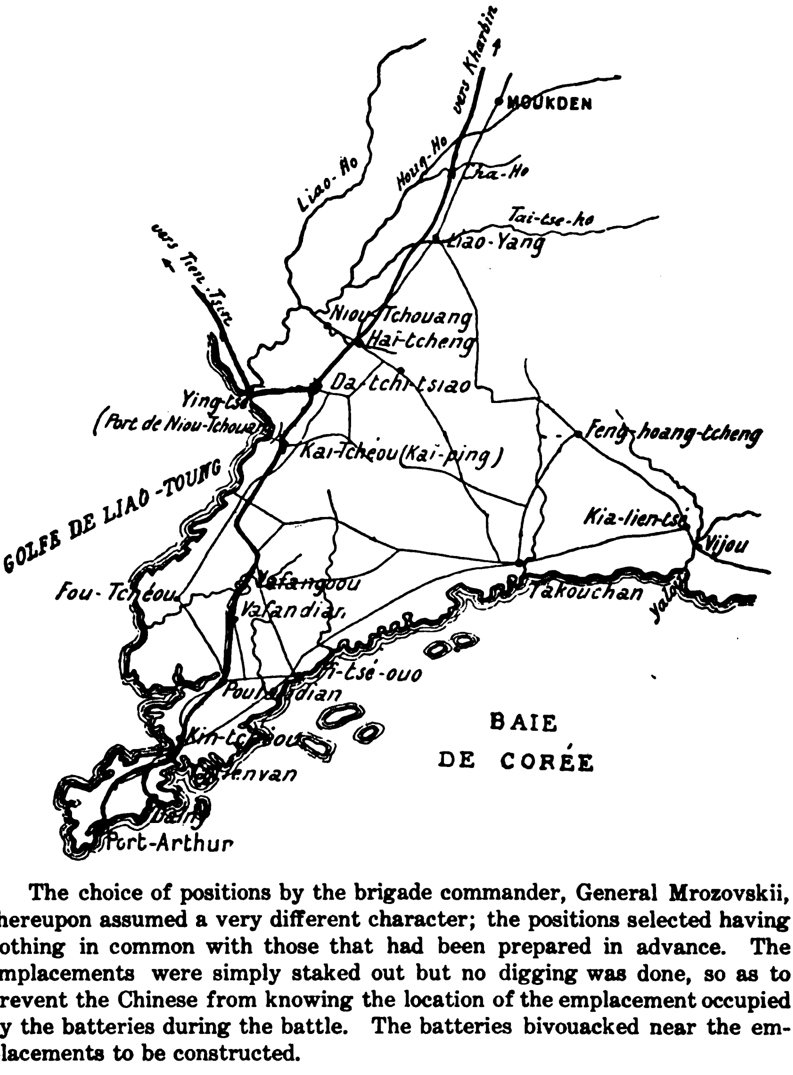
Mountain warfare from a tactical point of view has generally been but little studied by us, and at the beginning of our war with the Japanese we found ourselves confronted by many problems that had not been foreseen, especially as regards the role of artillery. This circumstance and the enormous superiority of the enemy's forces were for some time a great obstacle for us particularly with reference to the proper utilization of artillery. The recent transformation of the material of a large number of batteries, which had arrived at the theatre of war with the new guns, had not given the officers *time to familiarize themselves with the very remarkable properties of this new material* and above all with the methods of laying, which are of very great importance. Our *aversion to indirect fire,* the misunderstood use and the defective fire control of our artillery, were the sole causes of our reverses and of the loss of a certain number of pieces in the first encounters with the Japanese.

An inaccurate knowledge of our artillery led some superficial writers, who judged by the results of the first engagements, to consider the Japanese gun very superior to ours. But a little while after the battle of Va-fan-goou, the success achieved by our artillery, which the Japanese themselves were obliged to recognize, shook to some extent the belief in the superiority of the Japanese artillery. The battle of Da-tchi-tsiao, July 11/24, revealed for the first time all the valuable qualities of our field gun. This battle demonstrated clearly to all those who doubted the technical and ballistic value of our material that in order to prevent the enormous numerical superiority of the Japanese artillery from being so formidable to us, it was sufficient to know how to utilize to advantage the properties of this ingenious and complicated engine of war.

On July 11/24, the Japanese installed the principal mass of their artillery (13 batteries) opposite our right flank facing the artillery of the 1st Siberian corps. We had at the beginning, on our position of battle, four batteries, which were reinforced by a fifth only towards evening. But there were in reality only three batteries taking part in the action, because the emplacement occupied by us did not allow of concentrating the fire of all our batteries on the same point. Twenty-four of our guns, therefore, fought effectively seventy-eight Japanese guns distributed over a front of about 6 versts (6 km.). It may be noted that the positions at Va-fan-goou, Da-tchi-tsiao, Haitcheng, etc., had been chosen and fortified a good while in advance, so that the Chinese, and consequently the Japanese, knew them perfectly.

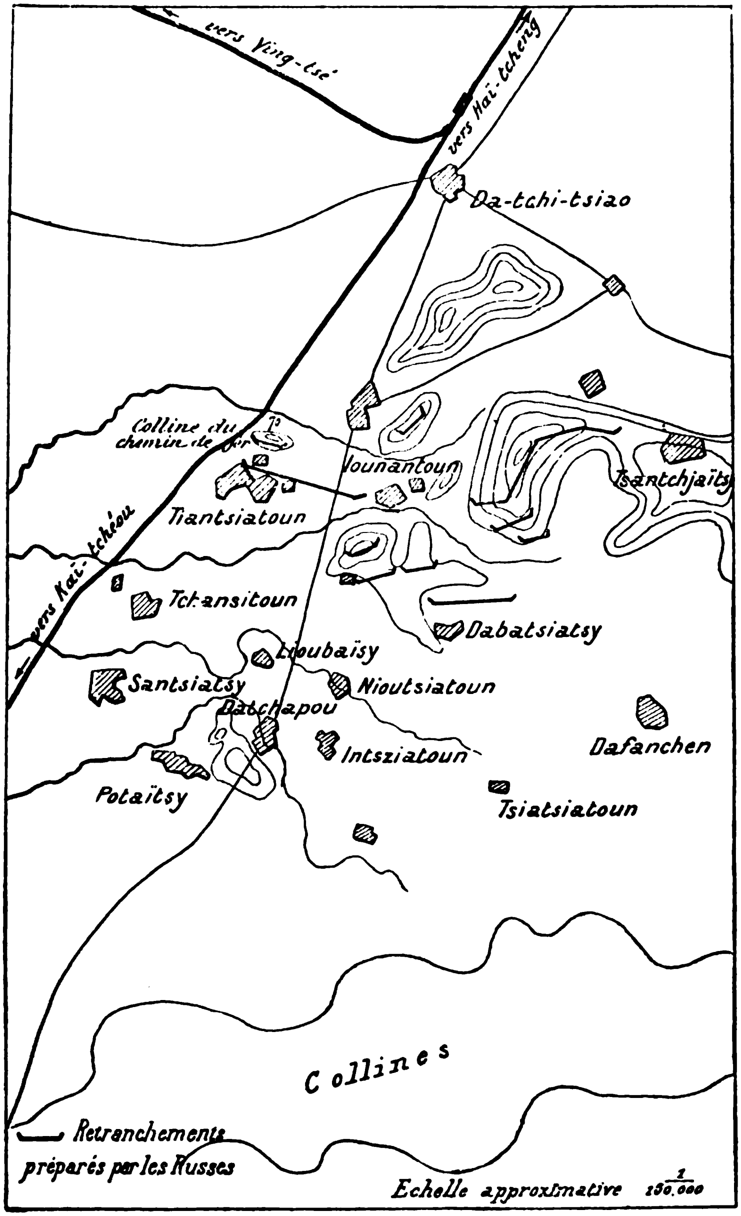
The positions prepared for the artillery comprised:

Four batteries near the village of Tiansiatoun (one of these, that nearest the Railroad Hill, was occupied by a mounted Cossack battery in the evening); four batteries between this village and the heights to the south of Iounantoun; twelve hasty gun-emplacements on those heights; two batteries on the *Artillery Mountain* (position of the 1st artillery brigade of the East Siberian Rifles), and one battery on the slope west of this height. The gun pits as well as all the positions had been prepared even before the battle of Va-fan-goou, but in that action we had lost an entire battery. This lesson could not remain without result. There was certainly some error, some defective practice, against which we had to take proper measures, energetically and without delay. Every one appreciated this, but the cause of this fault had not yet been discovered. General Kholodovskii of the artillery came to us one day and announced that he wanted to choose the artillery positions with the assistance of the brigade commander and battery commanders; he wanted to have our advice and to know our way of looking at things.



The choice of positions by the brigade commander, General Mrozovskii, thereupon assumed a very different character; the positions selected having nothing in common with those that had been prepared in advance. The emplacements were simply staked out but no digging was done, so as to prevent the Chinese from knowing the location of the emplacement occupied by the batteries during the battle. The batteries bivouacked near the emplacements to be constructed.

Two batteries (2d and 3rd) of the 9th artillery brigade (those that were to suffer the most violent fire) were installed behind a hill near the village of Iounantoun, at about 530 meters from the crest and 107 meters from the foot of the slope. Placed at this distance (530 m.) in rear of a height of 26 meters, the batteries could fire against the enemy approaching up to 2300



meters. On the 10/23 of July, upon a Japanese attack against our advance positions to the north of Datchian, our batteries themselves constructed the gun-emplacements at the place of bivouac and during the night of the 10/23 to 11/24 the guns were put in position with intervals of about 30 paces, 21 meters. It is to be noted in this connection that many artillerymen do not approve of intervals between pieces of more than 20 paces (14 m.), the normal interval being 12 paces (8.5 m.) only. But after having measured the Japanese intervals on numerous occasions *with our goniometer*, I was convinced that their normal interval was habitually not less than 30 paces (21 m.), and I concluded therefrom that our adversaries had exactly observed the breadth of the zone covered by our shrapnel. (For the shrapnel, in fact, the smaller axis of the ellipse of dispersion measures about 17 m.).

At break of day on the morning of July 11/24, the Japanese opened fire with their two most distant batteries (as was determined later). The first shots showed that they were directing their fire on the crest where the twelve gun-emplacements had been constructed, 530 meters from which our two batteries were in position. Fire began methodically with percussion projectiles. The first shot fell at the middle of the exterior slope of the hill, but the following shots reached the crest itself which was bordered by the infantry trenches. A third battery placed obliquely with respect to the batteries of our center opened fire at almost the same time. These three batteries were beyond the range of our shrapnel and at the limit of range of our fire. They fired with remarkable precision and were completely *concealed*,—two on the height south of the village of Datchapou, near a tower, and the third on our left flank, that is, opposite the batteries of the 1st artillery brigade of the East Siberian Rifles, near the village of Tsiantsiatoun.

We received orders to fire against these batteries, but less than half an hour later some new batteries of the enemy made their appearance, disposed by groups of two all along the whole front; namely: 2 batteries at the eastern edge of Datchapou; 2 batteries on the heights west of Datchapou; 3 batteries between Santsiatsy and these heights; 1 battery near the village of Tchansitoun; and one battery near the village of Intsziatoun. Counting the batteries already in position, there were, then, 13 batteries directed against the sector occupied by General Mrozovskii, 12 of which were on the right flank of this sector, that is to say fronting the 2nd and 3rd batteries of the 9th artillery brigade. It was difficult to observe the arrival of the Japanese batteries and the manner in which they took up their positions, but it is a fact that in one hour all these batteries had concentrated their fire on our positions and that their very accurate shell fire greatly damaged the infantry trenches constructed on the exterior slope of the hill, towards the enemy.

Credit must be given the engineers of the 1st Siberian Corps: During the first engagements with the Japanese they had accurately observed their fire tactics, and as a result they constructed for the infantry covered trenches very happily adapted to the requirements of the ground. The Japanese lost many projectiles in endeavoring to destroy these trenches, at which, *immediately after each salvo of percussion shell, they fired several salvos of shrapnel.*[*]

The "battle trenches" (*tranchees de combat*), which are occupied only at

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[*] It may be asked if these tactics are not those that have already been employed by the English howitzer batteries in South Africa.

"It will often happen that shrapnel fire alone will not succeed in dislodging the enemy. A few lyddite shells, followed by a "rafale" of shrapnel to put to flight the enemy, whom the lyddite will have driven out, will in all probability produce the maximum effect. It seems that in many situations in modern war, it is a combination of this kind that will be most efficacious."

the moment of fire, were on the exterior slope of the hill (towards the enemy), and those for the "waiting position" (*tranchees d'attente*) were in rear of the crest on the interior slope, and had overhead cover. The former were connected with the latter by defiladed communications provided to a great extent with overhead cover also.

The Japanese were evidently certain that our artillery occupied the 12 gun-pits on the crest for they concentrated on them the most intense artillery fire.* At first they directed a violent fire of percussion explosive shell and of shrapnel on the emplacements themselves, then they completely covered a zone 213 meters farther to the rear, thus coming to within 320 meters of our batteries. Seeing that their fire produced no effect on the intensity of ours, they began to beat all the slope towards our batteries, sweeping their fire to the right end left of the zone originally covered by it. But in this again they followed their usual practice: they did not go beyond a depth of 213 meters and hence did not reach our batteries.

Exasperated by this check, they simply rained explosive shell over the slope towards us. Some of these fell and burst at from 43 to 64 meters in front of our batteries; a few isolated shell fell on one battery even, *but without causing any damage.* The two villages of Iounantoun were destroyed by the accurate and well regulated salvos of the Japanese, who then proceeded to beat the ground *in rear* of our batteries.

Towards 3 o'clock the 4th battery of the 9th artillery brigade came up to take position on the right flank of our position; its movement was seen by the Japanese and with one or two batteries they opened fire on it with shrapnel, but with *much* less intensity than previously. As this battery, upon coming into action, happened to be insufficiently defiladed by the hill, the flash of its pieces was clearly seen by the Japanese from the heights north of Datchapou from the top of a tower where their post of observation was established (beyond the range of our fire).

The Japanese pay particular attention to emplacements occupied by observers and those who direct the artillery fire. It is customary with them to detach some batteries especially charged with firing on groups of officers and particularly on officers directing the fire. Their own artillery officers and observers place themselves in most cases outside of the zone of action of our fire, in rear of their front or on the flank.

As soon as the newly established battery opened fire the Japanese shrapnel began to fall on the height and behind it and we had some men wounded in our two batteries. Fortunately the Japanese had not foreseen the skilful disposition of our batteries and did not yet know their exact location. Moreover, they had installed their pieces at the limit of shrapnel range so that the mean interval of burst was not less than 320 meters with the fuze cut at its extreme limit (18.2 seconds). Due to the intensity and accuracy of our fire they could not move their batteries, of which only seven at the most were at this moment firing at ours. Twice did they endeavor to bring up to the batteries situated at the western edge of the village of Santsiastsy the limbers placed behind a wood near this village and each time they were prevented by the violent fire of our artillery. The horses ran

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* In the present war, which has often developed into battles of position, numerous analogous examples are found. The Japanese, who have an extremely well-organized service of information, have in most cases full knowledge of the masked emplacements occupied or prepared in advance by the Russians. This enables them to fire against them without delay, but it often happens that they fire in this way on positions that have been evacuated by the enemy.

away with their limbers and disappeared behind cover far in rear. The two Japanese batteries were soon unable to do anything and one would have said *they had been annihilated.*

The other Japanese batteries did not attempt to advance. Towards 5 p.m. the Japanese succeeded, however, in advancing one of their batteries and in establishing it near the village of Tchansitoun on the flank of our group and at a distance of about 4 versts (4200 meters). But at this moment a Cossack horse battery occupied the gun emplacements near Railroad Hill, west of Tiantsiatoun, and drew upon itself the fire of the Japanese battery. Being very well masked by the village our guns were invulnerable and the enemy could not regulate their fire upon them, while they caused serious losses in the Japanese battery. This attempt of the Japanese resulted, then, only in giving them a new and complete check.

About 8 p.m. by availing themselves of the cover offered by the village of Datchapou and the neighboring heights, the Japanese succeeded again in advancing one of their batteries which took up a position at the edge of the village of Lioubaisy. But it could not fire very long for we knew perfectly the range and azimuth of this village as well as similar data for all the villages lying in our zone of fire. Hence the first rounds of shrapnel fired by us rendered the fire of the hostile battery irregular and inaccurate, and upon some combustible matter in the village catching fire, the battery ceased firing. At about 9 p.m. firing ceased all along our front and all remained quiet.

After these fifteen hours of cannonade the 1st Siberian Corps had lost a total of hardly fifty men. Such are the results that can be obtained *by a proper use of the properties of our rapid-fire gun,* by discarding routine and old ideas in order to make the most of the powerful action of our artillery. It is well to add that a Japanese chief of detachment in his official report estimates at 100 the Russian guns opposed to him near Da-tchi-tsiao at the village of Tiantsiatoun.

At Da-tchi-tsiao for the first time our artillery was employed according to a new method. The whole of it was not used at once on the defensive position; only a part was designated for the distant combat, *the reconnaissance duel,* so to speak. It is true that in the case of artillery numerically weak, half the effective strength must be devoted to this purpose. The Japanese, indeed, have recourse to this method to a very much greater extent; first of all they put into action, as in this battle, two or three batteries, at most, out of thirteen; establish them, completely masked, beyond the range of our shrapnel; and then with their percussion projectiles and explosive shell, the range of which is not inferior to ours, they force us always *to reveal our emplacements.* We were obliged to do this, principally on account of the lack of instruments for measuring the range of the batteries; moreover the estimation of distances in mountainous country is greatly a matter of chance for persons not accustomed thereto. Since the adoption of the excellent Aubrey telemeter in many of our batteries, this ruse of the Japanese has lost its efficacy and our batteries, being able to determine rapidly the range of the enemy's artillery, no longer respond to the fire of batteries at such a distance. Each time we fell in this trap the Japanese, under cover of the noise, advanced the main mass of their batteries, habitually orienting it with great exactness, and then concentrating to perfection the fire of their units distributed over a broad front, consequently little vulnerable, they inflicted all at once serious losses on our batteries *disposed according to the principles of the old artillery*, which did not possess the improved means of laying, enabling the guns to fire from completely masked positions. Accustomed to making use of lateral observers in their firing and aided by the Chinese spies, the Japanese had not much difficulty in successfully overcoming the fire of our artillery. As soon as this result was accomplished, they made a rush forward of 213 meters and with their explosive shell stretched a curtain, as it were, between our batteries and their first supply echelons. They endeavored to reach our caissons and limbers and their infantry executed an energetic attack. As in the majority of cases we had concentrated our artillery for facilitating the command and control of it, they succeeded all the more readily in their purpose. It sufficed, then, to have a battery lose its personnel to make it impossible to withdraw the guns from their position. (It was only in similar cases that guns had been abandoned).

The picture changes completely when, by paying no attention to the *reconnaissance batteries* of the enemy, and having prepared in advance by the aid of the map all data of the firing (azimuth, elevation, fuze, etc.) which is to be executed in completely masked emplacements, our batteries patiently watch the ground in front of the enemy's position and seize the moment when his batteries come up to take their position for battle. The Japanese as a general rule open fire *very slowly*, in other words, the preparation of the pieces for the first shot is evidently deliberate. This gives us still another opportunity during the preparatory period of the battle. Again, our silence during the fire of their reconnaissance batteries disconcerts them, so much do they *seek to prepare their fire in advance of the action.*

There remains to be mentioned an original means which the Japanese made use of to supply their batteries with ammunition. In many cases at Da-tchi-tsiao the Japanese or rather the Chinese brought up the projectiles and cases by hand from neighboring sheltered places, and very often the supply was assured by chains of men passing the ammunition by hand from the masked positions where the caissons and limbers were, up to the firing battery.—*Revue d'Artillerie.*

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OPERATIONS OF THE ARTILLERY AND ENGINEERS AT THE SIEGE OF PORT ARTHUR

After the military operations preceding the investment of Port Arthur (beginning August, 1904), and the successive victories of the Japanese in driving the Russians back to their permanent positions, the Japanese, encouraged by the uninterrupted success of their frontal attacks in capturing these advanced positions, tried at first to storm the main defenses in like manner. But after seven days of continuous fighting, night and day, which cost them 25,000 men, they gave up the attempt and settled down to a regular siege of the place by successive stages and according to the classic method (September 1). The rapid success of the besiegers from that time on is to be attributed to the manner in which they used to the greatest advantage the most recent inventions and improvements in engineering science. This is especially true during the second period, that is to say, from the time when they found themselves arrested by the first line of the principal defense, or about 2.5 km. from the city. Up to that time the siege operations had been conducted with field guns, the ordinary siege material and some naval pieces, in all about 300 guns.

The permanent batteries of the forts of the principal exterior line of defense were so disposed that in case of capture of one of them by the enemy, the fire of the neighboring forts could be concentrated on it and thus render the position untenable; and, indeed, it often happened that the Japanes seized positions from which they were driven in this way. Moreover, the very steep exterior slopes of the hills on which the forts were built formed perfect and natural glacis, broad, smooth, and free from cover, rendering an assault by infantry practically impossible. These forts were captured, however, by sapping and mining, and it was not necessary to take the inner line of the principal defense.

A first parallel was constructed at a distance of about 1000 yards, from which, in front of each fort, ran a series of parallels and approaches defiladed and provided with overhead cover, usually of planks covered with soil and grass. These approaches ended in a second large parallel completely defiladed and situated close to the foot of the slopes. From this parallel tunnels were cut straight through the hills until they were immediately below the exterior walls of the forts which were then mined. All this work, executed during the night, was for the most part completely unknown to the Russians up to the last moment, though in some cases the trenches were located and night sorties were made in the endeavor to break up the work. While it was being completed, arrangements were made for installing and utilizing the 28-cm. coast mortars which were brought over from the coast defenses of Japan along the straits of Shimoneski and about the Bay of Yezo.

These mortars, 18 in number, each weighing more than 8 tons were brought from Dalny by railroad to within a few hundred meters of the emplacements where they were to be used. They were mounted on coast carriages (weighing 10 tons) resting on a circular concrete platform, 2.4 meters deep and 5.4 meters in diameter, and were distributed in batteries of 2 or 4 pieces. The construction of these batteries, the mounting of the guns and carriages, and the preparation and organization of the fire, were accomplished principally at night, in rainy weather and under the continuous fire of the enemy.

Though designed for a maximum range of 12 km., as the most distant objectives were not more than 3 km. away, these mortars were fired at high angles of elevation, about 60° as a rule; they did not begin firing until towards the time when all the work of sapping and mining was nearly finished. The batteries were masked by the natural features of the ground, and made use of indirect fire exclusively. The positions of the fixed targets were known perfectly by the Japanese, who had taken care, during the occupation of Port Arthur after their war with China, to have made a complete detailed map of the Liao-Toung peninsula; their information bureau had after this given them exact information in regard to all new works completed or in course of construction.

As the information they had was absolutely useless for regulating their fire on the Russian ships, which changed their moorings constantly, it was most necessary for them to secure a post of observation, so that they could observe their fire against such moving targets. Hence the terrific struggle for the possession of 203-Meter Hill which commanded a view of the whole region. From the top of this hill, observers telephoned to the batteries the effect of their fire, whether over or short, etc., thus enabling them to correct it.

The projectiles fired by these mortars are percussion shell, 4 calibers long, weighing 228 kg. (500 lbs). They are loaded with high explosive of a picric acid base, corresponding in bursting effect to lyddite or melinite, and have a detonating fuze with more or less delay-action. During the last bombardments, which continued each time for about four hours, each of these 18 mortars fired a shot every eight minutes.

The sustained and irresistible fire of these pieces, the firing of the mines under the forts to break down their walls and make a breach, and the fierce assaults of the infantry well protected up to the last moment and rushing from the advanced parallel to penetrate the breach when the forts no longer responded to the besiegers' fire, decided the fate of the place.

The siege lasted 327 days, from the 9th of February to the 1st of the following January, and may be divided in the following manner:

Attacks solely from the sea, February 9 to May 4, 86 days;

Battles on positions at a great distance from the city, May 5 to July 30, 86 days;

Battles in the immediate vicinity of the place and on positions within range of the artillery of the main line of defense, July 31 to September 23, 55 days;

Battle on the main line of defense and in rear of this, from September 24 to January 1, 100 days.

Of these 327 days of siege, the defense of the land front lasted 241 days, which may be similarly divided as follows:

Disembarkment and establishment of the siege corps, May 6 to July 20, 76 days;

Execution of the definite investment within short distance from the city, July 21 to August 16, 27 days;

Attempts at storming and attacks by assault, which failed, July 17 to 24, 8 days;

Regular siege, July 25 to January 1, 130 days;

The bombardment with pieces of large caliber continued, with the exception of short interruptions, from August 6 to the end of the siege, 149 days.

The length of the siege was remarkable but yet more astonishing was the complete failure of the attack by assault, a repulse that reduced the Japanese to undertaking a regular siege. The long duration of the resistance offered was due in a great measure to the care taken by the defenders to carry on the struggle at a distance from the city itself, but it must not be forgotten that the defense made good use of certain factors that may rarely be met with in other places: time, number of workmen, nature of the ground and qualities of the garrison. It may, above all, be attributed to the lack of results obtained by the artillery of the besiegers. Everyone seems to be in accord on this point without, however, being able to say whether this was because the efficiency of the siege guns was less than that which theory promised or because the attack by the artillery was of indifferent value, or finally whether these two factors combined may not explain this want of success.

This last hypothesis may, perhaps, be the correct one. In fact, from October the Japanese had before the place eighteen 28-cm. mortars and many 21-cm. and 15-cm. curved fire pieces, siege guns of 15, 12 and 11 cm. caliber and at least 128 field guns, all modern pieces firing explosive shell. From all information at hand, these guns fired with accuracy. The artillery of the attack gained the superiority and silenced that of the defense but not decisively. It concentrated its fire for whole days on works against which the attack was being prepared without this preparation being efficiently completed. It seems that the Japanese did not mass sufficiently the effect of their artillery; they had not in the beginning of the siege a sufficiently large number of heavy guns or curved fire pieces; and before the capture of 203-Metre Hill, observation of the points of fall was inadequate.

The course of events in this siege shows the necessity of having a large number of curved fire pieces in siege artillery parks and that the regular close attack is possible. It should, therefore, be prepared from a technical point of view as well as from that of materiel.

The events of the siege of Port Arthur also enable us to gain some idea of the defensive value of improvised fortifications. In fact the principal line of defense of the west front consisted only of field works or at the most of those of a semi-permanent type advanced to the exterior crest of the heights. On the other fronts the advanced and intermediate works were also of this nature. They nevertheless offered surprising resistance every time when, as on the west front, they were not subjected to regular bombardment, or when, as on the north-east front, there were permanent works in rear of them. On the other hand, they could all be taken by assault, while the permanent works could only be carried by the laborious, regular methods of sapping and mining. The position of Nanshan on the isthmus of Kinchow, although comprising two important field works could be held only 24 hours. It would have been better to have had permanent barrier forts in their place. But the works thus constructed after the declaration of war disagreeably surprised the enemy, who did not expect to encounter them.

The coast fortifications were adequate to their their task and fulfilled their functions well. They sufficed to keep the victorious Japanese fleet far from the coast and enabled the Russian fleet to leave and enter the port with impunity every time it so desired. These works on account of their altitude had nothing to fear from the Japanese fleet.

The following particulars may be mentioned:

Smokeless powder, as was to be expected, was all to the advantage of the defense. Machine guns were largely used by both sides and rendered excellent service. The artillery of the attack continued to fire on the works attacked up to the very last moment during the assault, even to the time when the assailants had already descended into the ditch. Defensive mines and accessory means of defense played an important role and were most useful to the besieged. Searchlights, rockets and bombs were used to light up the ground in front of the works, and rendered such service to the defense that they may be regarded as indispensable for repulsing night attacks.

As regards the combat at short range various means were employed, some old, which have been thought antiquated and hence would be no longer used, and others very original and ingenious, all of which were of marked value. Among others were the use: of hand grenades charged with high explosive, or charges of explosive thrown by hand, and fuzed charges thrown from improvised catapults; of iron shields for protecting the soldiers in the trenches, in addition to sand-bags; of small metal mortars for throwing charges of explosives a short distance; of ships' torpedoes for destroying the trenches of the attack; of land mines and mining operations both by the defense and the attack. Finally, it is impossible not to be struck by the leading role played by the bayonet in the attack and defense of fortified positions. The defenders seem to have made great use of it in the course of numerous counter-attacks which were often crowned with success.

—*Le Genie Civil, Kriegstechnische Zeitschrift.*

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ARMORED CRUISERS

In these last years the armored cruiser has developed into a fighting unit representing the most perfect compromise between warships of powerful armament and invulnerable protection and cruising ships, as they were originally intended to be. The question has actually been put: "Battleships or armored cruisers?" and some nations who could not afford to answer, "both," have decided in favor of the latter. The present Minister of Foreign Affairs in France strongly advocated some years ago the "unification of armored ships," and the standard type, proposed to answer all the requirements of naval warfare, was the battleship-cruiser—a sort of jack-of-all-trades war vessel carrying formidable guns, well protected, and running at 25 knots! The long-cherished dream of the *nouvelle école*, the "swift greyhound of the sea," is not far from realization in France. Mr. Charles Bos, in his report on the Navy Budget for 1905, formulates a naval program, the *clou* of which is the construction of nine battleship-cruisers, with a speed of 24 knots, and it is said that this program has been inspired by naval authorities of great competence, such as Admirals Fournier, Campion, and the Chief of Naval Constructions, M. Bertin. Whatever may be the standpoint of every particular country, it is admitted by all that any nation aspiring to the commercial or military supremacy of the sea, beyond the boundaries of the fatherland, can only obtain or maintain it with the aid of speedy warships—in other words, by means of armored cruisers. It is, no doubt, acting upon this theory that the British Admiralty has conceived the most radical reform in the organization of the fleet—the constitution of seven cruiser-squadrons attached to the Channel, Atlantic and Mediterranean fleets, or stationed in the Far East, Australia and India—the indispensable force to secure the command of the seas. At the end of this year England will dispose of twenty-six up-to-date armored cruisers of the Drake, Cressy, Monmouth, and Devonshire classes, not to speak of others of less importance, nor of those of doubtful fighting value forming the Particular Service Squadron. The Navy Department of the United States of America is also following, on a small scale, the policy of Great Britain. It has now created an Atlantic Squadron or station of armored cruisers, which will comprehend, at the time of their completion, the Colorado, West Virginia and Maryland. The new current of ideas is, therefore, decidedly in favor of this craft, and it may be worth while examining the progress of construction in this direction.

What confers now to the subject of armored cruisers a special interest is that, after a period of abstract speculations, the ideas and tendencies of two "schools" are being actually carried into practice. The Vittorio Emanuele and the Edgard Quinet are the results of the efforts made to create an intermediate type, a hybrid between the battleship and the armored cruiser; and as these results are remarkable for the great disparity which characterizes them, some information on the Quinet may prove instructive, especially as she possesses at least as many peculiar features to recommend her to public discussion as the Italian ship, on which so much has been said and written.

The keel of the Edgard Quinet was laid at Brest at the end of September, 1904. The original plans of this vessel have been repeatedly modified during this last year, and even at the present moment are not settled in all their particulars, owing most probably to the lessons taught by the Russo-Japanese war. The reports on the naval combats in the Far East are apt to be modified by later official publications, but such as they are, even if not completely reliable, they must be given attention by naval designers. If the British Admiralty has suspended the construction of the 18,000-ton battleships, no doubt owing to the importance torpedoes and mines have had in this war, it is most natural that French authorities should be so much influenced, as they have been, by the effects of gun fire at the battle of Chemulpo, and hence have modified many of the original features of the Quinet. The Edgard Quinet, as far as protection is concerned, was going to be an improved Gambetta or Renan; but side armor has been reduced to 6-inch, and the weight thus economized—300 tons—has been dedicated to an increase of the coal supply. The cases of the Gromoboi and the Novik are surely responsible for this decision. The former, belted with 6-inch armor and with 6-inch armor to protect her casemates, is reported to have scarcely suffered any damage, though most violently attacked by gun fire. The Novik, which had luckily escaped the Japanese scouts and taken refuge in a Chinese port, when compelled to leave it was sacrificed by her commander owing to her insufficient coal supply. The amount of ammunition provided for the Quinet marks a decided improvement on all other existing ships of her class; it has been much increased since the vessel was first projected.

With the rate of fire of modern guns, battleships engaged in a regular battle will run short of ammunition in a couple of hours. This is not a difficult prediction to make, but facts that confirm it are very likely to recall the attention of naval designers to this truth. The splendid performance of the Askold in regard to gun fire* may be gratifying to the artillerist, but constitutes a new source of preoccupation for the constructor. What will be the use of the wonderful instruments of destruction carried by warships, when these will have no more shells to fire? It is true that the enemy by this time is most likely to be in the same condition, but if a superiority is desired for gun fire it must be supported by a corresponding amount of ammunition. What is usually the case, especially in cruising ships, is that the strength of the armament is not in proportion with the ammunition supply. According to *Le Yacht*, it is the example of Kamimura's fleet of cruisers, which had to abandon the chase of the Russian ships in flight for want of ammunition, that has induced the French Minister of Marine to order a better ammunition supply for the Quinet.

The following comparative table is given to put in evidence the principal characteristics of the most important types of armored cruisers:

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* Before steaming for Shanghai on the 10th of August she took a very active part in the battle, and was able to fire 200 6-inch and 300 3-inch shells on that memorable day.

Principal characteristics	Edgard Quinet.	Duke of Edinburgh and class.	Washington and class.	Gromoboi.	Roon and class.
Nationality	French	British	U.S. of America	Russian	German
Displacement	14,000 tons	13,500 tons	14,500 tons	13,400 tons	9370 tons
Length at the waterline	528.2 feet	480 feet	502 feet	473 feet	404 feet
Speed	24 knots	22 knots	22 knots	20 knots	21 knots
I.H.P.	40,000	23,500	25,000	18,000	19,000
Machinery	Three sets	Two sets	Two sets	Three sets	Three sets
Boilers	Not yet decided	6 cylindrical 20 Babcock & Wilcox	16 Babcock & Wilcox	30 Belleville	16 Dürr
Coal { Normal	1500 tons	1000 tons	900 tons	800 tons	850 tons (?)
Coal { Bunker capacity	2400 tons	?	2000 tons	2500 tons	1600 tons + 200 oil

The principal data of the Quinet show that she almost realizes the ideal of a battleship according to the new school, in theory at least, because trial trips will say the last word on the choice of her great speed. Whenever high speeds seem necessary to secure tactical qualities, upon which special weight is laid, designers do not hesitate to over-power a ship, though they all admit that the practice is most uneconomical, and means a burden on the vessel throughout its life, in the best of cases, and is nearly always the cause of unpleasant experiences. The Jeanne d'Arc is an instance which the builders of swift cruisers ought to bear well in mind; her three engines and forty-eight boilers occupy nearly all the space available on the ship; the magazines, ammunition hoist, the auxiliary machinery, and the space reserved for crew and officers are all unfavorably influenced by the arrangement of the propelling machinery, estimated to develop 28,500 horse-power, and run the ship at 23 knots. It is well known that her trials were very troublesome, and some figures taken from official communications are likely to prove of interest. At her estimated power her mean speed was little above 21 knots; the ship was docked, painted afresh, the bilge-keels removed and the trials repeated. This time the combined efforts to raise to the *maximum maximorum* the power of her engines succeeded in obtaining more than 30,000 indicated horse-power, and the corresponding speed was again little above 21 knots. New trials took place on October the 21st, 1904, in the waters of Douarnenez, when with new screws and under uncommonly favorable conditions, she finally attained a speed of 21.8 knots, 1.2 knots less than the projected speed. No doubt every tenth of a knot above the 21, which was easily obtained, cost a disproportionate increase of power, and this proves that such a vessel, of 11,300 tons displacement, having 477 × 63⅔ × 26½ as principal dimensions, would have been a more efficient fighting unit with 21 knots speed, 24,000 indicated horse-power, and a stronger armament than that which it now has – two 7.6-inch in single turrets, and fourteen 5.5-inch guns as primary and secondary armament. A couple of knots above the average of speed reached by ships of the same class are not likely to confer on an armored ship such a decided superiority as the *nouvelle école* anticipates: it will always enable this cruiser to avoid a battle with rivals of the same size; but though this practice of refusing a combat may be under circumstances the right one to recur to, it must not be assumed as a canon of the art of naval construction. The most striking features of the Quinet are the speed and the horse-power projected to propel her at 24 knots. At first sight the figure 40,000 is more suggestive of a misprint than of the actual amount of horse-power estimated, but it is nevertheless a fact that the Quinet's engines will be projected to develop this, the highest power ever estimated for a war vessel. Comparing the Quinet to another armored cruiser, say the Duke of Edinburgh, a parallel between the two vessels is more than anything else likely to convey an idea of their relative military value. The boilers of the Quinet have not yet been decided upon, but will probably be of the Belleville type; the weight of machinery will be 3600 tons, and the corresponding weight in the Duke of Edinburgh is 2250 tons, the difference being 1350 tons, to carry which an increase of displacement of about 350 tons may be roughly assumed for increased weight of hull, equipment, personnel, etc. On the basis of this comparison it may be said that the tactical superiority of the Quinet over the Duke of Edinburgh—2 knots more in speed—costs her approximately 1700 tons. A comparison of the offensive qualities of both ships may be made on the basis of their armaments, as given below:

	Edgard Quinet.	Duke of Edinburgh.
Primary armament	Two 9.4-inch (540 mm.) in single turrets	Six 9.2-inch, 50 calibers, in single turrets
Secondary armament	Sixteen 6.4-inch (164 mm.) in double turrets and casemates	Ten 6-inch in casemates[*]
Tertiary armament	Eight 2.2-inch (65 mm.) Sixteen 3-pounders (47 mm.) Two 1-pounders (37 mm.)	Twenty 3-pounders Eight pom-poms (1-pdrs.)

As far as armor is concerned, both ships are equally well protected at the waterline—6-inch plates amidships. In the Duke of Edinburgh the side armor extends to the upper deck, forming a central redoubt between the battery deck and the main deck[†]; in the Quinet no side armor is carried above the berth deck. Of course, the Quinet is decidedly inferior to the Duke of Edinburgh in heavy gun fire and protection; it is clear that she is principally intended to fight minor cruising ships or auxiliary cruisers; to overtake them and annihilate them, and to destroy the enemy's commerce; she is further intended to protect colonies, and no doubt she has all the elements to answer these requirements; but it is irrational to think that a fleet of such fighting ships, backed by torpedo boats and submarines, could be successfully opposed to a fleet of battleships, cruisers, and torpedo craft. Are the enormous sacrifices made to speed, in vessels of big size, therefore justified?

The great length of this vessel will certainly please the naval designers, who see in the Edgard Quinet an "ideal" ship as far as her geomerty is concerned. The great length is sure to make of armored cruisers the favorite

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[*] Subject to alteration; it is intended to increase the caliber.

[†] The Duke of Edinburgh, the Black Prince, and the projected ships of this class, mark a great improvement on the Drake, Cressy and Devonshire classes, on account of their better distributed side armor; they are the first cruising ships of British design with complete belts.

target for destroyers and submarines, in sea fights in the future, not only on account of the size of the target, but also because of the incapability of rapidly altering the course of such long vessels. Their evolutions in maneuvers have already proved how difficult it is to steer them; those who will have to attack a fleet of armored cruisers in a line formation will find it a golden opportunity to show the efficiency of torpedo craft. The figures given below, which show the area of the immersed longitudinal plane of some typical armored cruisers, may be assumed as a measure of the probability with which they are likely to be hit by torpedoes; for the sake of simplicity it is assumed that they show the enemy their full broadside.

Ship.	Area of immersed longitudinal plane. Square feet.
Edgard Quinet	13,500
Duke of Edinburgh	12,500
Washington	12,650
Gromoboi	13,250
Roon	9,300
Vittorio Emanuele	10,500

The Vittorio Emanuele, which is also a compromise between the battleship and cruiser, may be well called an armored cruiser according to the meaning usually attributed to this denomination. All armored ships, even the Garibaldi class, are officially classified as *navi da battaglia* in Italy, and fighting ships is a more appropriate translation of these words than battleship. The ships of the Vittorio Emanuele class are a remarkable instance of the ingenious utilization which can be made of intermediate displacement; their 12-inch guns will reach and pierce the Quinet's side armor within any practical range, and their 10-inch belt will defy perforation from the Quinet's heavy guns. The Vittorio Emanuele type has a place in countries which, like Italy, have limited colonial interests but a wide-spread coast to protect; the Edgard Quinet has still to prove that she embodies the best investment a nation can make of the money devoted to the safety of the country and the preparation of war. The former is a recognized success, the latter an experiment, and an experiment to be closely followed by those whose take an interest in naval problems.

—*The Engineer.*

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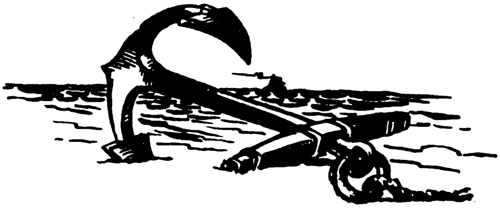
THE NEW JAPANESE BATTLESHIP KASHIMA.

Sir W. G. Armstrong, Whitworth, and Co. launched from their Elswick works on March 22 the third battleship and the tenth war vessel built there for the Imperial Japanese Navy. This latest vessel is named the Kashima, and is one of two ordered at the beginning of last year by the Japanese Government; the other is being built by Messrs. Vickers Sons and Maxim, Limited, at the Naval Construction Works, Barrow-in-Furness. The Kashima is the most powerfully-armed vessel yet constructed in this country. She has four 12-inch guns, twin-mounted in barbettes, the upper part being of 9-inch plating, and the lower part, where protection is augmented by the ordinary citadel armor, of 5-inch armor. These 12-inch guns, which have hydraulically-operated mountings, are 46.7 calibres long, and weigh 59 tons. Firing 850-pound projectiles with modified cordite explosive compound, it is anticipated that the penetrating power developed will be such as to cope at 3000 yards range with any armor yet fitted to a battleship, and that the rapidity of fire will exceed two rounds per minute from each gun. There are also four 10-inch 34-ton guns of 46.76 calibres, placed singly in barbettes, built up of 6-inch plates, located at the four corners of the citadel. There are twelve 6-inch 8½-ton guns of 47 calibres. Five are mounted on each broadside inside the 6-inch citadel armor, and are separated from each other by 2-inch screen armor. The two remaining 6-inch guns are on the upper deck within 4-inch screen armor. There are also twelve 12-pounder guns, three 3-pounder guns, and 6 Maxim guns. In the design of the arrangements for serving the guns, the lessons of the recent war have been utilised. There are five submerged torpedo-tubes, firing 18-inch Whitehead torpedoes; two are forward and two aft, firing on the broadside, with one firing right astern.

As regards the disposition of armor, the principle adopted is generally similar to that in the Mikasa, the most recently completed vessel for the Japanese Navy. The water-line belt is 9 inches in thickness for more than half the length of the ship, tapering to about 4 inches at the ram. This belt extends 5 feet below the water-line, and 2 feet 6 inches above it. Surmounting it is a belt of armor, extending from the aft 12-inch barbette to the stem, and 6 inches in thickness. Immediately above this is the 6-inch citadel armor reaching to the upper deck, and enclosing also the two 12-inch barbettes. It is within this that the 6-inch guns are placed, while above this, again, is 4-inch screen armor for the two upper-deck 6-inch guns. The conning-tower is of 9-inch armor, and there is an additional observation tower of 5-inch armor, while two more officers' shelters of 3-inch armor are provided on the boat deck amidships. In this way the fighting officers of the ship will have very advantageous positions, protected against the fire of the enemy's small guns. The protected deck is 2 inches on the flat portions amidships, and 3 inches on the sloping sides, where it joins the bottom of the main armor, 5 feet below the load-line. At the extremities where the side armor is reduced in thickness, this deck is made 2½ inches thick over all. Further protection is given to the upper structure of the ship by thick protective plating on the top of the screen armor at the level of the boat deck. The length of the Kashima is 455 feet; the breadth, 78 feet 2 inches; and the moulded depth, 43 feet 6 inches. With a normal draught of 26 feet 7½ inches the displacement will be 16,400 tons; the coal supply then will be 750 tons, but capacity is provided for 2150 tons. Triple-expansion machinery, and twenty Niclausse boilers, are being constructed by Messrs. Humphrys, Tennant, and Co., London; the designed power is 16,500 horse-power, which, it is anticipated, will give the vessel a speed of 18½ knots. —*Engineering.*



BOOK REVIEWS

Strategy Illustrated by British Campaigns. By Captain C. E. K. Macquoid, D. S. O., XXth Deccan Horse, Inspecting Officer Hyderabad and Mysore Imperial Service Troops. With Introduction by Field Marshal Earl Roberts, K.P., V.C. 20+252 p. 12 maps 7 plates. O. New York: Cassell and Company, Limited. 1904. $3.50 net.

An entirely new work on strategy, new not only in subject-matter but also in mode of treatment, is a pleasure to notice. The present work is original in both these respects, and constitutes a most valuable addition to the literature of the subject.

The author's purpose in writing this volume is set forth in the following statement:

"It is desirable that the British army should study the principles of strategy as applied to the conduct of British military operations. The peculiar feature, therefore, of this book is that all the examples are taken from the history of the British army, and the author trusts that it may prove acceptable, not only to officers of the regular and auxiliary forces, but to all patriotic members of an Empire whose glory and whose true greatness are already far 'beyond all Greek, all Roman fame.'

"When the British officer is fully acquainted with the strategy of campaigns undertaken by the British nation, let him then, if he will, turn his attention to those of Alexander, Hannibal and Frederick; to those of the great Napoleon, and especially to those of the Civil War in America."

The great principles of strategy are clearly set forth and discussed. They are illustrated by means of a great number of diagrams, which present graphic pictures, and are far more effective than any mere description can possibly be. There are several plates of such diagrams, in colors, and these constitute a unique feature of this work, adding greatly to its clearness and its general value.

The work is divided into two parts:

Part I. discusses the *Principles of Strategic Maneuver*, each principle being fully illustrated by several campaigns, some successful, others unsuccessful, the reason for each being made clear. This section of the work is illustrated by five campaigns of the Peninsular war, nine campaigns in India, and by campaigns in the Afghanistan, Egyptian and South African wars, as well as by Marborough's Blenheim campaign.

Part II. relates to the *Influences which affect the Principles of Strategic Maneuver*, such as strategic obstacles, rivers and mountains, fortifications, deserts and forests, climate, bases, configuration of frontiers, preparation for war, political considerations, steam and telegraph, and the command of the sea.

These are again elucidated by means of diagrams, and illustrated by campaigns, mainly Peninsular, and Egyptian.

Twelve excellent maps are provided for the study of the campaigns cited.

To illustrate the author's style and the general character of his remarks we make a few quotations:

After discussing the influence of steam and the telegraph the author concludes in the following words:

"The necessity of a proper study of the military geography of any theatre of war has already been insisted upon; it is unnecessary here to emphasize its importance, except to say that a geographical study of any given country should not be limited to its physical features only, but should include the whole of its resources, and, above all, its system of railways, and their carrying capacity, as well as its telegraph system."

And again, under Command of the Sea, he says:

"It is obvious that England being an island, her wars must be wars beyond the seas. Hence the safety and security of the sea lines of communications are an absolute essential to success. * * * But the influence on land strategy exerted by command of the sea is not limited to protection of the sea lines of communications of any army. It is closely connected also with all considerations concerning the selection of a base line and the choice of a base point in that line, when the base of the theatre of operations happens to be the sea coast. Moreover, command of the sea, when the coast is a base line of operations, permits as much or as little of that base being used as may be needed, and it further affords all the advantages which may be derived from any particular configuration of the sea coast. All these advantages permit of strategic movements being undertaken, which would otherwise be impossible. * * *

"When Great Britain has not had command of the sea, or when that command has been insecure and uncertain, the consequences have always been fatal.

"If our campaigns in two such widely separated spheres of interest as India and North America be studied and compared, it will be seen how command of the sea, maintained as regards the lines of communications with India, enabled us to maintain the footing there gained, and indirectly led us to far greater conquests in that Peninsula; as regards America, command of the sea, always insecure and eventually altogether lost, directly led to the abandonment of the war in that continent."

The work as a study in strategy is as valuable to our army as to the British, and since it is written particularly for the regimental officer, it will be more especially useful to the great majority of our officers. To them we heartily recommend it as a simple exposition of the great principles of strategy and an interesting manual of reference in the study of the art of war.

The publishers have done their part well: the book is a handsome volume, printed in clear type on excellent paper, substantially bound in red cloth, with excellent maps and diagrams printed in colors.

It is altogether a military work of a very superior character, and will serve not only as a manual for the younger officer, but can also be used as a text-book in military schools and at garrisons, a purpose for which its general systematic arrangement particularly fits it.

Die Festung in den Kriegen Napoleons und der Neuzeit. Herausgegeben vom Grossen Generalstabe. Studien zur Kriegsgeschichte und Taktik, IV. Berlin: E. S. Mittler und Sohn. 1905. With atlas. $2.50.

The series of studies in tactics and military history, of which this work constitutes Part IV. is one of the most important contributions to the subject of tactics which has been made in recent times.

The great significance of fortified places in war has been emphasized by the late events at Port Arthur, and will not be forgotten very soon. The lessons of this great siege have been brought home to all the world, and are still fresh in the minds of the public as well as of the tacticians and military historians. This particular volume of studies by the General Staff of the German army appears, therefore, at an opportune moment, and will commend itself to all military students.

This work, however, is not devoted so much to the attack and defense of fortifications, as to the strategic significance of fortified place in military operations. Their importance and bearing on the operations are illustrated by a series of historical examples, beginning with Mantua (1796) and comprising the fortifications in Napoleon's campaigns, the Italian fortifications in 1848 and 1866, the Bulgarian forts in 1828, 1853 and 1877, Sevastopol, Vicksburg and Richmond, Kars (1877), Metz, Paris and the French Provinces (1870-71). All the campaigns between 1796 and 1877, in which fortified places played an important part, are here considered and intelligently described.

Fortified places have attained a greater importance in recent times than ever before, a fact which has been recognized by all branches of the army. It is for this reason that the German General Staff has devoted this special volume to the subject. The attack and defense of fortifications is but one of the many phases of modern war, nevertheless a correct understanding of the technical means necessary for the execution of such operations is essential for success, and above all a true conception of the strategical and tactical significance of fortifications (a conception which is never to be found in their mere occupation), lies at the foundation of the art of war as applied to them.

At the close of the work the lessons to be learned are summed up in a masterly way, and the subjects of fortified passes and the fortifications of lines of communication are briefly considered.

The subject is treated in a comprehensive and thorough manner, and is presented in an interesting form. The language is clear and strong, the important and unimportant are carefully distinguished, the essential points are properly emphasized, and the lessons to be learned are presented in impressive words.

The importance of fortifications in the campaigns of the past two centuries or more, has undergone many changes. The degree of resistance which they opposed to the means of attack had a great influence, of course, on their value at different times. The developments in mechanical appliances are continual, and aid now the attack and again the defense, causing a never-ceasing contest between the two.

Nevertheless, if we consider the subject in the widest sense, it is evident that, as in field operations, the attack has the advantage over the defense. In the history of wars we find few if any examples of the attack of fortifications really up to date at the time of the attack: like warships, fortifications are also obsolete (in a sense) by the time they are completed. The main difficulty in the attack to-day, however, is not so much in surmounting the obstacles presented, as in overcoming the fire action of the guns installed.

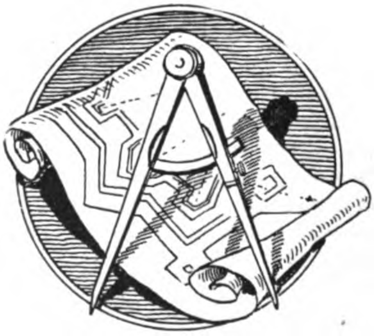
But technical improvements and varying powers of resistance are not the only elements influencing the value of fortifications: the energy and spirit of the strategy of the leader is a decisive factor.

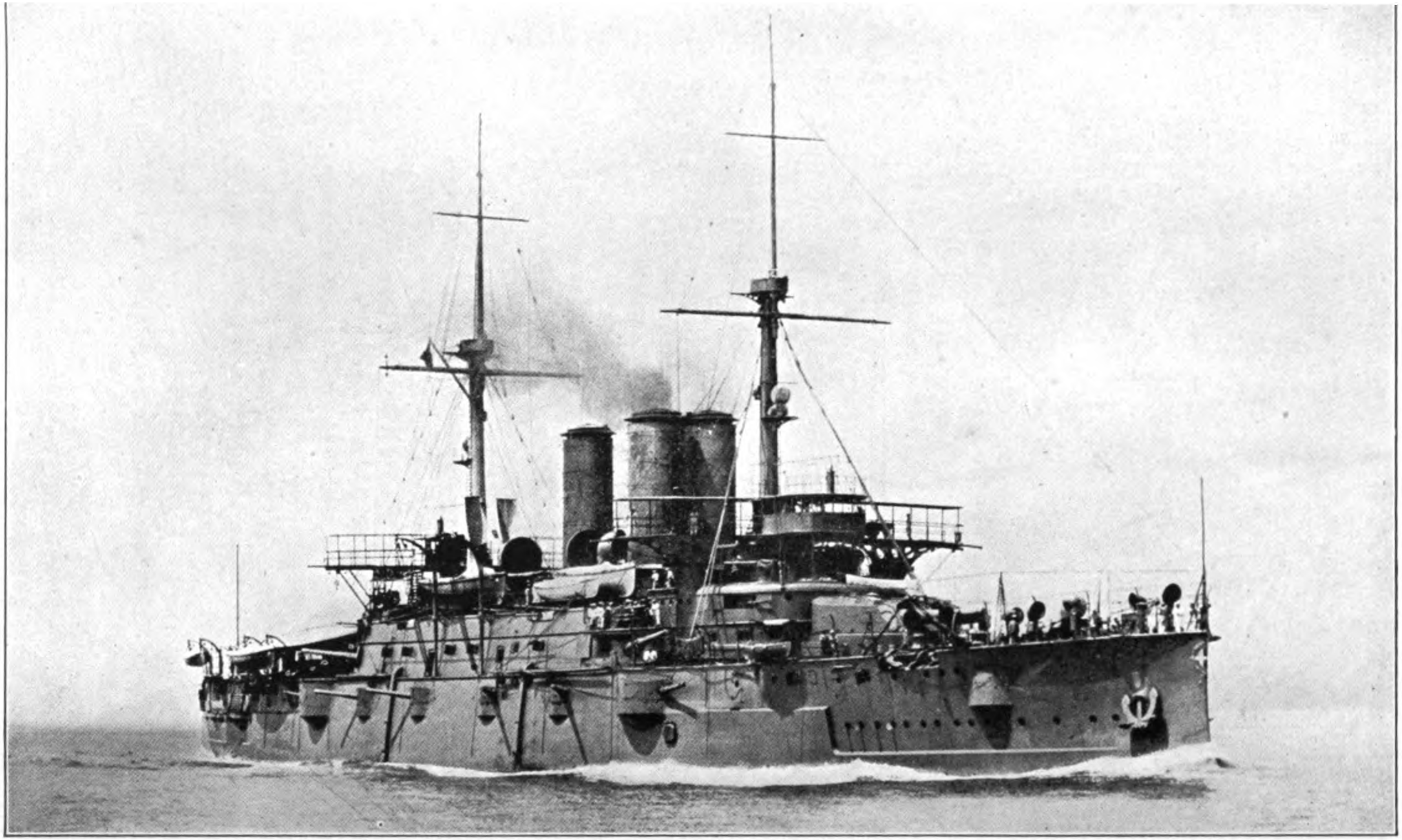
Napoleon, like Frederick the Great, sought to decide his campaigns by battle in the open field, and looked upon fortifications as merely an aid to strategy or troop leading. He did not thereby undervalue the importance of fortifications, but permitted them to influence his actions to attain his object as little as possible. On the other hand, he understood how to utilize fully their strategic value in a given case in the furtherance of his plan of operations.

These points are all illustrated in the text, and the philosophy of the subject, its spirit and true significance, is particularly emphasized, constituting, therefore, in the highest sense a *study* of the value, importance and influence of fortifications.

The work before us is a most valuable contribution to the literature of the subject of tactics, and deserves especial commendation for setting forth clearly the true value of fortified places in the theatre of operations. It is worthy of careful study by all military men, whatever their rank, as well as being of interest to the general reader.

An excellent atlas, containing twenty-nine clear and accurate plates, accompanies the text.





ITALIAN FIRST-CLASS BATTLESHIP "REGINA MARGHERITA", 13,430 TONS; 20,664-I.H.P., SPEED 20.2 KNOTS.

ARMOR PROTECTION:—Waterline belt 6-inch H. S. amidships tapering to 2-inch at bow and to within short distance of stern, 6 feet above waterline and 3 ft. 6 in. below. Transverse bulkheads 10-inch. Side armor above belt, 6-inch H. S. Heavy gun positions, 8-inch H. S.; small turrets, 6-inch H. S.; 6-inch guns, 6-inch H. S. Armored deck 3-inch.

ARMAMENT:—Four 12-inch guns; four 8-inch R. F. guns; twelve 6-inch R. F.; sixteen 3-inch; eight 1.8-inch and six machine guns. Six submerged torpedo tubes.

—*Engineering.*

JOURNAL
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UNITED STATES ARTILLERY

"*La guerre est un metier pour les ignorans,
et une Science pour les habiles gens.*"

VOL. 23 No. 3 MAY—JUNE, 1905 WHOLE No. 73

COAST ARTILLERY PROJECTILES

ARMOR-PIERCING PROJECTILES.

IN the development of the modern armor-piercing projectile, many kinds, with heads of different shapes, have been tried, but the ogival form has given the most satisfactory results. both at normal and at oblique firing. It has been found, too, that the simpler the structure of an armor-piercing projectile, the more efficient it proves to be.

All projectiles used in the United States seacoast service have practically the same form, a cylindrical body and an ogival head. The length varies from between three to four calibers, in the case of guns, to 4.7 calibers in the case of torpedo shells for mortars. The curve of the head is the arc of a circle described with a radius of from 2 to 2½ calibers and nearly tangent to the corresponding cylindrical element of the body. The most important part of the projectile is the head, and care must be taken that the cavity in it is so formed as to give a uniformly increasing section from point to shoulder.

Rotation around the axis of the projectile is obtained by a copper band forced into an undercut groove near the base of the projectile by hammering, after which it is turned in a lathe to the proper size. This band is a few hundredths of an inch larger in diameter than the caliber of the gun, and must be placed a sufficient distance from tho base of the projectile so that it will not be sheared off by the rifling. A number of grooves, or cannelures, are turned on the exterior of the rotating band to diminish the amount of metal to be cut through by the lands, to allow space into which the portion thus cut out may be forced, and at the same time, to retain unchanged the necessary width of the band.

The function of an armor-piercing projectile is to carry its charge intact through the armor which it is designed to perforate and to explode its bursting charge on the farther side. The bursting charge should be the maximum consistent with the strength required to accomplish such perforation. The stress on any cross-section is the product of the mass supported by that section and the acceleration communicated to it. Since the maximum rate of change in velocity while passing through armor-plate is much greater than that due to maximum powder pressure, it is evident that the thickness of wall in front must be greater than in rear. With a given thickness of armor it is thus possible to design the most effective projectile. Since it is impracticable to provide such a projectile for all thicknesses of armor, the field has been covered by two types for guns, the A.P. shot and the A.P. shell, and two, the D.P. shell and the torpedo shell, for mortars.

Shot.—Armor-piercing shot are designed to attack the heaviest armor that can be perforated by the gun in which they are used. The original purpose of boring out the interior of an armor-piercing shot was to remove the unsound metal in the interior and to facilitate the treatment by which hardness and toughness were attained. While black powder was the only explosive charge available a bursting charge could not be used, since black powder was unable to burst the strong walls of the shot and also could not be made to penetrate thick armor without exploding prematurely. The adoption of high explosives as shell fillers, and the invention of a satisfactory delayed action detonating fuze, rendered practicable the use of a bursting charge in the shot, and armor-piercing shot are now really thick-walled shell. The shell fillers used in United States coast projectiles are either maximite or explosive D; the weight of a charge of maximite is about fifteen per cent greater than that of explosive D, due to the greater density which can be obtained in loading the former. The weight of the bursting charge in the shot is about two per cent. of the weight of the projectile.

The only solid shot now issued to the coast artillery is the cast-iron shot, which is used for target practice and experimental purposes.

Shell.—Armor-piercing shell have larger cavities, thinner walls and less metal at the head than armor-piercing shot and contain a bursting charge of about 6 per cent. of the weight of the projectile. They are designed to attack armor which is only about one-half caliber thick and hence can be perforated by a projectile with thinner walls and larger capacity than the A.P. shot. They are intended for use at those longer ranges at which the perforating power of the gun does not exceed the armor-piercing ability of the shell, their greater explosive effect making them more efficient than shot against personnel and material protected by such armor; at the shorter ranges where the remaining velocities are high enough to obtain perforation of armor with which the shell can not cope, some explosive effect has to be sacrificed to obtain the necessary strength for perforation and the shot is substituted for the shell, the use of the latter being confined to the lightly armored or unarmored portions of the ship.

The fragmentation of the shot by its high explosive charge is but little less than that of the shell, but the fragments of the latter are dispersed with higher velocity.

Experiments made to determine the relative fragmentation of armor-piercing shot and shell gave the following results in the case of 12-inch projectiles:

A.P. shot.—733 fragments recovered with an average weight of 20 ounces, the largest fragment weighing 22 pounds. Weight of metal recovered, 949 pounds.

A.P. shell.—850 fragments recovered with an average weight of 15.3 ounces, the largest fragment weighing 15½ pounds. Weight of metal recovered 815 pounds. The weight of bursting charges were as one to three.

The deck-piercing shell used in the 12-inch mortar has about the same dimensions as the 12-inch armor-piercing shell, and contains the same weight of bursting charge. This shell is designed to perforate the protective decks of warships and carry its bursting charge to their vitals.

Shell designed to attack unarmored targets have the largest possible cavity consistent with the strength required to withstand the shock of discharge in the piece in which they are used. Such shell, often called common shell, are designed for explosive effect only. The torpedo shell for the 12-inch mortar is a common shell and is intended for use in vertical fire to produce an explosion upon the deck. It is not adapted for armor penetration and is intended for use only at those ranges at which the perforation of an armored deck by a deck-piercing shell can not be obtained. It is the opinion of some authorities that this shell will do material damage to a warship if it strikes the water within ten feet of the hull. The 1000-pound torpedo shell, as issued until recently, is made of cast-steel and contains 137 pounds of high explosive. Those to be issued in the future will be made of forged-steel and have possibly a smaller interior capacity in order to obtain the requisite strength, the cause of a premature burst in the bore of a mortar of a torpedo shell of the former design having been attributed to the weakness of the projectile.

MANUFACTURE.

Modern armor-piercing projectiles are made from either forgings or castings. The fact that sound castings can now be made has led manufacturers to take up the production of cast-steel projectiles, with the result that a much cheaper projectile can be made from the casting than from the forging; although the efficiency of forged projectiles still exceeds that of cast.

Until recently it was not possible to make cast-steel projectiles which could penetrate face-hardened steel. But now the material used in the manufacture of projectiles is superior in quality to that used some years ago, and improvements in the manufacture and treatment of steel have also rendered this possible. In addition, recent researches on alloys of steel have helped the manufacturer to produce castings having higher tenacity and corresponding toughness. The modern projectile is composed of steel containing carbon with one or more of the following metals: nickel, chromium, manganese and molybdenum.

All armor-piercing projectiles in the United States service are made of chrome steel. The metal is cast as an ingot, forged, bored, turned to proper dimensions, and then treated by a secret process. Projectiles thus made combine great hardness with toughness. The hardness of the metal at the point is limited by the condition that the projectile must not crack spontaneously from internal strains. The manufacturer is left a free hand as to the chemical composition of the steel and its physical qualities, except that the inspector (assigned by the Ordnance Department) is to be kept fully informed as to all analyses and the results of physical tests.

The armor-piercing projectiles are specified to be of forged and hardened steel, with base plugs of the same kind and quality of metal.

Forging.—Armor-piercing projectiles are usually forged from ingots from one-and-a-half to one-and-a-quarter times the diameter of the finished projectile. The ingots are usually removed from the moulds while hot, gradually reheated, and then carefully forged under hydraulic pressure. When the ingot has been reduced to a round bar slightly larger than the finished shot, the point is formed, and the projectile annealed at a temperature of between 1200° and 1500° F., after which it is ready for machining.

Casting.—In this mode of manufacture, many different methods are employed. The object aimed at is soundness and homogeneity in the casting, so that the parts of unequal section may not be unduly strained, due to irregular cooling, and thereby rendered liable to crack after the projectile has been tempered and hardened. The body of the projectile is usually cast in sand and the point partially or wholly in a chill of iron. Chilling the point accelerates cooling where the cross-section is greatest, and thus prevents unsoundness. Other methods employed have in view the proper gradation of the chill from point to shoulder, in order to improve the qualities of the head.

When the shell has been cast, the casting and the mould, the interior of which is coated with a carbonaceous substance, are put in a furnace to produce surface hardening by cementation. The head is afterwards tempered in oil.

Annealing.—In this important operation a pile of projectiles is put in a furnace and the temperature is gradually raised and is maintained at between 1200° and 1500° F. for several hours and sometimes days. It is then allowed to fall gradually until the projectiles are sufficiently cool to be handled.

After forging and after being annealed tangential tensile strength specimens are taken from near the base from projectiles selected at random from those previously designated for tensile test. Specimens are also taken for chemical analysis, and the chemical composition must not differ materially from that of the original ingots.

Machining.—Projectiles are machine-finished before final treatment as close to the prescribed dimensions as may be consistent with that operation. The cavity is bored, the body turned and the head is shaped to correct radius, either by cutting-tools or by grinding. The bases are faced, bored, and screwed for the base-plug. The threads upon the base-plug and its seat in the base of the projectile must fit closely to prevent flame from reaching the bursting charge. The fuze hole is bored, screwed, and recessed in the plug. These operations are carried out in turret lathes. The groove for the rotating band is then formed. Longitudinal scores about .05-inch deep and about 3 inches apart are cut in the bottom of the band seat to prevent slipping of the band.

Hardening.—This is the most difficult process in the manufacture of projectiles. Numerous methods are employed, many of which are kept secret by the manufacturers. The principal operations are heating and cooling.

The heating must be gradual as only the point and a part of the body require to be heated. It may be done in several ways, but more often in furnaces specially designed for the purpose. The quenching temperature is determined by the color test for any particular quality of steel.

A cooling medium is selected which is suited to the nature of the material and the form of the projectile to be hardened. Chrome-nickel steels are, as a rule, hardened in oil, or in air under pressure. The degree of hardness obtained varies generally with the nature of the material, the temperature to which it is heated, and the rate of cooling. The proper regulation of the application and intensity of the cooling medium (the action of which may be intensified by varying its temperature) are very important factors in successful hardening.

Testing after hardening.—After final treatment, and before acceptance for the ballistic test, all United States armor-piercing projectiles are tested for the detection of initial strains bordering upon rupture. For this purpose A. P. shot must be cooled to a temperature of about 40° F., and the suddenly heated by being plunged into a bath of water at a temperature of from 180° F. to 212° F., as may be directed. When thoroughly heated to this temperature, each projectile must be plunged, with its axis horizontal, half-way into a bath of water at a temperature not greater than 40° F., and after a brief period will be turned 180° for a like immersion of the opposite side, after which the projectile will be removed from the bath. Three days must elapse between the final treatment and this test. This test is not required for armor-piercing shell. In the case of deck-piercing and torpedo shell, after final treatment, the shell is subjected to an interior hydraulic pressure of 500 pounds per square inch; and all shell in which this test develops holes, cracks, or any unsoundness are rejected.

The necessity for such tests is due to the unstable condition of projectiles for some time after hardening.

CAPS.

All armor-piercing projectile are now fitted with soft steel caps which under certain conditions increase their penetrative effect when attacking hard-faced armor. The cap is of forged steel, cylindrical in form, with its bottom cored out to fit over the nose of the projectile. For securing the cap in our service there is cut around the projectile, near the point, a small groove with one or two small notches to prevent rotation. The cap is forced on to the projectile and made to grip in the groove by hydraulic pressure.

The cap is always attached to the projectile after the latter has been hardened. The steel for the cap must show a tensile strength not to exceed 60,000 pounds per square inch, an elongation after rupture of not less than 30 per cent. and a reduction in area of not less than 45 per cent. on standard specimens 2 inches long between measuring points and .505-inch in diameter. The caps are thoroughly annealed before being placed upon the projectiles, and must be free from cracks and all other defects.

Various methods have been devised for attaching caps to projectiles, but now all the devices in use involve some removal of material from the projectile itself.

"In the Russian method of attachment the nose of the shell is machined so as to leave an annular recess about one-sixteenth of an inch deep, dying away to nothing in a width of about half an inch. The cap is then forced on so as to get 'hitched' by the shoulder of this recess, which acts something on the principle of the barb of a fish-hook. Hadfield's method is to mill or grind recesses like thumb-prints round the nose of the shell, and into these the metal of the cap is hammered or pressed so that the cap can neither rotate nor come off. Johnson cuts or grinds an annular groove round the nose with one or two little notches to prevent rotation. The Firth-Sterling method is to make an annular groove in the nose, of semicircular section, and another in the inner surface of the cap, which latter is run out tangentially at two opposite points by holes through the metal of the cap. Into these holes two pieces of iron rod are inserted and driven till each piece fills half the circular groove and projects equally into shell and cap. Firth's plan is to have both in the nose of shell and interior of cap, which are tinned and sweated together with low fusing-point solder, three corresponding shallow annular grooves into which white metal is run. Judging by the success achieved, all these methods appear to be practically satisfactory, and it must be taken as demonstrated that the grooving or otherwise indenting of the projectile's nose has no appreciable effect on its strength.

"A very great difference is observable in the shape of the caps adopted by this country and Russia respectively. Our caps are not unlike an ordinary thimble in outline, the angle at the apex being about 150°, while the Russian caps are ogival over their whole length, and it is understood that much importance is attached to the precise method of describing the curves of the sectional outline. Theoretically, the Russian shape is the best for the projectile's flight through the air, and the English and American for its impact with the armor, but the punch experiment, alluded to later, shows what very slight lateral strength the cap requires to do all that it has to do, so possibly a great part of the weight put into the broadening of the forepart of the English and American cap might be dispensed with or redistributed with advantage. If the Russian shape assists perforation as much as the others, both for normal and oblique attack, then it is to be preferred, for it would certainly tend to promote accuracy of flight and reduction of air resistance."*

A number of theories have been advanced to account for the assistance derived from the cap, in the perforation of armor, but none as yet has been generally accepted. Captain Tresidder, in the *Naval Annual* for 1905, writes as follows:

"As there still appear to be in existence differences of opinion as to how and why the cap confers so much advantage on the projectile in the attack of hard-faced plates, the following observations may not be out of date or out of place. The hard face of an armor plate is designed to initiate the destruction of the delicate point of a projectile before the latter has obtained any appreciable penetration at all; for directly it has entered, as much as ⅛ inch even, it obtains a side support which increases the difficulty of breaking it; and the further it goes in the less support it needs and the more it gets. It follows

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* "The Naval Annual, 1905".

from this then (1) that the hard face has only a very minute fraction of a second of time in which to perform its main function; and (2) that anything which will enable the extreme point of the shot to hold together during this brief instant is likely to save the projectile from the fatal initial pulverization and to defeat the main object of hardening the face of the plate. This is the whole *raison d'être* of a cap, and its *modus operandi* may be (as it has been) clearly shown by the following experiment, which should dispose of the theory often seriously advanced that the action of the cap is in the nature of that of a lubricant.

"A chrome-steel punch of the highest quality, say, 3 inches long and $\frac{3}{8}$ inch diameter, is held upright with its point on the hard face of a plate by means of a cylindrical guide in which it is free to move vertically, which guide holds it centrally at the bottom of a pipe or tube also standing on the plate. Down this pipe, and guided by it, a cylindrical weight can be allowed to fall, when released by a trigger or electro-magnet, from various heights. This simple apparatus enables a fair blow of previously determined energy to be delivered, and repeated as many times as necessary, on the punch in the direction of its axis. A heavy blow will shiver the punch to atoms; but, by suitably moderating the force, the splitting of the punch may be initiated without being completed, and punch after punch may be reduced to the condition, in which the original point is detached as a double-ended cone held by the body of the punch split down its center, as a cherry stone might be held by the finger and thumb. The plate will not be indented.

"Now if the point of the punch is not placed directly on the plate, but there is interposed a cap of soft steel, say, $\frac{1}{8}$ inch thick and about the size of a sixpence, with a conical indent nearly perforating it and fitting the point of the punch, the same blow may be repeatedly delivered without damaging the punch at all, yet causing it to indent the hard face every time as if it were a soft one. The explanation is that when two hard substances collide with more force than can be supported within their elastic limits one of two things must happen: either one or both of them must break, or the harder must deform the softer. The point of a punch or of a projectile can always be made harder (owing to the greater rapidity with which the heat can be abstracted from it on chilling) than the face of a plate; so, given the former is properly hardened, it must indent the latter if it does not itself break. The apparently slight lateral support afforded by the cap prevents the point of a projectile from breaking in the excessively brief time available before it receives further and greater support by indenting the plate, and so it obtains penetration."

The extent of the gain in penetrative power conferred by the cap and the limitations as to its value imposed by low striking velocities and oblique impact, are matters of discussion. The following statements on these points conform, it is believed, to the opinions generally held. With striking velocities exceeding 1800 f.s. and with angles of impact with the normal of 15 degrees or less the cap adds one-sixth to the penetrative power. When the striking velocity falls below about 1800 f.s. the cap is of no value. As the obliquity of impact increases from 15 degrees the advantage conferred by the cap falls off until at an angle of about 30 degrees the cap adds nothing to the penetrative power of the projectile. The fact that caps give no advantage with striking velocities below about 1800 f.s. renders them of no value to low-velocity guns and of less relative service to the medium and small caliber high-velocity guns as compared with those of large caliber, as a medium caliber gun will lose about 33 per cent. of its muzzle velocity at 3000 yards, for example, while a large caliber one loses less than 20 per cent.

On the other hand, quoting the *Naval Annual* again:

"No information is to hand as to the effect of caps in increasing the perforating power of common shell, but the effect on armor-piercing projectiles is to improve their powers of penetration into hard-faced plates from 15% to 30%, and although it is generally held, in this country at least, that they give no assistance at striking velocities below 1800 f.s., nor at highly oblique angles of impact, neither of these conclusions is absolutely established, nor is either concurred in by the experts of the United States. Further and exhaustive trials to settle beyond question this important point would seem to be desirable. If caps are impotent when the S.V. is below 1800 f.s. most of the American tests plates would have to be considered as proved with uncapped projectiles and then their velocities of attack would be very inadequate."

In the case of two armor-plate trials of Krupp process armor and Bethlehem capped projectiles, in April and May 1904, where the velocity was only slightly under 1800 f.s. and the perforating power, if the shell had held together, would have been enough to pierce the plate, the shell, seven rounds, were wrecked as if uncapped. Either, then, the projectiles were inferior or the caps failed to protect them. So far this evidence tends to support the view that caps do not answer when the S.V. is below 1800 f.s.

"At the trial of a 4⅝-inch Krupp plate at Redington in March and April, 1904, the plate was presented at 45° of obliquity to the line of fire. Seven rounds were fired with 6-inch Bethlehem capped projectiles of 105 pounds. The first, at 1953 f.s., perforated, but the second at the same velocity failed to bite, and was deflected, indenting the plate only 3 inches. The third, at 1816 f.s., failed, and indented the plate 4¼ inches, but the fourth at the same velocity went through. The fifth and sixth, at 1702 and 2103 f.s., perforated. The seventh, at 1587 f.s., failed, and only made an indent of 1½ inch. All the projectiles were wrecked. The plate being 4⅝ inches thick normally at the point of impact, would measure 6.56 inches on the line of fire, and against that thickness normally attacked the perforating velocity of a 6-inch capped shot of 105 pounds would be 1900 f.s. The formula would then give 1752 f.s. for perforation at 45° of the 4⅝-inch plate. A 6-inch uncapped shot at 1750 f.s. would barely perforate 4⅝ inches of average Krupp steel normally presented and would have less chance still against 4⅝ inches presented at 45°, so the utility of the cap at this extreme angle of impact appears to be demonstrated."

Lieutenant Meigs, the ordnance engineer to the Bethlehem Company, states:

"Experiments have been continued from time to time with firings at inclined armor set at 45° to the line of fire, with a view of studying the effectiveness of capped armor-piercing projectiles against it, and of their tendency to 'bite' or take hold at this angle. Out of some twenty large caliber capped projectiles, which were fired with striking velocities of 1750 f.s. and over, all except three perforated the respective plates at which they were fired. Of the projectiles which perforated the plates, all apparently turned in to an angle of about 15° from the normal before penetrating into the plate to any extent."

BASE COVERS.

Formerly, in the use of high explosive shell fillers with base fuzes there was danger of premature explosions in the bores of guns due to the leakage of the powder gases through the fuze threads. This weakness was remedied by the adoption of a base cover fitted over the base plug. A circular under-cut groove is made in the base of the projectile outside of the base plug. A lead disk is placed over the base of the shell covering the plug and fuze, and over this is placed a flanged copper disk, the flange entering the under-cut groove into which it is caulked with lead.

BITING ANGLES.

The greatest angle of impact with the normal at which a projectile will take hold or bite is called the biting angle. Where the plate and projectile are about equally matched, the the thickness of the plate being equal to the caliber of the projectile, this angle for an uncapped projectile is about 40 degrees. In the case of capped projectiles this angle is probably not much greater than 30 degrees. If the plate is overmatched these angles are somewhat increased, as shown in a recent test in which a 4½-inch Harveyized plate was perforated by a 6-inch capped projectile at an angle of impact of 39½ degrees.

The character of the plates, however, has great influence on the results obtained. A 4.5-inch plate has been seriously cracked by a 12-inch capped shell at 15° with the face of the plate and by a 10-inch capped shell at 20°, while a 3-inch plate has been perforated by an 8-inch capped shell with 1066 f.s. striking velocity at an angle of 25°. But a 3-inch plate of superior quality and greater brittleness successfully withstood the attack of both a 10-inch capped shell with 1150 f.s. striking velocity at an angle of 20°, and a 12-inch capped shell, striking velocity 1246 f.s., at an angle 15° with the face of the plate, the projectiles showing no tendency to bite, and being deflected unbroken from the face of the plate.

The limitations of projectiles in the above respect have been taken advantage of in the application of armor to warships, in the more recent designs of which certain portions of the armor, particularly the front plates of turrets, have been given an inclination with the vertical greater than the biting angle of projectiles.

GENERAL REMARKS.

The original armor-piercing projectile, and the one which displaced the old chilled cast-iron projectile, is the Holtzer made in France. This projectile is manufactured in this country by the Midvale Iron Company.

The Wheeler-Sterling projectile, developed and made in Pittsburg by a recent process, is considered one of the best projectiles. The Krupp projectile as now made is considered practically the same as the Wheeler-Sterling as is probably also the Armstrong. The Johnson projectile, made in this country, is of cast-steel while all others are of forged-steel. Hadfield's cast-steel projectiles are noted for their excellence.

"Several experiments have been made to try the effect of flat or hemispherically-headed projectiles against hard-faced plates, but without important success. The drawback of the delicacy of an ogival point is of course absent, but so are its advantages; and as the former can be removed and the latter at the same time retained by the device of capping, there is no probability of any alteration being made at present in the standard form. Round-headed projectiles are, however, used in Germany for the proof of deck-plates. Such projectiles have a minimum of perforating but a maximum of punching, smashing and racking power. They are the chief enemies to hard faces on very thin plates: so much so that the best 2-inch plates yet produced for resisting high-velocity perforating attack have shown actually less resistance to them than would be expected from ordinary 'simple' steel plates.

"Projectiles aimed in action at hard-faced plates may strike upon plates that are not hard-faced, and anything, such as the blunt heads referred to, that would tend to lessen their chance of perforation in that case is naturally undesirable. Caps, indeed, would be better absent when the face attacked is unhardened, but the obstruction to perforation they would then cause is probably too insignificant to be worth consideration. At the same time, now that caps are being generally adopted and there are plenty of plates with unhardened faces in existing navies, it would be well worth while, if it has not already been done, to fire a few rounds, with and without caps, at a plate of this class to see how far, if at all, the cap detracts from perforating power."

EXTRACTS FROM REPORT OF BOARD OF ARTILLERY OFFICERS (SPANISH) ON OBLIQUE IMPACT WITH CAPPED PROJECTILES

Translated from the Spanish*

BY CAPTAIN ALSTON HAMILTON, ARTILLERY CORPS

FIRST REPORT, OCTOBER 10, 1904.

ON May 28, 1904, this Board rendered its report on firing with Hadfield projectiles in which was shown the excellence of the Vickers plates used, the efficiency of the Rueda 12 cm. (4."72) gun, (which perforated cemented armor of a thickness much greater than its caliber at more than 2000 meters and with angles of incidence of about 8° with the normal), and finally the marvellous effect of capped projectiles, using both small and large caps.

The above report gave rise to the Royal Order of June 23, which directed the consideration, first, of the suitability of the Hadfield projectile, the principal object of the experiments; secondly, the Board was to employ, to the greatest possible advantage, the armor plates and the Holtzer projectiles still on hand for the 12 cm. Rueda gun and thus obtain additional data on which to base conclusions as to the effect of the angle of impact on the penetration of capped projectiles.†

The Board decided to divide the angles of incidence into three classes:—

1°. Angles with the plate greater than the semi-angle of the face of the cap.

2°. Angles with the plate less than the semi-angle of the cap, but greater than the semi-angle of the ogive.

3°. Angles less than the latter semi-angle.

Upon consideration of the dimensions of the projectiles and caps the classification becomes:—

Angles less than 30°.
Angles between 30° and 37°.
Angles greater than 37°.
(All measured from the normal.)

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* "Revista General de Marina," April, 1905.

† The plates used in all these experiments were 155 mm. Krupp process plates manufactured by Vickers, Sons & Maxim, Ltd.

It was natural to begin with the first class, which was actually done, but there was strong temptation to begin with the second class because it seemed as if the May firings would fall under the first class. Then, however, the Board considered the uncertainty as to whether the angle of inclination would be equal to that of perforation; whether the angle of perforation is greater, as we are assured that it is by Loüel in his theory on oblique impact, or whether it is less, that is whether the cap will tend to move the axis of the projectile towards the normal, as other authors assure us will be the case and as is believed to be true by certain members of this Board, based on theoretical and practical investigations into this matter. It it evident, then, that the firings must be classified in order to secure conclusive results; and that firings must be made in each class.

For this reason it was decided to begin with an angle of impact of 22°, a considerable inclination, but one sufficiently below the superior limit of the first class. With this object the Board installed the plate which had suffered least in the May trials, so placing it that its normal made the required angle with the axis of the projectile on impact.

Assuming the conservation of the angle of incidence and decomposing velocities by the vector method, the Board assumed a normal velocity component of 630 m.s. (2067 f.s.) which was a fair mean of the velocities employed in May. This normal velocity is clearly due to an actual velocity of 679 m.s. (2227 f.s). In order to admit of the theory of Loüel a velocity of 752 m.s. (2457 fs.) would have been required.

The above striking velocity (679 m.s.) is that with which, according to accepted methods, this shot ought to penetrate the given armor, when capped, and fail when uncapped, but since a more extended study demonstrated that this method though generally accepted, would not be exact unless the penetrations were proportional to the first powers of the velocities, which is not the case, the natural course was to take as the thickness of the plate the oblique thickness measured in the direction of fire.

Further, this Board has held throughout that the falling off of the coefficient of merit of the plate due to the molecular fatigue endured would be an element of uncertainty in the determinations until it could be determined experimentally. Its value could not be deduced in advance.

NOTE. The calculations of the Board for velocities, charges, etc., for the actual firings were made both graphically and analytically, giving results which agreed.

A description of the grpahic process employed, reference being made to plates not given in the text, is, while interesting, omitted as being merely auxiliary. The curves used were those corresponding to the formulas of de Marre, Gavre, Krupp, and Tresidder for wrought-iron, using a proper coefficient of merit for the particular steel under consideration.—Tr.

Using a thickness of plate of 155 mm., an angle of impact of 22°, and a normal velocity of 630 m.s. (2067 f.s.), we find the striking velocity as follows :

By the formula of Gavre	697 m.s.	(2287 f.s.)
" " " " Tresidder	672 "	(2205 f.s.)
" " " " Krupp	660 "	(2165 f.s.)
" " " " de Marre	655 "	(2149 f.s.)

The Board decided to employ a velocity of 676 m.s., which is obtained with a charge of 5.5 kilograms.

The day for the firings, Sept. 27, having arrived the first shot was fired with this velocity, using a Holtzer capped projectile ballasted to a weight of 24 kilograms; complete perforation resulted, the projectile emerging entire and throwing to the ground a fragment of the plate.

The second shot was made with the same charge and the same projectile, but uncapped. This projectile was broken leaving the ogive imbedded in the plate, while the body was shattered.

If the Board had adhered to the letter of the Royal Order of June 23, it would have discontinued its experiments at this point; but the plate appeared capable of resisting another shot, and as the efficacy of the caps was also in question, it was thought best to obtain, if practicable, an approximate idea of the limit of this efficacy.

The results with capped projectiles are given below :

No. of shot.	Charge.	Kind of projectile.	Striking velocity.	Result.
	kg.		m.s.	
3	5.300	Holtzer capped	647	Complete perforation projectile entire.
4	5.180	"	630	"
5	4.975	"	600	Projectile struck a fragment and glanced.

Being unable to proceed on account of the condition of the plate, practice was suspended, but enough had been done to demonstrate that even assuming that with a velocity somewhat greater than 676 m.s. an uncapped projectile would have perforated, and that with velocities somewhat less than 600 m.s. the capped projectile would not have perforated (neither of which hypotheses is probably true), the effect of the cap may be valued at more than 14% of the velocity, for a given thickness, and at 18% of the thickness of plate, for a given velocity. These results were obtained from the formulas above quoted; so that the figures 16% and 20%, respectively, do not seem exaggerated within the limits of these experiments; that is to say, a capped projectile can produce the same effect as an uncapped one with one-sixth less velocity than the latter, or perforate one-fifth greater thickness of plate with the same velocity; or, finally, the effect of a gun on the enemy, using capped projectiles, is equal to that which would be obtained by using uncapped projectiles and firing at ranges less by 1000 meters.

Another conclusion of great importance was also reached by the Board. By measuring approximately the inclination of the four holes in the plate, it was observed that, in general, the holes did not make a greater angle with the normal than 15°. There is reason then to reject the theory of Loüel, and to admit as evident that the cap causes the projectile to tend towards a normal position to the extent of 7° in 22°, and this approximation takes place at the face of the plate since the holes were sensibly rectilinear.

There is much that is empirical in the discussion of perforations, and an apparently well established theory may be completely upset by subsequent developments and discoveries from experiment.

The reason for this is that we have not gauged thus far the successive efforts of a projectile in the different stages of the process of penetration. We do not know exactly the inter-relation of weight, form, dimensions, velocity and the resistance to deformation of the object to be perforated. The problem is not similar to that of recoil or of interior ballistics, because a cannon bursts, or a brake is broken only accidentally, and such an occurrence is habitually looked on as only a remote possibility; whereas in perforation either the projectile or the plate, or both, must be broken. Suppose for instance a formula is worked out giving the perforation. It asserts that with a given set of conditions the perforation is a certain amount. If the projectile ruptures, the energy intended for the target is used up in the destruction of the projectile, which is the vessel charged with the application of this energy to the plate.

The deductions of this Board cannot then have a mathematical rigor, but by noting facts observed and by collecting data, it must be possible to supply by repeated experiments the scarcity of repetition which until now exists. The Board deduces the following conclusions applicable to the caps and projectiles employed and to similar ones.

1. Up to 30° caps are useful.
2. The usefulness of a cap can be taken as 20% of the thickness of the plate.
3. The cap causes the projectile to move considerably toward the normal in a manner favorable to penetration.

NOTE. The Board on considering the matter of investigating the angles of the second class, found the means at hand inadequate for experiment, as the plates were so badly racked and punched as to promise only very abnormal results. They therefore discontinued the proof-firings and were reconvened later to conduct the necessary experiments. The date of the above report was October 10, 1904.—TR.

EXTRACTS FROM THE FINAL REPORT OF THE BOARD ON OBLIQUE IMPACT WITH CAPPED PROJECTILES.

The Board continued the experiments on the lines indicated above, so arranging the experiments as to include in them all the different cases and questions in order to get results in all cases with the limited means available. This necessity induced them to fire several shots with the capped Hadfield projectiles before dismounting the plate. Its normal formed an angle of 22° with the line of fire of the 12-cm. Rueda gun. The chances were taken of getting a perforation (which was not easy on account of the bad condition of the plate), there being three objects of interest in view: first, to try the Hadfield projectiles in oblique fire comparing the results with those obtained with the Holtzer; second, to compare also the effect of the small caps of the former with the large caps of the Rueda model, a question of great interest in oblique fire, since that is the respect in which they mainly differ; and, finally, the angle of the Hadfield cap being precisely 136°, it is seen that firing these against the plate mounted for the proof-firing with an inclination of 22° with the normal, permitted, since this inclination is the complement of half that angle, the study of that case in which an element of the conical face of the cap lies on impact in the plane of the face of the armor.

This case forms the dividing line between the first two general divisions pointed out by the Board in its report dated October 10; that is, between those angles of incidence with the plate greater than the semi-angle of the point of the cap and those angles less than this semi-angle.

On the 5th of November last these firings were made beginning with a Hadfield projectile, one of the hardest of the shipment from the manufacturers, ballasting it to 24 kilograms and firing it with a charge of 5.500 kilograms of powder which gives in the Rueda 12-cm. gun a velocity of 676 m.s., i.e. the first velocity used in the preceding proofs. The projectile perforated but broke up. A second shot was fired with a Hadfield projectile—medium hard—reducing the charge to 5.180 kg. giving only 630 m.s., and this projectile perforated but broke up.

Of the two shot holes resulting only one admitted of measurement of the angle of perforation, the other falling near the edge of the plate. The hole measured gave an angle of perforation notably greater than the angle of impact, showing that, *in the case of this shot*, though the cap served to retard the rupture of the projectile sufficiently to permit perforation, it did not turn it towards the normal, as appeared to be the case with the Holtzer projectile projectile provided with large caps. This is thought to be due to the fact that the cap is not sufficiently pointed; but the effect noted leaves much to be proved and requires full experimental confirmation.

The plate stood the firing as well as could have been expected, and although battered considerably, no fragment fell to the ground; but on separating it from its backing it was seen that it was split into two pieces.

Next, the other plate was established so that the line of fire made an angle of 33°30′. with the normal to the plate. These were the final proofs of December 23 and were witnessed by the inspector-general of the corps.

To determine the striking velocity in these firings, the fact was considered that in the firings of September 27, and in those of November 5, the perforations had been made with velocities of 630 m.s. and also that it was calculated that the effect of the caps must have reduced to 15° the true angle of perforation. From this there results 160.4 mm. perforation. As the perforation in wrought-iron of projectiles with that velocity would have been (according to the accepted formulas) in these firings 305 mm., it appears that under the conditions of the experiments the coefficient of merit of the plate finally used would be less than 1.90, but nearly that, since the last uncapped projectiles fired had perforated it.

It is not strange that the plate against which the firings of September and November were made should have had its coefficient of merit somewhat reduced, as was anticipated by this

Board in its report of October 10, since in the firings of May alone it suffered a striking energy of 1100 meter-tons per ton of plate which, considering the character of the metal, must have affected the condition of the entire mass.

In these last firings, then, since the plate employed had suffered an even greater striking energy, it is plain that an equal decline in its coefficient of merit may be properly assumed, which reduces it from 2.00, as determined by the first experiments to 1.90 for the final ones.

Assuming 1.90 and using an angle of incidence of 33°30′, with which obliquity the plate presented a thickness of 185.6 mm., there results from the formulas a striking velocity of 685 m.s. corresponding to a charge of 5.525 kilograms.

The first round was fired with this velocity and a Holtzer projectile ballasted to 24 kilograms, which perforated near the lower edge of the plate, the body of the shot breaking up on impact.

As the location of the shot hole was not a satisfactory one for deductions, the shot was repeated under the same conditions, and the projectile perforated, breaking off a piece of the plate and itself breaking up; also another shot was fired under conditions exactly the same, except that the projectile was not capped, and, as was expected, this projectile was shattered, without perforation.

A shot was then fired with the Hadfield projectile, capped and ballasted to 24 kilograms (53 pounds) employing projectile of class B, medium hard. This perforated, breaking off a piece of plate smaller than the preceding, and itself breaking up.

The condition of the plate, which was now in fragments, caused the indefinite suspension of experiments, it being evident, however, that the uncapped Hadfield projectile would not have perforated.

The results were such as to prevent the Board deducing accurate conclusions as to whether, in firing at great angles with the normal, the cap causes the axis of the projectile to move toward or from the normal, the plate being now hetrogeneous and the perforations inclining towards the direction of least resistance.

From these firings are deduced the following conclusions:

1. That the Hadfield projectiles are scarcely inferior to the Holtzer.
2. That the small caps give sensibly the same results as the large ones.

3. That the angle of incidence does not sensibly affect the linear perforation of projectile in the direction of its own axis.

The efficacy of the cap is, then, demonstrated completely for all angles since those of the third class of our report of October 10, are not referred to the shape of the caps but to the ogive of the projectile.

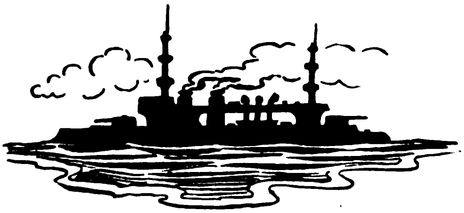
These results derive greater importance from the fact that, until recently, the efficacy of the cap was denied when the impact was not approximately normal, (and here this is shown to be untrue); and it is clear that in all attempts at perforation it is advisable to use the cap, because this is equivalent to diminishing by 20% the thickness of the armor attacked.

Using the cap, then, the gun has acquired supremacy in its long fight with armor, now that the coefficients of merit of the latter must be always a function of the projectile employed.

The character of our experiments has not permitted us to find the lower limit of this coefficient; but the latest experiments of the Bethlehem Company, so far as we are informed, gives us a descent to 1.83 in the Krupp cemented, and this same Company has obtained perforation of a plate 12 cm. thick with a 15-cm. gun (6-inch) and a 46 kilogram (105 pounds) capped projectile at an angle of 45° with a velocity of 732 m.s. (2400 f.s.).

It seems established that caps are applicable wherever perforation is expected, that all projectiles intended for perforation should be capped and that armor-plate has lost by the invention of the cap at least one-fifth of its efficiency.

Finally, it must be evident that penetration is not the only object of the projectile; in war conditions explosive projectiles must perforate, emerge entire, and explode. The experiments in which the projectile imbedded its ogive and ruptured the body indicate that the effect of explosion in those cases would have been practically nullified.



THE ACTION OF CAPPED ARMOR-PIERCING SHELL

BY EUGEN KODAR v. THURNWERTH

k.u.k. Marine-Artillerie-Ingenieur

Translated from the German*

BY CAPTAIN GEORGE BLAKELY, ARTILLERY CORPS

AMONG the most notable of the recent achievements in artillery, especially in connection with the effect of the projectile on the target, is the increased penetration that has been attained with armor-piercing shell by the application of a cap to the projectile. It is proposed in the following paper to examine briefly the reasons for this superiority of the capped projectile, on the basis of tests made with a variety of plates.

There has been waging an incessant contest between armor and artillery since the fifties of the last century, when wrought iron plates were first used as armor, which kept out completely the cast-iron balls of the smooth-bores of the period. In this struggle of armor against artillery, now one and now the other has been ahead, and despite the fact that the dead material seems to have been worked to its utmost limit, there does not yet appear to be any pause in the competition. Each year brings its improvements and its surprises.

The latest achievement in the domain of armor was the general introduction, since 1890, of Krupp cemented and hardened nickel-chrome steel; with this step, armor apparently rendered nugatory the action of the projectile. Though good K.C. plates were not inpenetrable to a good projectile of corresponding size, yet the inevitable shattering of the projectile seriously reduced its effect, or made it altogether ineffectual. But the armor-plate did not hold its victory long; hardly three years had elapsed after the astonishing results of these armor tests were known, before there appeared the still more wonderful news of the action of capped projectiles, whose overwhelming attack defeated the strongest Krupp plates. So with the general introduction of capped projectiles, the artillery has acquired a superiority, within certain limits, until something further develops.

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* From "Mitteilungen aus dem Gebiete des Seewesens," vol. 33, No. 2, Pola, 1905.

The relative superiority of armor or projectile is generally determined by the fact whether plates as thick as the caliber of the projectile can or cannot be penetrated at short fighting ranges. For example, a 15-cm. (6-inch) armor-piercing shell weighing 45.5 kg. (100 pounds) cannot pierce a 150 mm. (6-inch) K.C. plate at 500 m. (550 yards); but this shell would penetrate with ease a plate of equal thickness of unhardened nickel-steel even at 3000 m. (3300 yards). In the former case we speak of the armor as superior to the projectile, in the latter case of the projectile as superior to the armor. With this standard, capped projectiles are superior to the best armor-plate, for at short ranges with correspondingly large striking velocity they penetrate plates of 1½ and even 2 calibers thickness. The literature on this projectile, which is now used in nearly all countries, is fairly copious, and most of the writers are agreed that at present adequate protection against this projectile must be sought by increasing the thickness of the armor, or in increasing the fighting ranges. The reasons for the superiority of the capped projectile over the uncapped are often not discussed at all, generally they are touched upon in a superficial way, and the explanations offered fail to satisfy the requirements of even an elementary theory.

Perhaps the most widespread explanation is, that the material of the cap acts as a lubricant for the projectile in its passage through the plate, and reduces the great amount of friction that occurs between the surface of the projectile and the plate opening. Were it indeed true that the action of the cap lay in nothing else than this, the advantage would hold only in the case of soft plates, where the head and body of the projectile both come into sliding contact with the plate opening, and an advantage would not be found with hard plates where there is not sliding contact between plate and projectile. Now all experiments show that the superiority of the capped projectile is unquestionable only with hardened plates, whereas with soft plates the capped projectile is not better than the uncapped.

Against the hypothesis that the cap serves as a lubricant, there also stands the consideration of the great quantity of energy that would have to be spent in heating and melting the cap, which energy being drawn from the projectile would be lost for its especial work of penetration. In the tests of the Royal Naval Committee (Austrian) the weight of a cap of a 12-cm. armor-piercing shell (4.7-inch), was about 1.5 kg. (3.3 pounds). To heat this mass to the melting point would require

1.5×0.1165×1400 or 245 calories, and to effect the melting itself would require about 50 calories more; this would be equivalent to a loss of energy of about 124 meter-tons. Yet in some of the tests capped projectiles with about 376 m.t. striking energy have not only gone clean through the plate attacked, but have gone through a butt 4 meters thick and travelled 300 or 400 meters beyond. This result would be simply impossible if 33 per cent. of the striking energy were consumed in melting the cap. Uncapped projectiles fired under like conditions broke into fragments against the plate in spite of the fact of having to their advantage this 33 per cent. of energy.

It must be admitted that around the point of impact very remarkable heating effects are often noticeable, the vicinity of the opening in the plate and the shell fragments showing yellow to blue tempering colors. This points to a heating up to 300° C., but this is a good ways from a melting point of 1400° C.

A second widely accepted hypothesis holds that the cap takes up the first shock that occurs on the impact of the projectile, pretty much in the same way as a buffer of a railway car takes up the blow when one car meets another. In more precise terms this theory would run: The cap takes up that amount of energy which would cause the destruction of the projectile, and lets free only that part which is necessary to penetrate. But this leaves out of account the relation between the weight of the projectile and the weight of the cap, and in view of the great amount of energy present, this omission cannot be justified. By the theory of strains the cap could take up but a small amount of energy, still further reduced on account of the inferior material of the cap compared with that of the projectile, without having its molecular structure destroyed. Yet it is just in connection with great energy and high velocity that capped projectiles are most effective.

Another explanation is connected with the following illustration: A needle cannot be thrust through a board without deformation. Yet if the needle is first set in a cork stopper so that it cannot bend, this can easily be accomplished.

Now the small lump of metal on the end of the projectile cannot be regarded as the guide of the shot, especially because, as we shall soon see, it has become completely deformed when the projectile stands most in need of guidance, that is when its point is piercing the hard armor-plate.

The theory that the uppermost layer of the armor is softened and the plate so transformed into a homogeneous steel plate has very much more probability than any of the explanations so far adduced. It is very likely that a molecular change does take place in the plate under the combined influence of the great temperature and the violent concussion of impact. The only question is whether the short space of time is adequate for such a change.

To obtain now an explanation that avoids all these defects, and accounts for the superiority of the capped projectile in a purely mechanical way, let us proceed inductively, and figure in our mind the separate phases that occur during the penetration of various kinds of armor by hardened projectiles. Right here we shall see the essential difference that characterizes the penetration of hard and soft plates. With very soft plates, like wrought-iron, it needs but a moderate pressure at the point of impact, say 30 to 35 kg. per mm^2. (66 to 77 pounds), before the material of the plate begins to yield and flow aside, while the point of the projectile forces its way into the plate like a chisel. The iron thus under pressure moves of course in the line of least resistance, and thus there is formed on the front of the

Fig. 1.

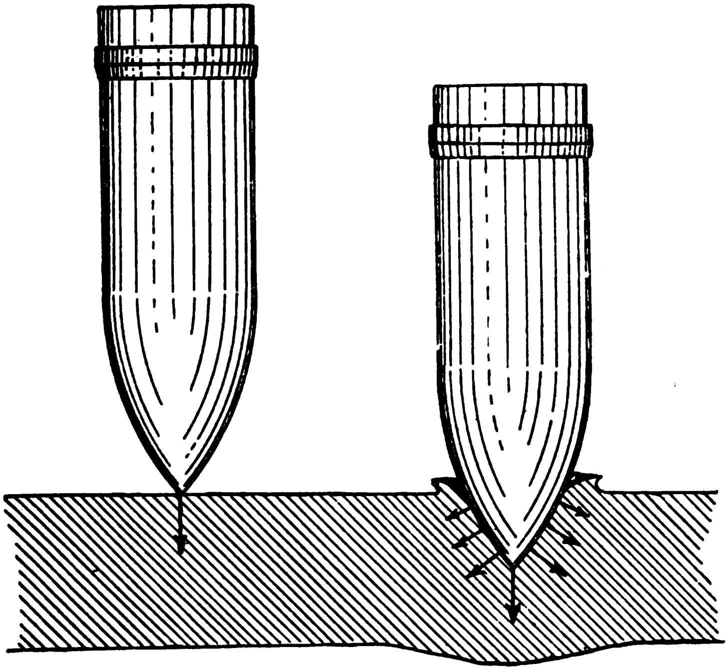
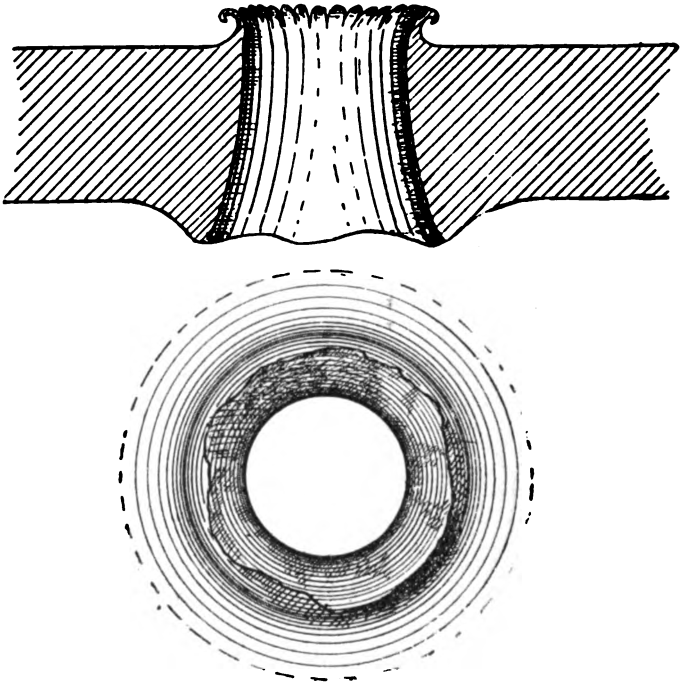


plate by the pushing up of the material very peculiarly characteristic curls and elevations, and at the same time a bulging occurs on the back of the plate. The pressure of the point in the canal that it is forming keeps growing, without passing beyond the limit of tenacity of the projectile and so without deforming it, until the point breaks through the plate, when the pressure quickly drops to zero, which it reaches when the point and ogival head of the projectile clear the plate. By the action of the projectile's head lateral motions are imparted to small masses and so the canal is widened, and on the back of the plate there is a considerable puffing up of the plate without any actual loss of material. The form of perforation shown in figure 2 indicates little hardness in the plate but great tenacity.

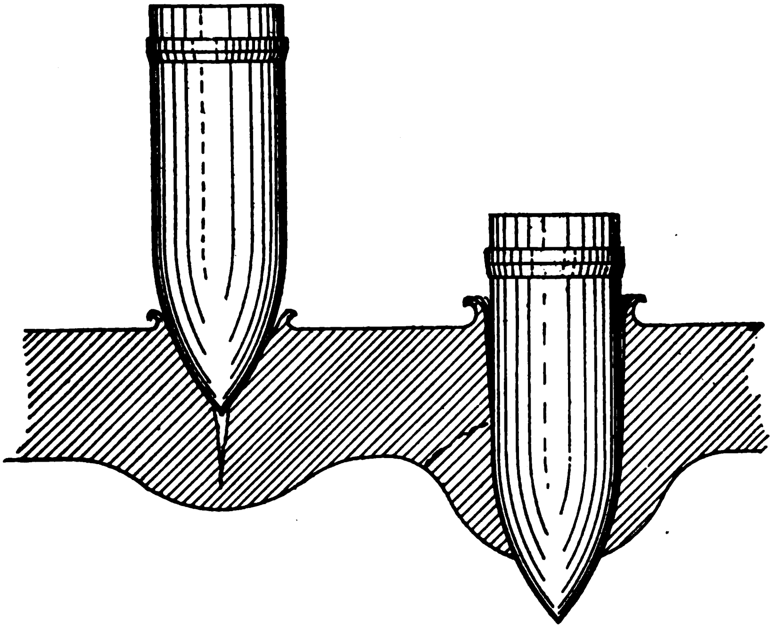
Fig. 2.



Homogeneous soft steel or unhardened nickel-steel behaves somewhat differently. In the first instant the same phenomena are observed as in the case of wrought-iron, with curling elevations on the front of the plate. But since the tenacity of steel is less than that of wrought-iron, radial cracks and fissures will occur on the back of the plate, and instead of a projecting collar there, we will find a rim of pyramidal-shaped teeth, some of which break off and are flung about, so that the back of the plate will present a broken surface more or less circular in shape surrounding the orifice made by the projectile.

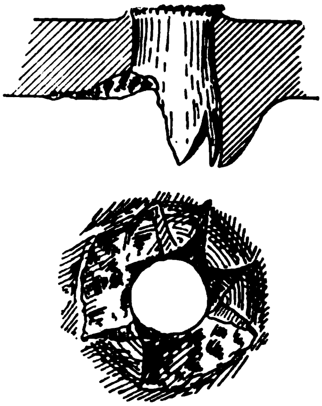
The behaviour of the best K.C. plates is radically different. Since the resistance to penetration is very much greater than is the case with unhardened plates, the projectile is arrested in its motion almost instantaneously, so that an enormous pressure occurs on the head of the projectile (not less than 100 to 200 kg/mm², 220 to 440 pounds) which the best material and the most careful hardening cannot withstand. Hence at the instant of impact the head of the projectile is deformed, and the broad rounded surface that the front of the projectile now presents seeks to compress the material of the plate, since piercing is out of the question on account of the broader dimension of the front due to the upsetting of the point. The result is that the front surface of the plate is pressed in, and of course the rear side bulges out.

Fig. 3.



During this process which occupies an extremely short time, the cylindrical body of the projectile continues its forward motion, until, arrested by the deformed head and the

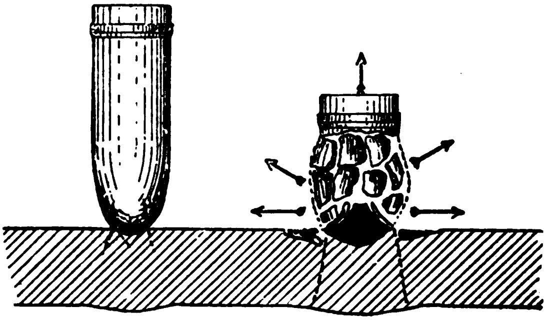
Fig. 4.



plate, the low tenacity of the tempered material is overcome and the projectile breaks up. The head of the projectile, broken loose by the resistance it has met, adheres with great force to the plate and is so to speak welded to it. The mushroom form that the head assumes is characteristic of this phase, the stem of the mushroom being bounded by the hollow interior of the projectile. In figure 5 the formation of this mushroom head is very noticeable. If the energy of impact is small, the plate will be able to keep out the projectile without further injury, that is, by its elasticity it will take up the energy that remains after the shattering of the shot and the heating of the place of striking. The effect of the projectile ceases then with the process we have described, the plate completely shutting out the projectile.

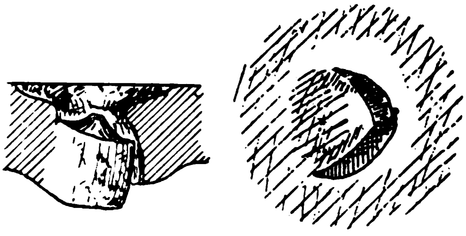
If the energy of impact is relatively large there is a portion of it transferred to the plate sufficient to effect an opening or to cause perforation. The process that then takes place can be readily explained on the basis of the law that governs the action of imperfectly elastic bodies.

Fig. 5.



The head already deformed in the previous phase becomes now the vehicle for the transference of a portion of the striking energy, and presses like a punch on a surface of greater or less extent, pushing out from in front of it a cylindrical portion of the plate like a stopper. The shearing strength of the material of the plate is overcome at the surface of this stopper, without

Fig. 6.



any actual piercing of the projectile into the material. As a final result the plate is either completely perforated, or if the stopper of metal punched out from the plate holds to the plate by a portion of its surface, the plate is said to be simply opened. In this way there arises on the back of the plate the characteristic form represented in figure 6.

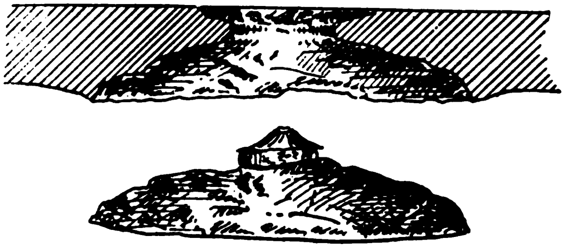
In any case whether the plate is perforated or not, the projectile breaks up into a great many very small pieces. This occurs to all projectiles, including those of the best quality, so that behind the plate even after complete perforation, are to be found but fragments of the projectile and of the metal forced out from the plate.

This manner of penetration is as characteristic for hard plates as that previously described is for soft ones. When plate-thickness and caliber agree approximately, there is practically never any other phenomena to be observed than that indicated. If this is not the case, that is, if the caliber of the projectile is considerably greater than the thickness of the plate, as for ex-example a 24-cm. (9.4-inch) projectile against a 160 mm. (6.3-inch) plate, the shock is so great that a large piece of the plate simply breaks off. On the front of the plate is to be seen an irregular cracking, and on the rear a large concave surface. But even in this case, the head of the projectile is deformed and welded with the plate, and the projectile is shattered into a thousand small fragments.

It is obvious of course that these phenomena are beyond our control. Aside from the fact that it would be extremely dangerous to observe the penetration of a plate in close proximity, the time occupied is so infinitesimally small, that the preservation of a record of the separate phases of the process, as by photography, is out of the question. Hence all of these explanations are but hypotheses, but a certain probability is not to be denied them, for they are deduced from actual experiments, and new tests always confirm them. The explanation of the action of capped projectiles that follows, possesses also but a hypothetical value, yet it fits so close to what has gone before, that a preference may also be given to it, in view of the defects in the theories that I have before referred to.

We have seen that the action of the projectile against hard plates is unsatisfactory because the great pressure per square inch that is brought to bear on the point causes the breaking up of the projectile. A certain amount of flattening of the head from this point of view should be looked upon as advantageous, for the greater the surface that bears the pressure, the less pressure is there per unit of surface. Tests that have been made, however, show that on account of the increased difficulty of penetration, a flat headed projectile does not give better results than a pointed one. Hence the construction of capped projectiles has been resorted to, for this diminishes the pressure on the unit surface, while at the same time the advantage of a point in the penetration of the plate is not surrendered.

Fig. 7.



The superior action of the capped projectiles rests therefore on the fact that the point of the projectile is not deformed at the first instant of impact with the plate. Due to the presence of the cap, the pressure is not confined simply to the point, but is distributed uniformly over a fairly large cross-section. The unit pressure therefore does not exceed the limit above which the choice tempered material of the projectile would be impaired. As a consequence the point is not deformed at the first instant of impact but pierces like a chisel into the hard layers. This work will be so much the easier for the projectile, since the "material cone"* formed in the plate due to the cap will already have begun the destruction of the outside diamond-hard surface layer of the plate, which is not more than a few millimeters thick.

At this stage the cap has already fulfilled its mission, and

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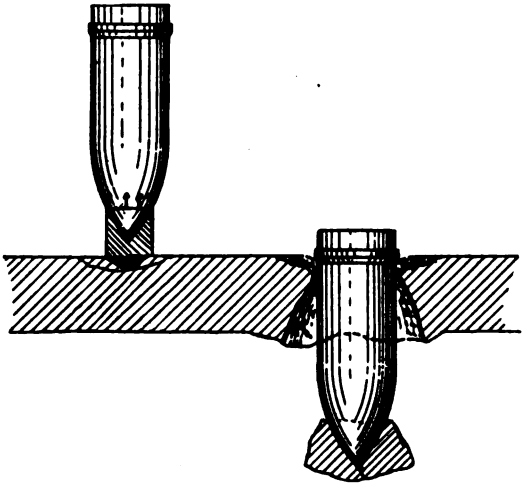
* According to the theory of Prof. Fr. Kicks there forms under the working surface of the tool in compression a thick conical-shaped body in the material worked, which facilitates deformation and splitting. The existence of this material-cone is readily detected by means of plates specially prepared. In pressure tests with very brittle material (sandstone) the material-cone breaks directly out of the body tested.

the projectile goes on its way through the plate alone and uninjured. The following process now occurs:

The point having once entered the exterior hard layer, forms a path for itself in this portion of the plate by its ever-widening head forcing aside the particles in its front, their cohesion having been already disturbed by the formation of the "material cone." On the front of the plate there is a crumbling characteristic of hard metal. Where the hard metal layers pass into the softer ones this crumbling no longer occurs on account of the greater tenacity of the latter. The perforation now narrows to dimensions not much greater than the caliber of the projectile. It might be thought that the further progress of the projectile would resemble the perforation of soft homogeneous steel plates. This however is not the case, for the qualities of steel intended for hardening differ very materially from those of unhardened steel. The material that the projectile now meets is less tenacious than homogeneous unhardened steel, so that a cylindrical section of the plate in front of the projectile is forced out like a stopper. After penetration therefore the back of the plate presents the appearance of a plate hardened throughout. The stopper of metal forced out of the plate is usually broken up into several pieces because the head of the projectile having passed through without injury, in normal penetration, this piece remains about the thickness of the caliber of the projectile. Hitherto no trace of the cap has been found. Probably it is driven radially on penetration, and

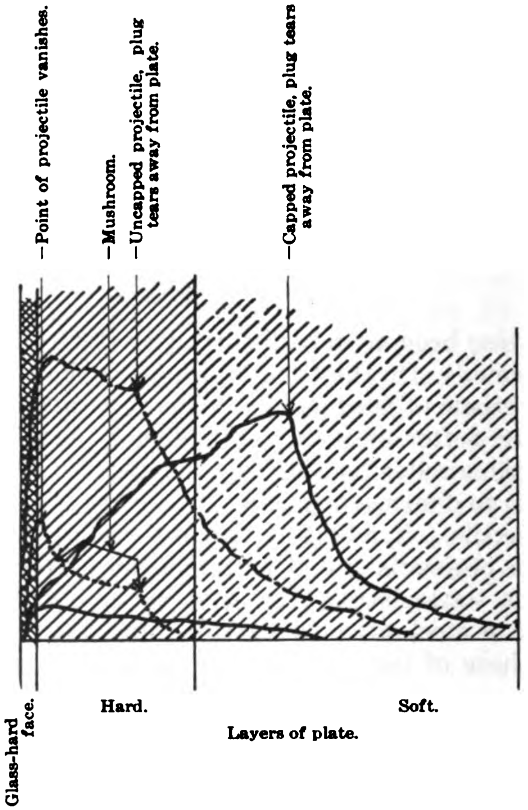
Fig. 8.



broken up, so that its pieces mingle with the fragments of the plate.

The superiority of the action of capped as compared with uncapped projectiles rests therefore, as stated, on the fact that the head of the projectile remains intact. With the ordinary projectile the velocity upon impact falls off so suddenly towards zero, that the pressure increases until it reaches a point where the cohesion of the metal of the projectile is overcome; with capped projectiles, however, on account of the distribution of the pressure over a larger area, the pressure per unit of area does not reach this limit, and it still remains below this limit in further penetration, because the hardened exterior layer is weakened by the formation of the material cone. The pressure curve for capped projectiles against hard plates will therefore resemble that for pointed projectiles against soft plates. At first, while the ogival head is entering the plate, the curve will slowly rise until the head has completely entered.

Fig. 9.



When the stopper of metal breaks out of the plate, the curve will fall steeply, so that at this point it will show an angle. This curve represents the total pressure, for the pressure per unit of area decreases from the start because with the increase of the total pressure, the surface receiving it also increases.

On the other hand the pressure curve for uncapped projectiles resembles that for a flat-headed projectile. The total pressure rises rapidly, and maintains itself at about a constant height so long as the shearing strength of the plate at the place of impact is not overcome; once the plate is punched it sinks rapidly. The pressure per unit of area on the head grows rapidly from the instant of impact until the head as such disappears. The area included between each curve, the axis of abscissas, and the extreme ordinates, must be equal in each case, since this area represents the work done.

It will be apparent from this discussion that the problem of the capped projectile, remarkable as the results appear at first sight, is yet capable of an explanation on a simple mechanical basis. The transfer of the pressure from the surface of impact, the front of the cap, to the working cross-section of the ogival head takes place in a wave motion at an enormously high velocity, practically instantaneously, and the pressure may be regarded as completely and uniformly taken up, if the cap is firmly seated upon the projectile, A good solid attachment of the cap to the body of the projectile is therefore the weightiest factor in the construction of the capped projectile. In order that the transfer of pressure may properly be accomplished, the cap must be seated in the closest contact with the projectile's head throughout its entire interior surface. If this condition is fulfilled, it insures that the cap will not part from the projectile either in the bore or in the air; the first might lead to accidents, the second to wild shooting. Such a firm and absolutely reliable attachment is only to be secured by means of metallic soldering. This method would also remove the defects due to any small room for play that might remain between the cap and the projectile after grinding. A solder suitable for this purpose must possess two qualities; first it must possess sufficient firmness, and secondly a low point of melting so that the tempering of the point will not be affected during the process of soldering. This requires that it should lie considerably below 200° C. Now these two qualities are opposite, since ready melting usually goes with small firmness.

Thus there are difficulties in the way of obtaining a suitable alloy, so that the method of soldering is not in general use.

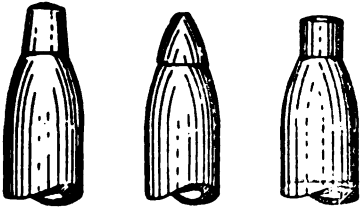
The method of soldering has the advantage that projectiles on hand can be easily fitted with a cap, and in manufacturing new shell no regard need be paid as to whether they will or not be furnished with a cap. A great advantage of soldering in comparison with other means ordinarily employed to attach the cap, lies in the fact that by this process the head of the projectile is not weakened, as it is when grooves or channels are turned in the head. Ridges in the vicinity of the head have the disadvantage that they are liable to cause a cracking upon tempering. When grooves are turned into the head in the finished projectile, the exterior surface is injured, and it may happen that the hard outer layer already under tension may be broken by the strain from within. Not only may the head be cracked in this way, but the whole projectile may disrupt before it is ready to be used.

Another method of attaching the cap is to screw it on the head. Of course this method applies only to the new projectile before hardening.

As regards the material out of which the cap is made, it appears on the whole, that there is more freedom of choice in this than would seem likely at first. The naval-technical committee employed in its experiments a number of different materials, differing very widely in their physical properties and yet no variation was observed in the results. Probably each firm and each State that conducts experiments with capped projectiles uses a different material from any other, with results more or less satisfactory. The chief requirement is a proper amount of elasticity of compression (the material must not be too soft), and a relatively large tenacity, so that the cap will not fly to pieces on impact with the plate.

Nor does it appear that the form of the cap has much effect on the results, since nearly every manufacturer chooses a different one. Some of the more common ones are represented in figure 10, but there are a great many forms besides these. It is essential that the front of the cap should present a broad surface and that it should rest against a large cross-section of the head. The first creates a larger material cone in the plate, the latter diminishes the unit pressure on the head. In any case the best form is the one that produces an adequate effect with a minimum volume and weight. On ballistic grounds it is indifferent what form of head is adopted, for with great velocities this modifies the trajectory very little, which is not the case with low velocities. The greater the velocity the less important is the shape of the head. At the same time it is to be noted that the displacement of the center of gravity towards the point influences favorably the trajectory, increasing both accuracy and range. Many tests by the Krupp firm confirm this fact respecting capped projectiles.

Fig. 10.



Besides the advantage that the capped projectile possesses over ordinary uncapped shell, in that its penetrative power is increased about 20 per cent., there remains to be mentioned the following advantage of the new type, namely, that the shell goes through the plate whole or at the limit of its energy breaks into a few large fragments. This tends to increase the bursting effect very much. The bursting charge of the ordinary armor-piercing shell (and the same applies still more to the weakly constructed fuzed shell) can never be fully utilized because the shell is shattered on the hard exterior surface, so that the explosion occurs in front of the plate and thus outside of the protected area. At best only a few fragments arrive back of the plate and these make a dangerous conical space only in the prolongation of the trajectory. The whole territory back of the place of impact is not rendered unsafe as it should be upon the penetration and explosion of a shell. A satisfactory shell explosion can only occur when the shell arrives intact behind the plate. The use of high explosive preparations insures a mine effect with capped projectiles, even when the inner cavity is small, and a result is produced much greater than that of uncapped fuzed shell that have a much stronger bursting charge.

Unfortunately the value of the cap is not the same for all velocities. A pronounced superiority of the capped projectile compared with ordinary shell is only to be secured with high striking velocities. With low velocities even when the capped projectile has sufficient energy to penetrate the thinner plate, the effect of both types is about the same. Hence at long ranges the capped projectile is no more effective than ordinary shell. The limiting velocity is about 500 m. sec. (1650 ft. sec.), and as this velocity with 12 cm. L/40 (4.7-inch, forty caliber) guns is attained at ranges of 2000 and to 2400 m. (2200 to 2625 yards), and with 15 cm. L/40 (6-inch, forty caliber) guns at about 2800 m. (3100 yards), and with modern 24 cm. guns (9.5-inch) guns at about 7000 m. (7650 yards), it will be seen that the utility of the capped projectile is at best limited to close fighting ranges. At these ranges the effect of the shell is so increased that the cap is of great advantage; beyond the limits indicated above the cap is of no advantage.

TARGETS FOR COAST ARTILLERY PRACTICE

By Captain ROBERT E. WYLLIE, Artillery Corps

THE ultimate object of all coast artillery target practice is so to train the personnel of a battery that it will be able to sink or disable the enemy's ships in time of war. This is evident, but the best means by which target practice can effect this result is not so clear. "Approximate war conditions as closely as possible" is a very general cry; "give us long ranges, such as we use in action, with a target the size of a battleship, then we will know by our 'hits' what we can do." This is true to a certain extent, it will give approximately the result to be expected in action. The entire material and personnel are tested together by this means, and errors in both contribute to cause deviations, but is this the object of the practice? Should we not have some ready method of ascertaining where the errors lie; whether to defects in material or to inefficiency in the personnel, in order that we can learn how to correct them? The training of the personnel is the main object of the practice, our guns, carriages, and ammunion are given to us in the artillery for use; if they are not perfect, if they have errors which we can not eliminate, we cannot help it, our business is to get the best possible results out of them, and let the Ordnance Department attend to the making of improvements in the future. At Sandy Hook is a proving ground where guns, carriages and ammunition are tested before being issued to the artillery for use, and from the results of these tests the Ordnance Department presumably knows the capabilities of its material hence there is no good reason for us in the artillery to include a test of this material in our practices. Let our practice be for our own benefit, to train our personnel to get every thing out of the material supplied us which that material is capable of giving; we can not hope to do more than that, and we should not be satisfied with less.

Does a hypothetical target of the size of a battleship give war conditions or even an approximation to them? It is difficult to see how it can. If we had a material target of the size and dimensions of a battleship our gunners could get some idea of what their battle targets would be like, but a hypothetical target is too immaterial for such a purpose. If we have a hypothetical target at all we are not approximating war conditions by assuming it to be the size of a battleship, whatever size or shape we make it does not change our conditions of firing one iota; at practice all we see is the regular pyramidal target, we bend our energies to the destruction of the object we see, and it would take a very vivid imagination so to materialize a hypothetical battleship as to make a man think that he was firing at a warship instead of at an ordnance target. The hypothetical target is simply to determine the result of the practice, not to affect the practice itself, and from the result of the practice we should obtain data which will enable us to improve our practice on the next occasion; it also affords a basis of comparison between units, leading to a healthy competitive spirit, and it gives to our superiors a measure by which they can gauge the efficiency or inefficiency of the several units. All of which tend to inprovement.

Now as to the means by which this can be effected: First, we must be able to differentiate between the errors due to material, and those due to personnel. With the former, we have nothing to do; it is the latter that demand our attention. We all know that no gun is perfect: that with the same laying no gun will put two shots in the same place; that if a series of shots are fired, with the same laying, from any gun, the points of impact will be dispersed round an imaginary point called the "center of impact"; that a rectangle of a size just large enough to contain all shots which could be fired with that laying is called the "total rectangle"; these matters are fully set forth in the Manual of Coast Artillery, just published, and in the article by Lieutenant-Commander W. S. Sims, U.S.N. entitled "Training Ranges and Long Range Firing," which was reprinted in the JOURNAL,* and it would be like trying to paint the rainbow to enter into a discussion of the subject here. I will therefore assume that the contents of these writings are familiar to all.

Given a perfect comprehension of the total rectangle of any gun, it is evident that any shot fired from that gun, if perfectly laid, *must* fall within the total rectangle, and that is the nearest that can be predicted. As the "Manual" puts it (p. 47): "to keep all the shots within the total rectangle is the best that can

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* See JOURNAL U. S. ARTILLERY, January-February, 1905.

be expected from the gun and indicates perfect accuracy of laying,'' and in par. 17 we find, ''the absolute deviation of the center of impact from the target is the measure of the accuracy of the practice.'' If then at any practice the center of impact coincides with the target, it shows a maximum for the accuracy of the practice, and a rectangle of the same dimensions as the total rectangle drawn about the target as a center will contain all the shots.

This is called the ''total target rectangle'' (par. 19, Manual Coast Artillery), and in general if we find all the shots included within the total target rectangle, it shows that all range-finding and laying have been accurate, in other words that the personnel is well trained and that the deviations of the shots from the target are due to the inherent defects of the material, which are unavoidable and cannot be corrected by us. On the other hand, if all the shots do not fall within the total target rectangle, the center of impact is displaced from the target and errors have been made, either in the range-finding or in the laying, and we can investigate in order to find the error, knowing that there must be one somewhere in the work of the personnel.

In this way all considerations of defects in material are eliminated, and the results will teach us where to look for errors, with a consequent improvement in practice; the practice of different companies at different batteries can be compared without elaborate calculations to allow for ''conditions,'' since the conditions would be identical, and the efficiency or inefficiency of the personnel will be apparent and entirely distinct from the efficiency of the material. And these are the results we want to accomplish.

Our present hypothetical target is 145 yards, by 25 yards, by 8 yards, and it is of the same size for all guns of 4-inch caliber and above, and for mortars, and for all ranges, and makes no pretense of fulfilling the total rectangle conditions. No data is on hand from which the total rectangle for any of our guns can be computed, presumably the Ordnance Department has the data but it has never been issued for the information of the artillery, so far as I am aware, although the Manual says, (par. 18) ''it is exceedingly important that a battery commander should know what is the best a gun will do under the most favorable conditions.'' That is, that he should know the ''errors'' of his gun, and the size of the total rectangle (see pars. 21 and 22, Manual Coast Artillery), but in the absence of any such data, every artilleryman knows from his personal observation that our present hypothetical target is radically different in dimensions from the total rectangle.

Let us first consider the hypothetical target from the point of view of lateral deviation. Under the necessary conditions of practice, the longer axis of the target is never far from being at right angles to the line of fire, this then gives us a permissible deviation of 72½ yards, right or left. Anything inside of that will score a hit, longitudinal deviation not being considered. This is manifestly much greater than the error of the guns. Eighty-eight shots have been fired in target practice from a battery of 10-inch guns at this post, and in no case has the deviation been as great as seventy yards, in fact it is hardly conceivable that such a large error would ever be made except with mortars; "a hit," therefore, means absolutely nothing so far as deviation is considered, and in fact, it is the common experience of all artillerymen that very little attention is paid to deviation, particularly since the end-on target was abolished. It is the "overs" and "shorts" that count, the deviations can take care of themselves,—which is manifestly wrong.

Now as to longitudinal deviations. Our hypothetical target gives us half the beam which equals 12½ yards, plus the danger space for "overs," and half the beam plus half the danger space for "shorts," when considered on the horizontal plane. Our visible target is, therefore, not at the center of this hypothetical target, and if, at any range, this hypothetical target is equal to the total rectangle, it follows that in order to get a maximum number of hits, the center of impact must be beyond the visible target; in other words we have a visible target out there, but if we use it as a target, we do not get as many hits as if we use an imaginary point at an unknown distance beyond. We can never expect to do our best work under such conditions. Now as to the size of this hypothetical target considered in a longitudinal direction. Inasmuch as the danger space forms the greater part of the target, the shorter the range, the larger the target, and *vice versa,* when we all know that it should be exactly the opposite in order to counteract the greater accuracy of the gun at the shorter ranges. Then too, since mortars have practically no danger space, the target permits a deviation of only 12½ yards "over" and the same amount "short", and mortars are certainly the least accurate of all our pieces. At medium and long ranges, experience tells us that it is impossible to make a hit every time, no matter how accurately our personnel may do their part, or to put it another way, the target is smaller than the total rectangle and hits then become largely a matter of luck. The number of hits form no criterion as to the relative efficiency of companies if the target is smaller than the total rectangle, and a failure to get hits does not necessarily indicate poor work, in fact it is not a proper test of anything, and the same applies if the target is larger than the total rectangle. Our consideration of the present hypothetical target thus leads to the conclusion that laterally considered it is too large, and longitudinally too small, that the center is not in the proper place, and that it increases in size when it should decrease, in fact its dimensions are founded on a wrong principle.

If we adopt a target equal in size to the total rectangle, we have something logical. The dimensions of such a target would vary for different guns, and for different ranges, but it would always be of such a size that if the personnel did their work accurately a "hit" would be the result; this would inspire confidence, and, of itself, tend to improve the practice. The battery commander would also have at his fingers' ends the information which he is supposed to have (according to par. 18 Manual Coast Artillery) regarding the best that his guns can do, and this would be of the greatest assistance to him in correcting his fire. I can hear the advocates of the so-called war conditions object to this with such arguments as: "but we will not be firing at a total rectangle in action," or "in that case a ship should be like a lozenge, so it can take the proper size and shape to suit the gun that is firing at it." Such arguments (?) are utterly ridiculous and show that their promoters have failed to grasp the first principle of shooting, whether with large guns or with small arms, which is that a man must first be trained so to use his weapon as to get its maximum efficiency; he will then do good practice at a target no matter what its shape or dimensions may be, and his training target should be the one which would train him best. It is believed that a careful study of the new Manual of Coast Artillery and Lieutenant-Commander Sims' article taken in connection with the above, will show that the total rectangle target will fill this requirement better than any other. If such a target could be a material one it would be of great advantage; Lieutenant-Commander Sims strongly opposes hypothetical targets, but he is, of course, speaking for the navy. Our conditions are not quite the same as those that obtain in the navy; there the gun pointer is the man who needs the training, the range-finding system does not compare in accuracy with what we can do; in fact it is not as accurate as the gun, while with us it is much more so. Since the gun pointer in the navy is the real man to be trained, the range of the target is of small moment, providing the size is equal to the total rectangle for that range; consequently short ranges are the rule, in order that the rectangle will not be too large to prohibit the use of a material target. With us, the range-finding details need training equally with the gunners, it is therefore essential that our firing be at all ranges and at moving targets, but a material target of the requisite size would be entirely too large for handling. We must therefore fall back on the hypothetical, not as a matter of choice, but from necessity. The use of such a target by us is not attended by such disadvantages as would obtain with one in naval practice, we can get the deviations with greater accuracy than can be done there, and we can obtain the range to within the error of the gun.

Our methods of plotting and range finding are such that we can, after the firing, easily see whether material errors have been made in that branch,—provided the proper records are kept,—and, in fact, a hypothetical target, while entirely out of place for naval use, is perfectly feasible and proper for the coast artillery.

When we consider small caliber guns, however, we find that our conditions and those of the navy are very similar. Firing in action for such guns will be at comparatively short ranges, they have no range-finding system, it is simply a matter of getting the range in the first place, and then keeping it. The gunners are the men who need the training, we can therefore revert to the material target, employing it at short ranges only, of a size equal to the total rectangle of the gun for the average range of the practice, which is precisely the same as the navy system and also that used in the army for practice with small arms.

As stated previously a material target of the size and shape of a battleship would be a very useful thing in order to give our personnel a thorough appreciation of the appearance of a battle target; this would be an approximation to war conditions which a hypothetical target can never be, but practice at it should only come after the personnel has been trained to get the best possible results out of their armament by firing at the total rectangle target, in precisely the same way that an infantryman is first trained to shoot at a bull's eye target,—the bull's eye being large enough to include all shots correctly aimed and held,—and after that he takes up skirmish runs at silhouette figures. A material target of such a size is unfortunately impracticable, so that part of the program must be omitted.

The principal targets at which small caliber guns will have to fire in action will be torpedo boats and destroyers, and other swift craft. Our present method of towing targets gives a comparatively slow speed. General Orders, 14, H. A. Division, 1904, in which the practice records for all companies in the Division were published, shows that one company only had the target moving as fast as ten miles per hour, and the majority were not over six; such speeds may do fairly well for practice with large caliber guns, but rapid-fire guns should have faster targets. The Quartermaster's Department is building boats for Artillery District service, towing targets, etc. Why cannot the equipment of such boats include a steam winch at the stern, capable of pulling the target up to the boat, at a speed equal to the speed of the boat? This would double the speed of the target, theoretically. Assuming a speed of eight miles for the boat, with a towline 700 yards in length, two minutes would elapse before the target came within 200 yards of the boat, which is long enough for a series from any of our small caliber guns. This would give much better practice for our rapid-fire gunners.

This is not written in a carping spirit for the sole purpose finding fault with existing methods, but in an honest endeavor to throw light on an important subject, so that when war comes, our coast artillery may be fully prepared for the emergency and render the best possible account of itself.

MOBILE ARTILLERY*

BY CAPTAIN GEORGE W. BURR, ORDNANCE DEPARTMENT

THE term mobile artillery is used designedly in the title of this paper to include all those classes of artillery material which are commonly designated as field, siege, horse, and mountain artillery. There is a certain looseness, or at least lack of definiteness, in the meaning of the terms "field" and "siege" artillery as generally used in the United States as well as abroad, while the term "horse artillery" more frequently carries with it an idea of method of transport of *personnel* rather than that of a distinct type of material. The term "mobile artillery" while very comprehensive in its scope, possesses the merit of definiteness and includes all the classes above mentioned. To traverse such a broad subject in a satisfactory manner within the limits of a brief paper is impossible. The purpose of the following pages should, therefore, be understood to be a general view of the field of progress with an exposition of a few of the fundamental principles governing the design of the latest types of mobile artillery in use in the United States.

Progress in ordnance engineering.—Probably no branch of mechanical engineering has made more rapid progress in the past two decades than that pertaining to the construction of ordnance material. The first half of that period witnessed the development of the modern high-power breech-loading steel gun mounted upon disappearing carriages, of rapid-fire guns of the same type mounted upon ship or fortification mounts and using metallic case ammunition, of the small caliber magazine rifle, and of smokeless powder, not to enumerate many important minor inventions. In fact, to the layman, a casual survey of the field of ordnance construction in this country, as well as abroad, a decade ago, would seem to indicate that the mobile artillery constructor was lagging in the rear, while his colleagues in all other departments were in the van of progress.

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* From a paper entitled "The Art of Designing and Constructing Mobile Artillery," read before the International Engineering Congress, St. Louis, Mo., October 3d to 8th, 1904, held under the auspices of the American Society of Civil Engineers. Published by permission of the Secretary.

Radical innovations and improvements in material were the order of the day, but the mobile artillerist, apparently, had nothing to offer that commended itself to the military wisdom of the day.

The lack of progess in the construction of improved mobile artillery at the time alluded to was more apparent than real. The introduction of smokeless powder and of small arms of great range and accuracy had materially altered battle-field conditions. With the disappearance of the tell-tale smoke of battle, concealment of positions became possible and the exposure of targets short and infrequent. Under such circumstances, the necessity for an artillery of increased power, accuracy and rapidity, to take certain advantage of these fleeting opportunities, was imperative. A subject of such urgency and importance could not fail to be attractive to ordnance engineers, and abroad the best efforts of many able constructors were devoted for years to its consideration. Unfortunately, in this country the incentive to private effort in the line of ordnance construction is not alluring. Experimentation in that field is most expensive, and few individuals or corporations are willing to devote time and money to work of doubtful outcome without some certainty of ultimate adequate recompense. To the credit of our leading gun-makers, it should be stated that much expensive work in this line was done by them with resulting valuable contributions to the fund of ordnance knowledge. It remained for the Ordnance Department of the Army, however, to take up the subject in a thorough investigative manner. The problem was studied diligently from the beginning, experiments were made, and faulty methods and ideas rejected until finally the present types of mobile artillery were designed.

I. COMPONENTS OF A COMPLETE MOBILE ARTILLERY SYSTEM.

Kinds of guns determined by nature of fire required.—Experience gained with some experimental carriages of the new type showed them to be so superior to, and so different in many details from, the old service material that a complete replacement of the latter seemed desirable and was decided upon. This determination immediately brought up for consideration a most interesting question. Under existing conditions, what kinds and calibers of guns should constitute the field and siege artillery of the army? Military men have frequently discussed and seldom agreed upon this and cognate subjects, and it is not the intention to enter here into that discussion, but rather to state the decision reached by the authorities in this country and to give reasons therefor. For the attack of targets, visible or concealed, animate or inanimate, such as troops in the open or in trenches, the walls of buildings or similar objects, a powerful and accurate direct-fire gun is to be preferred in all cases where its firing can reach the target; for the attack of targets which are protected from direct fire, and for use in positions so concealed and sheltered by the terrain that direct fire cannot be utilized, curved-fire guns are necessary. These two kinds of fire are furnished by field guns and field howitzers, and the mobile artillery armament of the army of the United States is to consist of the proper proportion of each.

Considerations affecting the caliber of field guns.—The question of the proper caliber or calibers of field guns is more difficult of decision, although there is general agreement that the caliber of the gun should be proportioned to the work it has to do. A gun of sufficient power for efficient use in the operations of a siege would be too cumbrous to participate in the usual field maneuvers of an army. The caliber of the gun to be used in any given operation is in a measure governed by its maneuvering ability. The piece must possess sufficient power to accomplish the object for which it is used, but the operation as a whole must not be unduly delayed by any unnecessary lack of mobility of the artillery arm. In action a heavier gun would probably prove the more efficient, but the advantage to be derived from its increased size would, in many cases, be more than counter-balanced by the delay in getting into position for use. Thus, the requirements of sufficient mobility and power are seen to be contradictory and interdependent, and the caliber of the gun is obtained by a compromise of these two essentials. If the principles embodied in the preceding remarks were strictly followed in practice, there would result a multiplicity of calibers of mobile artillery, increasing by small differences from the smallest to the largest. The increase in first cost and the difficulty and confusion to be anticipated in active service in the maintenance and ammunition supply of such a large number of different sizes, renders such a system inadmissible. The number of different calibers must be kept to the minimum consistent with an efficient system.

Statement of general principles governing the caliber.—As a result of the foregoing considerations, it may be laid down as a principle that the field gun of general utility should be as powerful as it is possible to make it and still retain sufficient mobility to enable it to hold its position in the more rapidly moving columns in the field, and that the one of next larger size should possess such increased power that the advantages to be anticipated from its use would compensate for the complication of supply and maintenance which its presence would entail, as well as to justify the additional effort required to bring it into action. By this principle the caliber of the gun which constitutes the bulk and main reliance of a field army is first determined, and from it, as a basis, suitable calibers for the other guns of the mobile artillery system are logically deduced. The principle, however, is far from being decisive, and, in its application, a thorough knowledge of past experience and of the possibilities of the new material is necessary.

Total weight limit as a constant factor.—The question of mobility touches upon the one factor in the problem unchanged by the new ideas—the power of the horse. The designer for field artillery is continually hampered in his work by the limitations imposed by this one factor, and therein is found one of the reasons which make the design of such material more difficult than that of seacoast and naval artillery. The experience of many years indicates that the total load behind the horse must not exceed 650 lb. if the artillery is to accompany a field army, actively aiding and not retarding its operations. The figure given is the maximum, and any reduction below this limit is very desirable. The total weight of the gun, carriage, limber and equipment with a suitable amount of ammunition is, therefore, limited to 3900 lbs.

Calibers of light field guns.—Considering now the question of gun power, it may be stated that the shrapnel is the field gun projectile of the most importance, and that the efficiency of its shrapnel fire is a good measure of the efficiency of the gun. That is, other things being equal, the caliber of the gun should be so adjusted as to give to its shrapnel the highest attainable efficiency. The usual battle ranges for guns of this class are from 1 to 3 miles. Tentative computations indicate that a gun of 3-inch caliber firing a 15-pound projectile, will have an efficient shrapnel fire at 6500 yards, or 3.69 miles, and that its maximum range for shell fire may be stated at 4.25 miles. This is a very powerful field gun, and is suitable for adoption, provided the conditions of mobility can be fulfilled. The caliber mentioned fortunately lends itself to a high percentage of weight efficiency in shrapnel construction. Since preliminary calculations showed that the total weight of a 3-inch field carriage with limber and a liberal allowance of ammunition would not exceed the limit of 3900 pounds, that caliber, with a 15-pound projectile, was adopted for the basic gun of the new system of mobile artillery. As actually constructed, the gun and carriage complete with shield, weigh 2300 pounds, the limber 820 pounds, and 36 rounds of ammunition carried in the limber 680 pounds, making a total weight behind the team of 3800 pounds, an amount well within the limit decided upon.

Calibers of heavy field guns.—Economy of transport makes desirable that the gun of next larger size, or the heavy field gun, should habitually be drawn by six horses, a consideration which at once indicates that it is to accompany the slower moving columns of the army and is not to compete with the 3-inch battery in rapidity of movement. It should, however, be capable of rapid movement for short distances. Compliance with these conditions and with the principle previously laid down, requires it to have a marked increase of power with but slight decrease in mobility when compared with the 3-inch field gun. A gun of 3.8-inch caliber, similar to the 3-inch, and firing a 30-pound projectile, would be sufficiently powerful. Computations indicate that such a gun would require a total weight behind the horses of not to exceed 4800 pounds, and, consequently, would have considerable mobility. A piece of that caliber has been decided upon for the heavy field gun of the United States' service.

Calibers of siege guns.—For the siege train, the gun should be as powerful as it is possible to make it, and should not exceed the draft power of an 8-horse team. A piece of 4.7-inch caliber, using a 60-pound projectile, gives a total load behind the teams of not more than 8000 pounds, and has been fixed upon as the siege gun of the service.

Calibers of the howitzers.—As companion pieces for these guns three field howitzers have been laid down. These are of 3.8-inch, 4.7-inch and 6-inch caliber, and fire projectiles weighing 30, 60 and 120 pounds, respectively. Preliminary calculations indicate that the 3.8-inch howitzer material can be constructed to have the same mobility as that of the 3-inch field gun; similarly, the 4.7-inch howitzer has the same mobility as the 3.8-inch gun, and the 6-inch howitzer the same as the 4.7-inch gun. The relatively heavy projectiles of these howitzers give them an enormous shell power compared with guns of the same mobility. It should be noted that the agreement of calibers is not a coincidence, but is the result of calculation in the effort to reduce to a minimum the number of calibers in the mobile artillery system.

Horse and mountain artillery.—For the horse artillery, no separate piece has yet been provided. To give the requisite mobility to such an equipment, the total weight behind the teams should not exceed about 3000 pounds. Our mountain artillery has, in the past few years, been equipped with an efficient material of foreign design. This equipment is of 75-mm. caliber, arranged for pack or draft transport, and is built on modern lines. An attempt is to be made to improve this material by increasing the caliber to 3 inches, and by giving the gun a long recoil upon the carriage so as to increase the firing stability.

Recapitulation.—To recapitulate, the complete mobile artillery system, as proposed, consists of:

The mountain artillery;
The light field material, comprising the 3-inch, 15-pounder gun, and the 3.8-inch, 30-pounder howitzer;
The heavy field material, consisting of the 3.8-inch, 30-pounder gun, and the 4.7-inch, 60-pounder howitzer; and,
The siege material, consisting of the 4.7 inch, 60-pounder gun, and the 6-inch, 120-pounder howitzer.

All this material, except the mountain outfit, is of domestic design and construction, and embodies our most advanced ideas in this line of engineering. All the carriages are of the class known as gun-recoil carriages, in which the energy of recoil is absorbed, and the gun returned to the firing position by devices in the carriage itself without sensible displacement of the latter upon the ground.

II. THE INITIAL VELOCITY.

Remaining velocity necessary for efficient shrapnel fire.—The kinds and calibers of pieces and the weights of projectiles to be used having been decided, the next important point to be determined is the proper initial velocity for each piece. Fortunately, the reasons which have induced engineers in other departments of ordnance construction to increase the initial velocity to the extreme practicable limit do not hold good in the design of mobile artillery. Their object is to obtain at extreme ranges the greatest possible penetration of targets protected by armor or by permanent works. The target of the field artillerist is composed for the most part of animate objects, either unprotected, or but slightly shielded by hastily constructed shelter, and is, therefore, quite vulnerable. The projectile most commonly used is the shrapnel, which is satisfactory, ballistically considered, when its balls have a velocity destructive to animate objects at all practicable ranges. Some indication of what velocity will fulfil this requirement may be gained from the fact that the velocity of the caliber 0.38 army revolver bullet at a range of 25 yards, is 690 feet per second, and at a range of 100 yards, 637 feet per second; its bullet is known to be fatal at these ranges. An equal velocity for a shrapnel at its point of burst would make its missiles effective if of equal sectional density.

Influence of improvements in gunpowders on the remaining velocity.—The improvements in gunpowders in recent years, from which mobile as well as other artillery has greatly benefited, have resulted in a better regulation and utilization of the force of the powder gases, so that it is now possible to fire, from a gun of given caliber, a projectile of much greater weight than formerly without a corresponding increase of the maximum pressure in the bore of the gun. The heavier projectile, as is well known, has a much better carrying power than the lighter one of the same caliber; it retains its velocity for a longer time and for greater ranges. In other words, the shrapnel range of the modern gun has been greatly extended. For the 3-inch field gun firing a 15-pound shrapnel, at the muzzle velocity usual for such guns, 1700 feet per second, the remaining velocity at a range of 6500 yards is, approximately, 700 feet per second, so that if the shrapnel were opened at that point in its flight without change in the velocity of its balls, they would have an effectiveness comparable to that of the revolver bullet at the ranges before stated.

Influence of improvements in shrapnel construction. Range limit of shrapnel fire.—But advances made in shrapnel construction enable this showing to be improved. Using a strong steel shrapnel case with a base charge and a point fuze united to the case in a joint forming a section of least strength, the explosion of the charge projects the balls from the case to the front with an average increased velocity of 250 feet per second. The 3-inch field-gun shrapnel bullets would, therefore, have, at a range of 6500 yards, a velocity of approximately 950 feet per second. There can be no doubt of the destructive effect of such missiles; in fact, this velocity could be reduced or the range increased and a shrapnel fire, efficient as far as velocity is concerned, still maintained. For the 3.8-inch field gun, the range corresponding to an equal velocity of shrapnel bullets is about 8000 yards, and for the 4.7-inch field gun 10,000 yards. It should be stated, however, that the maximum ranges of shrapnel fire for these guns are less than those given, and are limited by the difficulties attending the manufacture of time fuses, and that a range corresponding to a time of flight of 22 seconds, is probably the present limit of effective shrapnel fire.

Effect of changing the initial velocity.—The results before stated are for a muzzle velocity of 1700 feet per second. An increase or decrease of 100 foot-seconds in the muzzle velocity changes the remaining velocity at the extreme range only 15 foot-seconds. As it has been shown that the remaining velocity is ample for efficient shrapnel fire, no necessity exists for increasing it on that account, while consideration of the firing stresses upon the carriage would lead to its decrease rather than to its increase. For a given gun and projectile, the velocity of free recoil varies with the muzzle velocity of the projectile, and the energy of recoil which is taken up by parts of the carriage, varies with the second power of the velocity of recoil. It follows that the work which the carriage must do in withstanding the firing stresses, increases quite rapidly as the muzzle velocity is increased, and, consequently, from that point of view, it should be kept as low as possible. On the other hand, as this velocity is decreased, the elevation necessary to reach a given range is increased. In the practical construction of the modern type of field carriage, it is difficult to secure for the lighter carriages an elevation of more than 15° or 16°, and for the heavier carriages, 17° or 18°, without undesirable complication or extension of parts. These elevations give approximately the maximum ranges before stated with a muzzle velocity of 1700 feet per second. Since preliminary computations indicated that the different sizes of direct-fire gun carriages could be constructed of ample strength to endure the stresses due to this velocity, and, at the same time, come within the prescribed limits of weight, an initial velocity of 1700 feet per second was adopted.

Initial velocity for howitzers.—The field howitzer carriages are specially designed to permit high angle firing. The angle which the direction of the firing stresses makes with the principal lines of the carriage is unavoidably large, so that the stresses must be reduced as much as possible. The use of the howitzer for searching cover at all ranges makes a large angle of fall desirable. These conditions require the muzzle velocity to be as low as is consistent with proper ballistic effect at the target. Projectiles moving at the velocities which would be regarded as suitable for howitzers, are not subjected to the high air resistance that so rapidly reduces and tends to equalize in the first moments of flight the rates of motion motion of field gun projectiles of different initial velocities. The result is that for the same howitzer a difference of initial velocity is well preserved down the range, and the constructor, instead of having considerable latitude in his selection, is limited to such as will give an adequate remaining velocity. A consideration of these conflicting requirements leads to the selection of an initial velocity of 900 feet per second for the howitzers of our artillery service.

III. POWER OF THE PIECE.

Service 3-inch field material selected as a type for further discussion.—Having reviewed the general principles which have governed in the adoption of a logical mobile artillery system, and in the selection of types and calibers of pieces and the proper initial velocity for each, it is next in order to consider the various points in which this new material is believed to show a marked advance over that formerly in use. The subject may be better discussed by reference to some particular equipment, and for that purpose the service 3-inch field battery is selected. This equipment has been fully described in technical publications,* and it is only necessary to state here that the gun moves in recoil upon an enclosed U-shaped slide or cradle, which forms a housing for the single hydraulic buffer that checks the recoil, and for the springs that return the gun to firing position. Pointing in elevation is provided for by a movement of the gun and cradle about the axle, and, in direction, by a movement of the same parts upon a pivot directly over the axle. Motion of the carriage upon the ground is prevented by a fixed trail spade.

Comparative powers of the 3-inch and 3.2-inch guns.—One of the more noticeable points of superiority of the modern field gun over that in use ten years ago is to be found in the power of the piece as measured by the energy of the projectile at different points of the range. In Fig. 1, are plotted curves giving the remaining energy as a function of the range for the 3-inch field gun and for the old 3.2-inch gun. At all ranges

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* JOURNAL U. S. ARTILLERY, November-December, 1903.

common to the two pieces, the power of the latter model is about 40% the greater, and, at the extreme range of 7000 yards, it is approximately equal to that of the 3.2-inch gun at 4500 yards. This result is, of course, due to the smaller caliber and greater weight of projectile of the 3-inch gun. Compared with the 3.2-inch, 13.5-pound projectile, the 3-inch, 15-pounder, has more weight and energy per unit of cross-section, presents less surface to the air resistance, expends less energy in overcoming it, and, consequently, has more remaining for useful work.

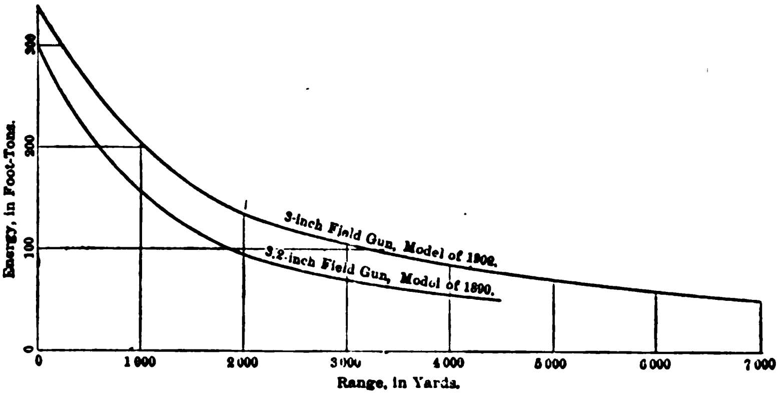


Fig. 1.

Increased power mainly due to powder used.—As has been intimated this superiority is due in the main to improvements in gunpowders, a discussion of which is beyond the scope of this paper. It is sufficient to state that the tendency has been so to regulate the evolution of the powder gases, as to develop and maintain a much higher pressure than formerly during the passage of the projectile through the forward portion of the bore, without exceeding at any time the limiting permissible pressure. The gun is a simple form of an engine; the powder-pressure curve is its indicator card. The powder maker and the gun designer work together; the former by providing a suitable size of grain, the latter, a suitable weight of projectile and length of bore, to the end that as large a proportion as possible of the powder energy may be imparted to the projectile; in other words, to secure the highest efficiency for the engine.

Changes in gun construction—Use of nickel steel.—The increase in power has led to no radical change in the construction of the gun. The higher chase pressures require a strengthening of that portion, while the more gradual development of the maximum pressure has permitted a slight decrease in the diameters of the powder-chamber sections. The greatest advance is to be found in the use of nickel steel as a gun material. The physical requirements for this steel, with those of the carbon steel formerly used for field guns, are given in Table 1. The increase in the elastic strength of the structure consequent upon the use of the stronger metal requires no comment.

TABLE 1.

Designation.	Elastic limit, in pounds per square inch.	Tensile strength, in pounds per square inch.	Percentage of elongation after rupture.	Percentage of contraction of area.
Nickel steel for tubes, jackets, etc	65000	95000	18	30
Carbon steel for 3.2-in. tubes.	42000	78000	20	35
3.2-in. jackets	46000	86000	17	30

IV. RAPIDITY OF FIRE.

Causes contributing to increased rapidity.—A second point in which the new material excels the old is rapidity of fire. To this there are several contributing causes, such as fixed ammunition, smokeless powder, percussion primers, quickly set fuzes, rapid-action breech mechanisms, improved pointing arrangements and better sights. But all these, while necessary, are in a measure subsidiary to the one factor that renders a rapid fire from a field gun practicable—that is, the stability of the carriage.

Effect of fixed ammunition and improved fuzes.—For any material the interval between successive rounds is determined by the time necessary to load, aim and fire. Any change that reduces the time of these operations conduces to rapidity of fire. The time required for aiming is closely connected with the subject of sighting and pointing mechanisms, and with the larger one of the stability of the carriage under firing stresses, and, in that respect, will be considered later. The time required for loading and firing depends mainly upon the nature of the ammunition and the type of the breech mechanism. It was greatly reduced by the invention and adoption of a time fuze capable of quick adjustment, and by the substitution for separate powder charge, projectile and friction primer, of a single cartridge combining these three elements. The increased visibility of the target, or aiming point, due to the use of smokeless powder, and the omission of the smoke-producing cartridge bag, has, in many cases, a considerable influence upon the time between rounds. As far as the nature of the ammunition is concerned, these changes comprise the principal items of progress toward rapidity of fire in the last decade.

Essentials of a field gun breech mechanism.—A suitable breech mechanism for a modern field gun must be arranged so as to be opened and closed rapidly, and when closed, fired by a simple motion. It must, moreover, be fitted with such positive appliances as will render the firing of the piece impossible before the breech is safely locked. The mechanism used on the 3-inch field gun is of the interrupted-screw type, opened by a single motion of a horizontal lever. The firing pin remains uncocked until the last movement in closing the breech. The piece is fired by a short lever motion arranged so as to be inoperative when the piece is not in a safe position in battery. The safety devices are positive and prevent accidental firing when the breech is open or before the gun has returned to its in-battery position.

Points of merit of the service breech mechanism.—Mechanisms of various types have been proposed for adoption and tested in the United States in the past few years, but none have possessed more points of merit than the service mechanism. These advantages may be enumerated as follows: Rapid rate of fire; great power of extraction and ejection of empty cases and also of rotation of block; cartridge does not require to be pushed as far into the breech in loading as in many other types; breech, well closed for protection against dust; parts, few and simple, and easily assembled without tools; light weight of mechanism; prevention of premature discharge in closing the block, due to a protruding firing pin. This last point covers the most potent objection urged against the interrupted-screw type of mechanism, since there are on record enough instances of fatalities, due to such premature discharges, to condemn any system in which they are not positively prevented. The safeguard adopted for the service mechanism consists in locating the firing pin eccentrically in the block, so that it is brought opposite the primer only when the block is safely closed.

Mechanically operated breech mechanism.—This mechanism is opened, closed and fired by hand. Devices for performing these operations mechanically are in use on seacoast and naval guns of small and medium caliber, and contribute somewhat to increase the rapidity of fire, and to reduce materially the manual labor of serving the piece. For field guns, such devices have not been favorably considered. They unavoidably lead to some complication of parts and additional weight. For slow firing, they are obviously unnecessary; for rapid firing, experience indicates that the time required for verification and correction of aim between shots, is generally greater than that necessary for performing the operations of loading and firing by hand. The idea of a mechanically operated breech mechanism for field guns is, however, a very attractive one, in that it reduces by one the number of gun servants, and, for work requiring regularity and precision, substitutes an unfailing mechanical agent for an uncertain human one. Its adoption for mobile artillery service is apparently in the line of progress and will probably follow the perfection of a suitable simple device.

V. STABILITY OF THE CARRIAGE.

Necessity for preventing carriage recoil.—In all mobile artillery material existent some years ago, the carriage had considerable ground recoil at each shot, and the interval between successive rounds was determined, in a large measure, by the time required for the gun crew to replace the carriage in firing position, to relay the piece in direction and elevation, and to jump clear of the carriage before firing. These operations were performed consecutively, consumed much time, and, in rapid work, were quite fatiguing. It was apparent that efforts to increase the rate of fire must be directed toward reducing or preventing altogether the ground movement of the carriage. Attempts to accomplish this end by placing recoil brakes of different kinds between the carriage and the ground were found unsatisfactory; the action of such brakes was not uniform, due to the diversified conditions of the firing grounds, while the carriage movement compelled the gun crew to jump clear of the wheels before each round. Constructors then approached the problem in another manner and gave the gun a movement in recoil upon the carriage, in the endeavor to control and reduce the force which produced recoil of the carriage upon the ground. The idea was not a new one, since existing naval and fortification gun mounts utilized such a gun movement to reduce materially the firing stresses transmitted to the carriage.

Conditions necessary for stability.—The results of experiments indicated that the carriage should have no motion upon the ground and no jump of the wheels if the time of aiming is reduced to a minimun, and the maximum rapidity of fire obtained. To eliminate the jump of the wheels, the resistance to the movement of the gun upon the carriage must be regulated so as to make the moment of this resistance around the end of the trail less than the gravity moment around the same point. The latter moment is limited by the conditions of mobility, so that for a suitable firing height and length of trail, the moment of the resistance to recoil can be kept within the desired bounds only by increasing the length of recoil from 4 calibers, that usually given naval and fortress guns, to 15 calibers. The difficulty of obtaining this length of recoil within the prescribed limits of weight is increased by that of providing means for returning the gun to the firing position after recoil. On the service field carriage, the gun is given a movement of 45 inches upon the carriage.

Use of trail spade.—The ground recoil is prevented by a fixed trail spade. Upon the average firing grounds, such a spade will not satisfactorily prevent movement of the carriage when the pressure of the earth against its working surface exceeds about 50 pounds per square inch, a rule by which the proper size of the spade may be determined. The angle made by the spade surface with the ground line is important, and should be such as to cause the spade to take hold well, while avoiding an excessive tendency to bury. This burying should also be guarded against by floats or horizontal wings attached to the spade and bearing on the surface of the ground.

Proper location for spade.—A trail spade should not interfere with limbering up, or limit the turning angle of the carriage, and should be arranged so as not to reduce the free height under the vehicle on the road. In larger sizes of mobile artillery, these conditions cannot be fulfilled by a rigid spade, and resort must be had to a pattern which may be folded up out of the way for limbering up and traveling. The spade, located at the end of the trail, is set by the pressure of the latter upon the ground in firing and is subject to the objection that considerable effort is required to shift the trail when the spade is once set. This trail spade, however, is found from experience to be less objectionable than one attached to the axle, or than any form of wheel shoes for accomplishing the same purpose. In firing the weight sustained by the wheels is relieved largely, with the result that the carriage "rides" upon a ground recoil brake, if placed near the front, and its stability is greatly impaired.

Hydraulic recoil brake and spring return on the service carriage.—In the service carriage, the gun recoil is checked by a single hydraulic buffer, and the gun return secured by helical springs—each movement being independent of the other. The hydraulic brake is preferred to other styles because it can be readily arranged to give that regulation of resistance to gun recoil considered essential, and, moreover, it is shown by experience to be simple, effective and reliable. Springs are well understood, simple mechanical contrivances, not easily gotten out of order and require practically no care when once assembled. The provision of an independent mechanical means of securing counter-recoil is regarded as superior to the use of compressed air for that purpose, or of a spring pressure upon a liquid column. The practicability of confining compressed air under service conditions without leakage is doubted, while the use of springs acting on a liquid column, constituting the recoil check, makes the proper regulation of the recoil difficult and introduces other complications.

Advantage of having cylinder recoil with gun.—In the service field carriage as constructed, the hydraulic cylinder recoils with the gun, the piston being attached to the carriage. This arrangement increases the weight of the recoiling mass and decreases the maximum velocity of recoil. The result is a decrease in the total energy of recoil and in the resistance to recoil, with an increase in the stability of the carriage. Some of this advantage is neutralized by the decrease of the gravity moment around the end of the trail, due to the rearward movement of the additional weight, but the net result is a gain in stability and should be secured in all cases where this particular construction is otherwise adaptable. Where the counter-recoil device consists of a single column or of concentric columns of springs, this construction possesses the additional advantage that the springs may be assembled upon the cylinder, affording it protection and saving the weight of a separate spring rod.

Stability line of the carriage.—The regulation of the total resistance to gun recoil, so as to suppress the jump of the wheels, is accomplished by suitable variation of the area of the orifices for the flow of liquid past the piston in the cylinder. The moment of this resistance about the end of the trail must not exceed, at any instant, the gravity moment of gun and carriage about the same point, which is a maximum when the gun is in battery, and decreases as the piece moves to the rear in recoil. The resistance required to neutralize this moment is graphically represented by a line, as *A B*, in Fig. 2, called the "stability line" of the carriage. This stability line is laid down for the gun at 0° elevation since, if the carriage has sufficient stability at that elevation, it will have greater stability at all positive elevations.

Components of the resistance to gun recoil.—In practice, to secure excess stability, the total resistance to gun recoil is placed somewhat below that given by the stability line, and may be represented by the line, *E F*, in Fig. 2. The total resistance is the sum of the frictional, spring and hydraulic resistances. The frictional resistance may be assumed as constant. The counter-recoil springs are assembled under sufficient initial compression to return the gun to its firing position at maximum elevation. The spring and frictional resistances are readily computed, and their sum may be represented by the line, *C D*, in Fig. 2. The resistance to be offered by the hydraulic cylinder at different points in recoil is then given by subtracting these values from the corresponding total resistances (ordinates of line, *E F*, minus those of line *C D*).

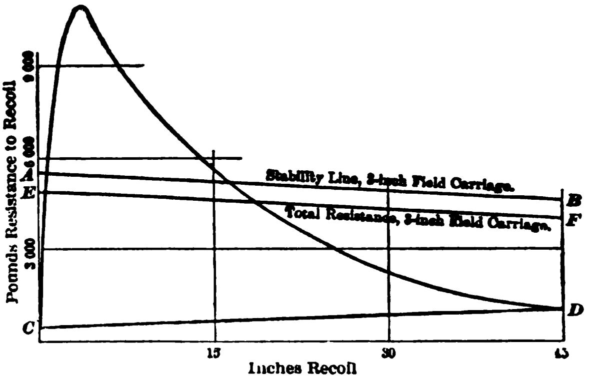


Fig. 2.

The desired cylinder resistance being known, the problem to be solved by the constructor is to determine the area of the orifice, so as to develop this amount of resistance to the flow of the liquid past the piston.

Method of constructing cylinders to give correct throttling areas.—In the design of these cylinders, the proper variation of the areas of the orifices is secured by notches in the periphery of the piston, registering with throttling bars of uniform width but varying height, forming solid ribs on the cylinder wall. Throttling bars thus formed give the cylinder the necessary longitudinal stiffness and permit easy verification, with the star gauge, of the accuracy with which the prescribed dimensions are attained.

They are to be preferred to throttling grooves cut in the wall of the cylinder or to any form of valve for accomplishing the same purpose. The moving parts of the latter are objectionable, and their correct working under service conditions problematical. Throttling grooves avoid these objections but involve unnecessary thickness of the cylinder wall and difficulties in the verification of their sectional areas. The bores of the service field carriage cylinders are approximately 2.25 inches in diameter and 6 feet long, and their finishing to the accuracy required is a tedious and rather unusual machine-shop operation; but once accurately finished and assembled, the parts cannot become disarranged and must continue to perform their functions with regularity,

Automatic regulation of length of recoil.—A feature of these cylinders with variable orifice is a practically automatic regulation of the length of recoil under varying ballistic conditions. With reduced powder charge, the velocity of recoil and the cylinder resistance is low, and the recoil is slightly less than normal; with excessive charge, the cylinder resistance is higher than usual, and, at the end of normal recoil, the orifices of flow are closed (except necessary clearances), so that the motion of the piece is arrested with but little excess movement. This feature forms a simple yet valuable safeguard against injury to the recoil mechanism, due to excessive powder pressures.

With cylinder resistance graduated as described, the total initial resistance to recoil is pitched as high as the stability requirements will permit, and throughout recoil the resistance is similarly maintained, so that the length of recoil is the shortest possible under the conditions imposed; in other words, the efficiency of the carriage as a recoil-controlling machine is the highest obtainable. Compared with it, a carriage with a cylinder having orifices of constant area would have a greater length of gun movement for the same stability, or less stability for the same length of recoil. This is shown diagrammatically in Fig. 2, in which the curve represents approximately the total resistance to gun recoil for the 3-inch field carriage with an assumed constant orifice and a length of recoil of 45 inches.

All those portions of the ordinates of this curve above the stability line *A B*, measure force acting directly to produce jump of the wheels.

Control of counter-recoil.—To maintain that steadiness under firing stresses considered necessary, the counter-recoil, as well as the recoil of the piece, must be accurately controlled. If this is not done, the gun may return to battery with sufficient violence to raise the trail from the ground and to throw the piece off the target. In the service field carriage, the counter-recoil movement is secured by spring action sufficiently powerful to to return the piece at maximum elevation, and, therefore, stronger than that needed at lower elevations. All shock of return is, however, avoided, and the gun eased into its firing position by a buffer, consisting of a rod fixed to the cylinder and fitting with small clearances into a bore in the front end of the piston. Liquid caught in this bore can escape only by these small clearances with the result that the energy of return is dissipated without derangement of aim. For the most effective action, the buffer should be of considerable length, and its cross-section so varied as to offer a suitably graduated resistance to the return motion. Thus arranged, the resistance of the buffer is highest for low elevations, when the springs have excess strength and give a rapid return motion, and lowest for high elevations, when the springs have comparatively little surplus strength, and the counter-recoil is correspondingly slow. Thus, the device is, in a measure, self-regulating; it is simple and positive and has no loose parts to get out of order.

Use of road brake as a firing brake.—In connection with the methods of maintaining the firing stability of the carriage, the use of a well-constructed road brake as a firing brake should be mentioned. On gun sites such as macadam roads or paved streets, where the trail spade cannot get hold, such a brake materially limits the carriage movement; on firing grounds sloping to the front, it should be used to check forward movement of the carriage, due to the impulse of counter-recoil; and, in general, upon sites of all kinds, it will be found a valuable aid. The brake should be capable of being set and released quickly on the road as well as in action, sufficiently powerful for one man to skid the wheels, and so placed as not to interfere with the laying and serving of the piece. This latter condition almost necessarily requires the shoes to be placed in the rear of the wheels (carriage limbered). For the smaller calibers of mobile artillery, a lever-actuated brake is sufficiently powerful and should be used on account of its rapidity of action. For heavier carriages, some form of a screw brake giving more power is to be preferred.

VI. THE POINTING APPARATUS.

Necessity for, and method of, securing azimuth movement of gun on carriage.—Having now discussed the methods by which the modern field carriage is given that steadiness in action deemed essential for rapid fire, it is in order to consider in what manner these changes have influenced the pointing and serving of the piece. The use of a trail spade for checking the ground recoil put an end to the old practice of pointing in direction by shifting the trail; in fact, without the trail spade, the time required for accurate pointing by that method was incompatible with rapid fire. The modern carriage being fixed in position, so to speak, it is necessary to give the gun a motion in azimuth upon it, so as to permit of limited changes in the direction of fire without the necessity of shifting the trail. Two methods of securing this motion have been proposed and are in use to-day—one by axle traverse, in which the gun and carriage are moved along the axle about a center of motion at the end of the trail; the other by pivot traverse, in which the gun and upper carriage are pivoted upon some part of the lower carriage. The former method has the advantage that the direction of gun recoil is directly toward the point of support of the trail, and the tendency to sidewise displacement of the wheels in firing is a minimum. It is open to objection on account of the mass to be moved, the great amount of movement for relatively small changes of direction, and the complications involved in the attachment of road brakes, shields and axle seats to a carriage so constructed. In the pivot system of traverse, as adopted in the United States, the mass to be moved is smaller, the center of the mass is placed directly over the center of motion, giving a rapid movement with but little effort, the center of motion is placed over the axle requiring a smaller opening in the shield, and a large portion of the axle is left free for the attachment of shields, axle seats and other fixed parts of the carriage.

Limit of azimuth movement.—The amount of angular motion which can be obtained by either method is limited to about 4° each side of the center. For axle traverse and the usual length of trail, this requires a total movement of the upper carriage upon the axle of approximately 16 inches, which is fully as much as can be secured with due regard to other features of the construction. For pivot traverse, the amount of azimuth movement is limited by by the fact that, except when the gun is in the position of mean traverse, there is a component of the force of recoil tending to displace laterally the carriage wheels. For angles of traverse exceeding 4° this component becomes so large as to cause such derangement of of the aim as to interfere with rapidity of fire. An azimuth angle of 8° sweeps a front equal to approximately one-seventh of the range, or much more than sufficient to cover any usual target. For greater changes in direction, the position of the carriage must be shifted.

The elevating apparatus.—No noticeable change has been made in the elevating apparatus in recent years. The old form of double screw is rapid, simple and sufficiently powerful and, with a suitably designed nut, is practically self-housing. The provision of an elevating gear crank at each side of the trail permits of giving elevation from either side, as desired.

Manner in which the improvements noted increase rapidity of fire.—Since the gun moves in recoil upon a slide or cradle, it is necessary that the latter participate in the motions of azimuth and elevation, and the universal joint giving these movements is placed between the cradle and the lower carriage. The sights are attached to the gun slide and remain in position during firing. The carriage does not move, and the gunner is seated upon some portion of it, with the elevating and traversing hand-wheels conveniently at hand, so that the operation of sighting is made a continuous one. Similarly, the other gun servants remain in proper position, either seated or standing during the firing, and the time between rounds is reduced to the time actually necessary for the motions of loading and firing. Thus the stability of the gun-recoil carriage enables the operations of running the carriage by hand to the firing position, shifting the trail for pointing and jumping clear of the wheels before firing, characteristic of the ground-recoil carriage, to be eliminated. These operations were the time-consuming ones which prevented real rapidity of fire with the old carriage.

Gun sights.—The sighting apparatus for field guns has kept pace with their improvements in other respects. The open sights are attached to a non-recoiling part and remain in place during firing. They are not subjected to the same amount of rough usage as the earlier style of sight and embrace more refinements. Thus the rear sight is provided with a seat for a telescopic sight and is fitted with sensitive clinometer and cross-levels—the former for quadrant elevations, and the latter for difference of level of wheels. Some form of telescopic sight is a necessary result of the great increase of range of the field gun, the target of which may be at such a distance that it is unseen, or but dimly seen by the unaided eye. The increasing use of cover and of indirect fire have necessitated a sight permitting rapid laying of the gun where the target is hidden. These two requisites are combined in the panoramic sight, which is a telescopic sight, so fitted with reflectors and prisms that the observer, with his eye at an eyepiece fixed in position, may bring into the field of view any object upon the horizon, the image of the object appearing magnified, but otherwise as if viewed directly by the unaided eye.

The range quadrant—Division of duties of pointing the piece.—Such a sight may be used for direct aiming and is very accurate; but for indirect laying when the aiming point is to the right or left of the gun position, the actual elevations are not as accurate as they should be. In such cases, direction should be given by the sight and elevations by the quadrant. For this purpose an improved form of quadrant is provided, in which the ranges in yards are set off directly on the quadrant dial. The sights are located on one side of the carriage, and the range quadrant on the other, and, since the elevating and traversing movements are entirely independent of each other, the arrangement permits of the assignment of pointing for direction to one cannoneer, and of that for elevation to another. This division of the pointing duties reduces the total time of aiming, and, as the interval between rounds in rapid fire is determined by the time required to rectify the aim, the arrangement tends materially to increase the rapidity of fire.

The battery telescope.—Full advantage cannot be taken of the greater range and accuracy of the new material and of the refinements of the sighting arrangements without some means of observing and correcting the fire. For this purpose each battery is provided with a telescope of the general form of the panoramic sight, but much larger and more powerful. The telescope has an all-around azimuth motion and a limited motion in elevation, and forms an accurate angle-measuring instrument. It is used in observing, range finding and fire directing. The scales of the telescope, the different sights and the range quadrant are similarly graduated, so that a reading may be transferred from one instrument to another without computation or reference tables.

VII. PROTECTIVE SHIELDS.

Necessity for protection.—When cannoneers had to step clear of the wheels before firing and manhandle the carriage after each round, they were necessarily much exposed, and protective shields placed upon the carriage would afford them but intermittent shelter, while the wisdom of supplying shelter which they would be slow to quit in emergencies was doubtful. In the service of the modern carriage, the cannoneers are seated or closely grouped near the breech of the gun, in such a position that excellent protection is possible. Their duties seldom require them to leave such shelter. The caisson is unlimbered beside the carriage so as to have the ammunition close at hand, and the ammunition servers pass the cartridges to the gun crew without quitting their positions. An uninterrupted gun and ammunition service requires that these crews, if possible, be undisturbed by hostile fire. Shield plates of sufficient strength to resist small arm and shrapnel fire are, therefore, considered a necessary addition to modern field carriages and caissons.

Form of shields.—In the design and manufacture of hardened steel plates, complicated forms are to be avoided—the simpler the design, the better the resulting plate, while complication leads to increased weight. For the service field carriage, three flat shields are used—an apron hinged under the axle, a main shield fixed above the axle, and a top shield hinged to a main shield and arranged to fold down upon it in traveling. The joint between the main and top shields is below the tops of the wheels to avoid injury to the shield from accidental overturning of the carriage. The caisson protection consists of a shield plate forming the front of the ammunition chest, and an apron hinged under the axle.

Test of shields.—These plates are 0.2 in. thick; each one is subjected to a ballistic test before being accepted. This test consists in firing at the plate at a distance of 100 yds. with the service rifle and ammunition (muzzle velocity 2300 ft. per sec.). The plate must not be penetrated, cracked or broken. Each shield in the service bears the scar of this test, which is thus an affirmative guaranty to the soldier of the quality of the protection afforded him.

VIII. AMMUNITION TRANSPORT—MOBILITY.

Method of carrying ammunition.—The change in the nature of the ammunition used with the new artillery has necessitated a change in the provisions made for carrying it, but otherwise no radical alteration has occurred in the design of mobile artillery limbers and caissons. A simple and satisfactory method of transporting fixed ammunition in the field is to place it horizontally in the chest, each cartridge resting in holes in vertical diaphragms, provided for the purpose. The chest should be rigidly connected to the frame of the vehicle and not mounted upon springs or cushions of any kind; tests show that cartridges packed, as stated, will withstand the hardest usage and will be uninjured by treatment that will destroy the springs, unless the latter are made so stiff as to preclude any benefit from their use. No separate holders or baskets are required. They add weight, are in the way when empty and time is required to extract the cartridges from them. The baskets are seldom of use for carrying the ammunition, since it is habitually served from the caisson alongside the piece. When carried as indicated, the ammunition is held in place by the closed chest door pressing against the rear face of the cartridge. When the door is open, all ammunition in the chest is available for use without any further release of the fastenings. A valuable detail of such an arrangement is a suitable corrugation of the chest door, stiffening it, acting as a primer shield and rendering unnecessary any wooden or felt lining or separate protection.

Kinds of ammunition to be carried.—The ammunition carried by a field battery includes high explosive shell and shrapnel, forming cartridges of different lengths. The chests should be made of sufficient capacity and so arranged as to take either of these cartridges. The proportion of each to be carried in each chest and in the battery is then not limited by the construction, but remains a matter for regulation according to the particular service in hand.

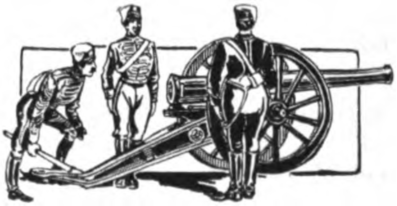
Number of rounds carried.—The quantity of ammunition carried in the chests of the different vehicles is determined by the weight limit, which for light field artillery is 3900 pounds. The weight limit thus fixed enables 36 rounds to be carried in limber chest. The carriage and caisson limbers should be interchangeable, and all vehicles of the battery should have equal mobility. The weight of the loaded caisson fully equipped should, therefore, be the same as that of the carriage, a condition which permits of provision for 70 cartridges in the caisson chest. The ammunition load for each caisson with limber is thus 106 rounds, and for each carriage with limber, 40 rounds (4 rounds for emergency use being placed on the carriage in special receptacles under the axle seats). With a battery organization of 3 caissons per carriage, the total ammunition supply is 358 rounds per gun.

System of draft.—Closely connected with the subject of mobility is the method of draft and the diameter of wheels to be used. Experience of many years shows the continuous-trace system and pivoted double-tree to be superior to pole draft and rigid splinter bar, in that the former is more flexible, gives better control of the vehicle, and causes less horse fatigue.

Diameter and lubrication of wheels.—Theoretically, the tractive force required increases as the diameter of the wheels decreases, and practical tests confirm this view. Wheels of large diameter give a greater free height under the vehicle; but for gun-recoil carriages, an increase of the height of wheels increases the firing height, requires a longer trail to secure the same stability, and adds weight. After careful consideration of the advantages and disadvantages of large wheels, the American constructor has decided in their favor and has adopted wheels of 56 inch diameter for light, and larger ones for heavier field carriages, and, in that respect, has departed from contemporary foreign practice. The service field carriage wheel is connected to the axle by a dust-proof, oil-retaining device instead of the old form of linch-pin and washer. The wheels are oiled without removing them from the axle. The latter is hollow and forms a reservoir for oil, so that the lubrication of the wheel is continuous. This improved lubrication with a rational system of draft, large wheels and limited weight gives the material a mobility greater than that of the older types.

IX. TENDENCY OF PRESENT EFFORTS AT IMPROVEMENT.

In the preceding pages, an attempt has been made to present a general view of field artillery construction as it exists in the United States to-day. The progress in the last decade has been most decided. The accuracy, rapidity and power of the gun have been vastly increased; the type of carriage has been radically altered, but the method of transport remains unchanged. The period of progress seems not yet passed, and perfection in mobile artillery material is still far from being realized. What the next decade will bring forth cannot be foretold, but judging by the tendency at the present time, important changes may be anticipated. Such changes will most probably assume the form of automatic guns of large caliber, improved recoil mechanism for carriages, or power transportation for the greater part of the material. The new model caissons are provided with pintles, so that they may be coupled together as trailers. The increasing use of traction engines for transportation purposes was one of the reasons for this addition; the rapid development of self-propelled vehicles of various types was another. The Ordnance Department of the Army has made experiments with an automobile battery wagon. The advantages of an efficient transportation of that kind for field artillery material are so great that unusual efforts undoubtedly will be made to perfect it.



PROFESSIONAL NOTES

GROWTH IN POWER OF GUNS

No great changes in systems of construction of ordnance are to be recorded during the year, but the improvements in existing types of all calibers have been considerable. It must be remembered that the process of evolution of the modern gun must necessarily be a slow and gradual one. Too large a step in advance, without making sure of the ground to be covered, is apt to lead to disaster; as has often been proved in the past, notably in recent times by the failure of the American heavy guns to stand the large increases of forward pressures obtained with an improved propellant. There are many points that require to be considered when improving the design of any type of gun, which attain different relative values at the various stages of evolution; such are the size and shape of chamber, maximum pressure allowable at the muzzle, twist and form of rifling, nature of driving-band, and at last, but by no means least, the form of propellant. In the early B. L. gun, such as the 12-inch 25-caliber, using quick-burning powder, the pressure rose to its maximum before the projectile had moved more than a caliber down the bore, fell off almost at once, and decreased rapidly as the shot neared the muzzle to a minimum of little more than three tons. Little advantage was therefore to be obtained by lengthening the bore, and the gun consequently was short, thick at the breech end, tapered rapidly towards the muzzle, and had a small chamber. With the introduction of a smokeless propellant which could be more easily controlled in rate of burning, it became possible to maintain approximately the maximum pressure for a considerable distance down the bore, and, at the same time, to more than double the pressures at the muzzle. This necessitated a large increase in the size of chamber and increased strength in the forward part of the gun; and, at the same time, enabled much higher velocities to be obtained by lengthening the bore, so as to utilise through as great a distance as possible the large pressure on the base of the projectile. Hence we have the present type of B.L. gun, reaching to 50 calibers in length, cylindrical for a large portion at the breech end, and tapering very gradually towards the muzzle. By modifying the form of propellant it is possible to obtain a very regular curve of pressures along the bore, even with the present long guns, the maximum pressure developing slowly and falling off very gradually as the shot nears the muzzle. By this means very high muzzle velocities would be secured, which would on paper give an extremely powerful gun. If, however, the muzzle pressure is too high (and the limit seems to be not much above eight tons, if as much) the projectile is unsteady in flight, and the shooting becomes so erratic that the value of the gun is seriously discounted. It is also necessary to secure the complete combustion of the propellant before the shot has left the muzzle, otherwise varying quantities are expelled unconsumed, and irregular velocities are experienced from round to round which are hopelessly detrimental to accurate shooting, especially at long ranges.

As regards rifling, the increasing twist has been employed for several years both in this country and in the United States, and has given very satisfactory results with velocities up to 2600 f.s., but now that velocities are increasing far beyond this point it is found to have certain drawbacks, and expert opinion on both sides of the Atlantic now seems to be in favor of a uniform twist combined with an increased number of grooves, as giving less frictional resistance and lower mean pressures on the material of the driving-band. With respect to the latter, copper has been found to be an unsuitable material for these high velocities, and better results are obtained with a harder alloy of cupronickel, and it is not at all improbable that a still harder material will be found necessary for guns of the latest type.

We seem now to have reached the greatest length that is practicable in guns of the latest type, as, apart from the difficulty of ensuring sufficient rigidity and freedom from tendency to droop at the muzzle, the further the center of gravity is moved forward, the larger must be the amount of armour required to protect the breech end and loading-gear; and as muzzle pressures, as previously mentioned, must at present be regarded as incapable of increase, the natural direction in which to look for increase of power is by increasing the maximum pressure and maintaining it further along the bore, whilst keeping the final pressure at its present figure. Hitherto, a pressure of 17 tons per square inch has been regarded as the maximum permissible, though in some of our more recent guns it has lately been increased to 18 tons; but there seems no adequate reason why a pressure of 20 tons per square inch should not be worked up to; indeed, the Elswick Ordnance Company have already designed a 9.2-inch gun calculated for a working pressure of this amount. Using the wire system of construction, there should be no difficulty in providing sufficient strength without unduly increasing the weight.

In the case of guns made entirely from forged tubes the question is not so simple, and propably some improvement in the quality of material will be necessary before it can be carried out. Nickel steel is the material that naturally suggests itself in this connection, as when sound it represents a great advance on ordinary steel in regard to tensile strength and elastic limit; the former being about 30 per cent., and the latter as much as 50 per cent. higher than in the case of the mild steel usually employed. No Power has yet adopted it for heavy guns, owing to the difficulty of obtaining thorough soundness in large forgings, though a commencement in this direction has been made both in this country and America by utilising this material for the new type of field gun; the forgings, however, for these are comparatively small. Some prospect of the removal of this objection is held out by the introduction of the Harmet process of casting, which is being extensively adopted in this country. By this process the metal, while still fluid, is subjected to very heavy compression from the lower end, and it is claimed that the material is free from cavities and piping, and that very little wastage occurs in making the forging, the inventors stating that the increase in the amount of available metal is not less than 25 per cent.

England is still the only country that uses the wire system of construction, though experiments are being made in America with wire guns of different types, probably with the idea of obtaining a sufficient increase of strength for their slow-burning powder in the forward part of the gun without adding materially to the weight. The great advantages of wire in ensuring thoroughly sound and strong material are sufficient to outweigh the disadvantage of lack of longitudinal and girder strength, especially as no great difficulties have been experienced in adequately providing for strength in these respects by the inner tubes and outer coverings. France and Russia have tried this system, but it was abandoned by both on account of the expense of manufacture and difficulties encountered in retubing the interior, the latter an important point with guns such as ours that use a nitroglycerine powder. Here, however, the last has been successfully dealt with, though, of course, the operation of retubing is a lengthy one, and can only be carried out where a gun-manufacturing plant is available.

The tendency to increase of length of guns of all calibers has been well marked on the Continent and in America, as well as at home. France was the forerunner in this respect as much as fourteen years ago, when guns of 40 and 45 calibers were introduced, whilst ours of that date as a rule did not exceed 30. But though the step, in the light of subsequent experience, has been proved undoubtedly a wise one, too much was sacrificed to obtaining high velocities, and to this end the French were content with light-weight shells. This is a far from sound basis on which to work, as loss of weight in the shell entails a corresponding loss in muzzle energy, and the diminution becomes more heavily marked as the range increases, loss of velocity being inversely proportional to the sectional density of the projectile, and the heavy shell has a great advantage in range and flatness of trajectory. Thus, if we compare the 12-inch Elswick gun with shot of 850 pounds and velocity 2900 f.s. with the French 45-caliber gun of the same velocity, but with a shot of only 750 pounds, we find that the muzzle energies are 49,500 ft.-tons and 43,700 ft.-tons, respectively; but at 5000 yards the velocities are 2120 f.s., as against 1985, whilst the striking energies are 26,500 ft.-tons, as against 20,520 ft.-tons. The penetration is also seriously affected, for at 5000 yards the French gun will only perforate 26 inches of iron, while the Elswick gun will easily perforate 31 inches. Even greater variations are shown if we compare the French 9.45-inch, with its velocity of 2625 and shot of 317 pounds, with our present service 9.2-inch, with a velocity of 2601 and shot of 380 pounds, for their respective energies at the muzzle and at 6000 yards are 17,830 ft.-tons and 6250 ft.-tons, as compared to 15,170 ft.-tons and 4140 ft.-tons, while at the latter range the 9.2-inch will get through an additional inch in the latest K.C. armor. Germany has also committed the same mistake with their heaviest naval gun, the 11-inch, the shot of which should weigh 650 pounds, to be in the same proportion as the British or American 10-inch or 12-inch, whereas it is only 534 pounds.

France is now reported to have adopted a 50-caliber 12-inch gun, no other country having as yet ventured upon more than 45 calibers. This gun will be an extremely powerful one, though with the usual defect of a shell of 750 pounds; the weight is to be 61 tons and a muzzle velocity of 3035 f.s., is expected. The higher ballistics are obtained by enlarging the chamber, and forward strength by reinforcing tubes along the chase; the thickening of the chase, combined with the increased length, indicates that the centre of gravity has been moved further forward from the breech end, and it would appear that this will entail a very considerable addition to the weight of armor required to protect the breech and loading mechanism.

Germany shows no sign of reconsidering her decision to use nothing heavier than the 11-inch gun, and the latest of this size is only 40 calibers long, though the velocity (it is credited with 2700 f.s.) is good. For some years the Germans have devoted much attention to the development of heavy Q.F. guns, having tried a metallic cartridge-case in as heavy a gun as the 9.45-inch. The system, however, cannot be commended, as, apart from the question of the disposal of the fired cases (an awkward matter on board ship with large guns and rapid fire), it does not lend itself to the easy realisation of high ballistics. With slow-burning propellants a large chamber is necessary, and this can only be obtained by either enlarging the breech opening, with the consequence that a heavy and unwieldy breech screw is required, or by increasing the length, which reduces the distance of shot travel, and is moreover apt to generate dangerous wave pressures.

The United States have adopted a 12-inch of 45 calibers for the battleships of the Connecticut and New Hampshire classes, of about the same weight as the new French gun, but considerably more powerful, as its velocity of 3000 f.s. will be obtained with a shot of 850 pounds. In medium guns they have nothing better than the 8-inch of 45 caliber which is a very inferior weapon to our present 9.2-inch, especially at long ranges, and not even equal to the latest 7.5-inch. The failure of several of their older guns, through high forward pressures and faulty material, has directed their attention to the merits of wire-wound guns, and two 6-inch guns on this system have been made, with which they expect a muzzle velocity of 3540 f.s. One of the main features is the large size of the powder-chamber, which is nine inches in diameter, with a capacity of 3120 cubic inches (as compared with 1715 cubic inches of the 6-inch Mark VII.) Though the working pressure is to be high, nearly 19 tons per square inch, with such a high velocity the muzzle pressures will probably be very great, and the shooting is likely to be somewhat erratic. Moreover, trouble may be expected with the rifling and driving bands when the trials are carried out. Difficulties in this latter direction have already been experienced with their 12-inch and 10-inch guns, and quite recently it has been found necessary to return the projectiles of those natures to be fitted with a new type of band. Much attention in America has been directed to the development of coast artillery, but they do not seem at present inclined to repeat their 16-inch B.L. gun, which, with its shot of 2400 pounds and muzzle velocity of 2317 f.s. is likely to long remain the largest and most powerful gun in the world.

An interesting point is the large extent to which provision has been made of 12-inch mortars in coast batteries, nearly four hundred of which have been already supplied. These are mounted so as to be practically out of reach from attack from the water, and are said to make, with the aid of long horizontal base range-finders, very accurate shooting up to 10,000 yards. If we remember the effect that the 11-inch Japanese howitzers had on the Russian fleet at Port Arthur, we can realise what serious risks would be encountered by any fleet attempting to bombard a fortress armed with these weapons. Even with the low velocity that would be obtained at long ranges, no armored deck would be proof against such heavy shell falling almost vertically and filled with high explosive.

Full particulars have not yet been published of the new guns that are in course of manufacture for the British Navy, and it is therefore impossible to discuss them in detail. It is, however, known that 50-caliber guns of 6-inch, 7.5-inch, and 9.2-inch caliber have been approved, and that the velocity of all these will be in the neighborhood of 3000 f.s. The 3-pounder semi-automatic will have a velocity of 2800 f.s., an increase of 900 f.s. over that of the old pattern 3-pounder which has been in use for so many years. It is not only in the power of the gun that improvements have taken place, but also in the simplicity and rapidity of working of breech mechanisms and loading-gear, all of which tend to increase the rate of fire and reduce the liability to damage on service. One of the most important developments for breech-loading guns in recent years was the introduction of the Welin breech-screw, which enabled a single motion mechanism to be used, and owing to its shortness enabled a great saving to be effected in the weight of the gun. Messrs. Vickers, Sons and Maxim have now further improved this mechanism by applying what they term a "pure couple" to turn the breech-screw, by which friction is reduced and power required to operate it materially lessened, a matter of some moment when we consider that a lever mechanism has been fitted to so large a gun as the 10-inch. Some trouble was at first experienced with the obturator used with the Welin screw owing to its steep slope, but this has now been remedied by the use of split steel rings combined with a copper protecting disk.

The improvements that have taken place during the last few years in the manufacture of projectiles have led in most countries to the substitution of armor-piercing shell for shot; Russia having taken the lead about six years ago, and having soon been followed by the other Continental powers and the United States. Given sufficient penetrating power, there can be little question as to the better projectile; but unfortunately until comparatively recently this country has been somewhat behindhand in this respect. Great progress has, however, been made in the last year or two, and now our best manufacturers have no difficulty in making shell that are equal if not superior to the best foreign productions. The result has been that our Navy is now being supplied with a shell containing a bursting charge of from 2 to 2½ per cent of its weight, that can be relied upon to carry its bursting charge through a plate of the best K.C. armor its own caliber in thickness, and to be in a condition to explode on the other side; and this with the moderate velocity of under 2000 f.s.

—*The Naval Annual*, 1905.

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BRITISH NAVAL GUNS

Public discussions of Imperial subjects are always welcome, alike in the interests of the nation and of the service, because in the end they result in the better education of the people on matters of State; and although many fallacies and ill-informed hypotheses are aired, the truth eventually becomes known. Moreover, the public can never be too well educated, or made too deeply interested in such questions as the maintenance of our defenses, and particularly in those concerning our Navy. For this reason the articles on naval guns which have appeared in a daily contemporary are interesting, and may prove advantageous; and it is well that the opportunity should be utilised of enforcing the lesson which some of the facts suggest. In the interests of peace it is as important that foreigners should have a true conception of our state of preparedness for action as that our defenses should be as efficient as they are represented to be.

In the series of articles in question there was, at all events in the earlier stages, a suggestion that the wire system of gun-construction is unsatisfactory, and although this view was modified later, any remaining doubt should be dispelled. Lieutenant A. Trevor Dawson, who is one of our foremost experts on the subject of gunnery, has done useful service by his lucid and convincing letter on this subject. He has never been reticent in his criticism, when such was necessary, and his letter may therefore be accepted as an independent support of the wire-wound system. In his letter he points out some of the well-established advantages of the wire-winding system of constructing guns, as compared with the built-up solid-steel design; but before entering into a consideration of these, it may be well to refer to the stresses to which a gun is subjected, and also to the standards of strength according to the practice at Woolwich Arsenal, which are followed also by the great gun-construction firms in this country. These latter, at all events, are in no way behind the Government establishment in this respect.

Few realise the enormous stresses set up in modern guns in order to attain even the comparatively low velocities of 2000 feet and 2150 feet per second as compared with the 2600 foot-seconds attained in European practice. This velocity necessitates a pressure in the bore of 17 tons per square inch in the case of the 12-inch gun, firing an 850-pound projectile, while at the muzzle it is 7½ tons. The tangential and longitudinal stresses due to such pressures are, it will be recognized, considerable. When the projectile is passing through the bore there is the stress due to the powder acting on the projectile to increase its acceleration, and at the same time that due to the rotation of the shot. Thus the inner tube is subjected simultaneously to three straining influences—one of elongation, another of torsion, and the third is radial. These are transmitted from the inner tube by means of suitably placed shoulders and perfect shrinkage to the "A" tube, which is really the backbone of the structure. The question at issue is whether the "A" tube is more effectually reinforced by a system of wire-winding supplemented by outer tubes shrunk on, or by the system of depending on a series of rings of solid steel shrunk on in successive layers. It is clear that the stresses brought on the inner tube subject it to very complex strains, and especially near the muzzle of the gun, where the tube is thin, and where the torsional stress is increased with the sudden release of the projectile through the muzzle. Here there is not support on both sides of the point of tension, as in the other parts of the bore, because there is a termination to the supporting metal.

The strong argument in favor of the wire-wound system is that steel, as wire, is the strongest form of material utilsable in gun-construction, for, as pointed out by Lieutenant Dawson, "it enables the factor of safety, so far as radial stresses are concerned, to be enormously increased, as compared with that in the solid-steel construction." This view also receives corresponding suppport from other authorities, including Admiral O'Neil, who until recently was director of Naval Ordnance to the United States

Navy. Microscopic observation of steel has shown the extreme danger traceable to flaws in solid metal, which are undiscoverable when it is used in masses, so that there is no need to refer further to this. In the case of wire there can be absolute certainty as to the molecular or fibrous state of the metal. The steel wire is tested throughout its entire length, whereas in the case of the solid-steel construction of guns the test is only carried out upon a small piece taken from the steel forming each component part of the gun. At Woolwich the practice is to use steel wire of a breaking strain of between 90 and 110 tons per square inch, and of this something like 110 miles are used on a 12-inch gun, forming a band around the inner and "A" tubes more than equivalent in strength to the series of shrunk rings in the solid-steel construction. The "A" tube is forged of high-quality gun-steel of a tensile strength of 34 to 44 tons per square inch, with an elongation not less than 17 per cent in a 2-inch bar.

The effect, so far as the strength of the whole structure is concerned, may be briefly explained. The wire tension and shrinkage are so arranged as to give an internal compressive stress of 25 tons per square inch at the breech end, varying to 14 tons per square inch at the muzzle; this, of course, is the condition when the gun in a state of repose. Even when the gun is fired with charges to attain the high velocitities now reached there is still an enormous amount of safety. This is due, first, to the fact that the steel for the inner and "A" tubes has a yielding point of over 21 tons to the square inch, while the working stress, based upon accurate calculation, is estimated not to exceed 18 tons per square inch. The tension with which the wire is wound on the gun results in a very much higher yielding point than would be the case with solid bands. The tension depends, of course, upon the thickness of the inner and "A" tubes, and upon the number of layers of wire, or tape, as it might more correctly be termed. As a rule it ranges from about 54 tons per square inch on the inner wires to 32 tons per square inch on the outer wires. It varies at the different sections in the length of the gun to suit the gaseous pressure along the bore to be supported. We think it is clearly established that the wire-wound system, when employed in a suitable construction, gives results superior to those attainable by the solid-steel design. The test pressure in the British service is about 25 per cent. above the working pressure—considerably higher than in the case of many foreign guns.

As to the statement made about the failure of the inner tubes of some of the 12-inch Mark VIII. guns, the Admiralty have already acknowledged that there has been failure in some instances; but these will be recognised from what we have written as not necessarily inherent to the system; nor need it be assumed, as has somewhat hastily been done, that failure must necessarily occur in the case of all guns of this class. As Lieutenant Dawson remarks in his letter, "flaws may occasionally develop on service, either to minor errors in manufacture or to a premature explosion of a shell, which may cause cracks." What did happen in the case of some of the Mark VIII. guns, made at Woolwich, was a contraction of the bore at certain places in the chase, which in a few instances caused splitting. This may have been due either to soft metal, to wear, or to the failure of the inner tube, under firing conditions. It is well that the public should know of these failures, even although they may be insignificant, because, as we have pointed out, a healthy, well-informed public opinion is useful as an incentive towards a high efficiency in the public service. On the other hand, there is no need for exaggeration or disquietude. Under ordinery conditions the worst that could happen would be a cracking of the inner tube, but even then the gun is by no means put out of action, although in peace time the correct procedure is to have the inner lining removed and a new and stronger one put in its place. In the event of our being at war, however, the gun could still be used with the liner cracked. The consequent reduction in tangential strength would not reduce the total resistance of the gun structure to the stresses set up to anything like the breaking point. Indeed, that is one of the conditions taken into consideration in determining the structural strength of every gun, a fact which alone proves that such partial failure has been anticipated. Lieutenant Dawson, in his letter, is very clear on this point. He says that "actual experience has shown that a gun constructed on the wire system can still be utilised effectively without the destruction of the weapon or without dangerous effects, even with its inner tube split through its entire length." Even so, the re-lining of a gun is a matter of comparative simplicity and little cost. This, indeed, is one of the commendations of the wire system of construction.

After re-lining, the gun is as good as new, and in proof of this Lieutenant Dawson quotes a typical result—that of a 6-inch wire gun, "which, after being re-lined, showed in service firing, at 8367 yards, an error in range of only 10.2 yards." Other calibers of wire guns, after satisfactory relining, will, he adds, attain similar accuracy on service, and at the same time will give the greatest possible security and effective naval utility. This, no doubt, is a measure of considerable security; but we hope that Lieutenant Dawson does not assume that even a reserve of tubes would meet the case. The process of re-lining cannot be carried out in much less time than three months, and when, after action, this work has to be done, every minute will be an important factor in the ultimate success of any naval campaign. It is no disparagement to any system of gun-construction to say that in a comparatively short fleet engagement every gun must suffer—they are built to suffer—and, whether successful or otherwise, the fleet which can most quickly return to the fighting base with all its offensive qualities repaired must ultimately succeed. We may not, like Admiral Togo, have the great advantage of many months in comparative safety to carry out this rehabiliment of the fleet, and therefore dependence upon the long process of re-lining the guns might be dangerous. Even if inner tubes were kept in reserve, the case would not be materially improved, because new tubes could be forged and prepared during the time taken to withdraw the inner tube.

The obvious conclusion of the whole affair is that our battleships and cruisers must, to be regarded as efficient, have an adequate reserve of guns. At present the reserve aimed at is one gun for every four of large caliber, and one for every five weapons of 6-inch caliber. The utter inadequacy of this is shown by the fact that, say, were the Channel and Atlantic squadrons engaged together in a great fleet action, it is quite possible to conceive that from twenty to twenty-four 12-inch guns might require to be renovated or renewed; and according to present conditions there would only exist six guns in reserve for the purpose. To attempt to re-line the remaining eighteen guns, with the limited number of gun-heating pits in the country, would necessitate such a delay as might jeopardise our sea-power, and would certainly forfeit a splendid opportunity of bottling effectually the injured ships of the enemy in their repairing ports. The cost of such a reserve is a small item in the balance. Even if all the guns in any ship were duplicated, one set being held in reserve, the increase in cost for any ship would not exceed an amount equal to 7 or 8 per cent. of the aggregate cost of the vessel; and the great advantage thoroughly justifies the increased expenditure.

It may be urged against this that this is duplicating the accumulation of war material which is every day becoming obsolete; but since science knows no finality, that view might be urged against practically all naval expenditure; and until the periodicity of war can be accurately determined, so that due and completely modern arrangements can be made, the maintenance of peace demands a continuance of expenditure. But it can be said that the guns made as duplicates under an improved system would be quite as effective as the guns fitted on board the ship. With an increased aggregate reserve added to from time to time, as each successive ship is commissioned, it might be possible to send ships for a second time into action with, perhaps, one or two improved guns. The tendency is all towards increased strength of metals, and it is possible to conceive that, without increasing the weight, higher ballistics might be obtainable in reserve guns. Even without this advantage, there is attainable such an increased measure of efficiency in times of war from a warship which possesses a full reserve of guns as to justify the moderate expenditure desired. Apart altogether from the wear of the gun, the aim must ever be to destroy the weapons of an enemy, so that the chances are that guns, which must be exposed more or less, will prove the most vulnerable parts of a ship. The expenditure, therefore, of 70,000*l.* or 80,000*l.* on reserve guns, which will enable a ship costing from 1,250,000*l.* to 1,500,000*l.* to return as soon as possible to the line of battle at the most crucial moment of the campaign, is so obviously a small premium of efficiency that we are certain that only public support is necessary to encourage the present Board of Admiralty to carry this reform into effect.—*Engineering.*

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ARMOR-PLATE AND PROJECTILE TRIALS

Before a large party of Japanese officers, several trials were carried out at the Eskmeals range of Messrs. Vickers, Sons and Maxim, Limited, to show the resistance qualities of the latest type of armor forming the belt of the Japanese battleship No. 1, now building at the Naval Construction Works of the company at Barrow-in-Furness.

This battleship, which embodies several important developments in the design, is in an advanced state of construction. The ship will be fitted for the greater part of her length on the water-line wlth armor of approximately 9 inches thick, tapering forward and aft to 4 inches and 2½ inches in thickness. The whole of the armor for the ship has been made at the company's River Don Works, at Sheffield, and two plates were selected from the belt by the Japanese authorities, from which standard-size pieces were cut for testing purposes. These were attacked with modern guns, firing projectiles constructed by other makers under Japanese inspection, and made to the British Admiralty standard pattern.

Two rounds were fired at the 8¾-inch belt-plate from a 9.2-inch gun, and as these proved in every way satisfactory the plate was accepted. Captain Iwamoto then asked that a third round with an exceptionally high velocity should be fired, which gave an equally good result.

The thin K.N.C. armor was then tried, and the result was considered still more satisfactory; it was accepted after the second round. The firm then suggested firing a third round from a 4.7-inch gun, to show what resistance such a plate would offer to this attack. A velocity of 1500 feet per second was obtained, the shell being completely broken up on the face of the plate, no portion going through the armor. As the velocity thus obtained was 155 per cent. above that required by the De Marre formula for the perforation of steel, the result was considered highly satisfactory.

After these trials, the remaining portion of the 8¾-inch plate (which was treated and hardened at the same time as the official test-plate) was attacked by a 9.2-inch gun, firing a new type of uncapped shot, made by the Vickers Company; the charge used and the striking velocity was practically the same as the third (high velocity) round fired at the official test-plate. In this instance the shot passed completely through the plate, and through a screen of sand-bags 10 feet thick at rear of the target. On being recovered it was found that the shot was broken off at the head, but otherwise it was entirely whole, and showed no signs of setting up.

The details of the trials and results follow:—

A 360-pound plate, measuring 14 feet, was selected from the belt armor for trial from which a piece 8 feet square was cut to form the test-plate for the acceptance of the armor, backed with 12 inches of oak and 1½-inch skin-plate behind that; the remainder of the plate was hardened at the same time as the 8-foot square plate, and was used for the trial of shot, also made by Messrs. Vickers Sons and Maxim, Limited. The plate actually measured 8¾ inches thick. The projectiles used for the trial of the 8-foot square plate were those of another maker, made under Japanese inspection to the English Government standard pattern, weighing 380 pounds, 380¾ pounds, and 382 pounds, respectively. A 9.2-inch gun was used for the trial.

Round 1.—The striking velocity was 1817 foot-seconds, and the striking energy 8698 foot-tons. No cracks appeared on the plate, very slight shelling was the result, and the actual penetration measured when the point of the projectile was jarred out by the second round was 3.4 inches.

Round 2.—Striking velocity, 1766 foot-seconds, and striking energy 8234 foot-tons. No cracks appeared on the plate, although the shelling was slighly more than in the previous round; but the actual penetration measured when the point fell out after the third round was only 3.2 inches.

The plate was accepted on these two rounds, and it was then decided to fire a third shot with a very much higher velocity. The striking velocity in this instance was 1955 foot-seconds, and the striking energy 10,120 foot-tons. There were still no cracks on the plate, and the penetration, as far as could be measured, was only 3.5 inches; the point of the projectile remained fused in the plate. This velocity is equal to a percentage of 155.33 above that required by the De Marre formula for the perforation of steel.

The results as given above are illustrated on Fig. 1; while Fig. 2 shows the back of the same plate.

The next plate fired at was 100 pounds per square foot 2$\frac{7}{16}$ inches full, thick, 4 feet square, backed with 6 inches of oak, and 1-inch skin-plate. This sample was cut from one of the plates forming the after-end belt-armor. This was a K.N.C. plate, face-hardened.

The first round was from a 6-pounder gun, firing the English Government Mark IV. service pattern steel shell. The striking velocity was 1831 foot-seconds, and the striking energy 139½ foot-tons. The indentation on the plate was 0.3 inches, only one small portion of the base of the shell being recovered. There were no cracks on the plate, and no surface shelling.

The second round was a 6-pounder gun firing the same pattern shell, the striking velocity being 1906 foot-seconds, and the striking energy 151 foot-tons. The indentation in this case was 0.5 inches. There was no shelling off the face of the plate, and no cracks. No portion of this shell was recovered. The plate was then accepted.

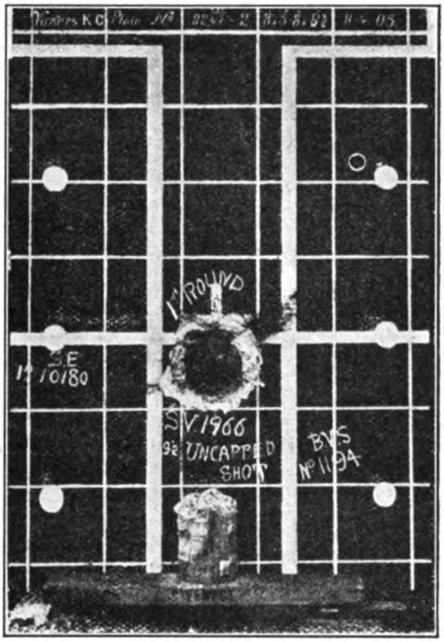

Fig. 5. 8¾-inch Plate Perforated by 9.2-inch Vickers Uncapped Shot.

It was then decided to fire a third round, to show what resistance such a plate would offer when attacked with a 4.7-inch gun. An English Government service pattern steel A.P. shell, weighing 45 pounds was used. The striking velocity was 1501 foot-seconds, and the striking energy 703 foot-tons. The shell was completely broken up on the face of the plate. At the point of impact a circular disc, measuring about 9 inches in diameter, was driven back from the surface of the plate, 1.8 inch at the bottom and ½ inch at the top; but the upper portion of the disc was not detached from the plate.

The results in connection with the 100-pound plate are shown on Fig. 3, and the back of same plate is shown on Fig. 4.

When the trial and acceptance of the armor was finished, it was decided to fire the Vickers 9.2-inch A.P. uncapped shot No. 1194 at the other half of the 8¼-inch plate (which was fixed on a target without any backing), with the same charge as was used on the third round on the 8-foot square plate. The actual velocity obtained was 1966 foot-seconds, owing to the shot weighing 379¾ pounds instead of 382 pounds, as in the case of the third round on the other plate; the striking energy being 10,180 foot-tons. The shot completely perforated the plate, and passed through a screen of sand-bags 10 feet thick. It was recovered with the head broken off, and showed practically no sign of setting up. The results in this case are shown in Fig 5.—*Engineering.*

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FIELD GUNS, GERMANY AND AUSTRIA

Tranformation of the German field material.—The *Frankfort Gazette* gives the following details in regard to the field gun with which the German army is to be supplied. By altering them it has been possible to retain different parts of the carriage and the tube itself of the gun. On the other hand, it has been found necessary to adopt a new model of limber and caisson. Consequently these have to be constructed wholly anew. The following changes are to be made. The axle and the wheels of the carriage remain as they are at present. The trail of the carriage is to be replaced by a new one lighter than the old form ; the slope of the cheeks is done away with and gives place to a cradle enclosing all the recoil mechanism. On this cradle the gun, attached by a lug to a double glycerine brake, slides from front to rear in recoil and returns in battery. As to this lug which is not on the old gun, it forms part of a band which is shrunk on the breech of the gun. A seat is arranged on each side of the trail, one on the right for the cannoneer who fires the piece and one on the left for the gun pointer.

The piece is provided with shields. They differ from those used in the French artillery in that, placed perpendicular to the axis of the gun, they protect the heads of the cannoneers. Held in place by an hydraulic arrangement, they make no noise when the piece moves across fields or along roads.—*Revue du Cercle Militaire.*

The new Austrian field gun.—The new model of field gun is now definitely adopted. The *Internationale Revue* gives the following information on this new material which will probably receive the designation Model 1904.

The tube of the new gun is of forged bronze, 30 calibers long, and is manufactured at the Vienna Arsenal. The fermeture is of the flat wedge type. The gun is mounted on a long recoil carriage provided with light shields of chrome steel, with hinged portions. The lower carriage is of the usual construction, steel flasks united by transoms.

Fixed ammunition is used, the projectiles being shrapnel and explosive shell. Canister is definitely discarded from the ammunition supply. The shrapnel is about 3½ calibers long and contains 320 balls; its charge adds from 90 to 100 meters to the remaining velocity of the balls after burst.

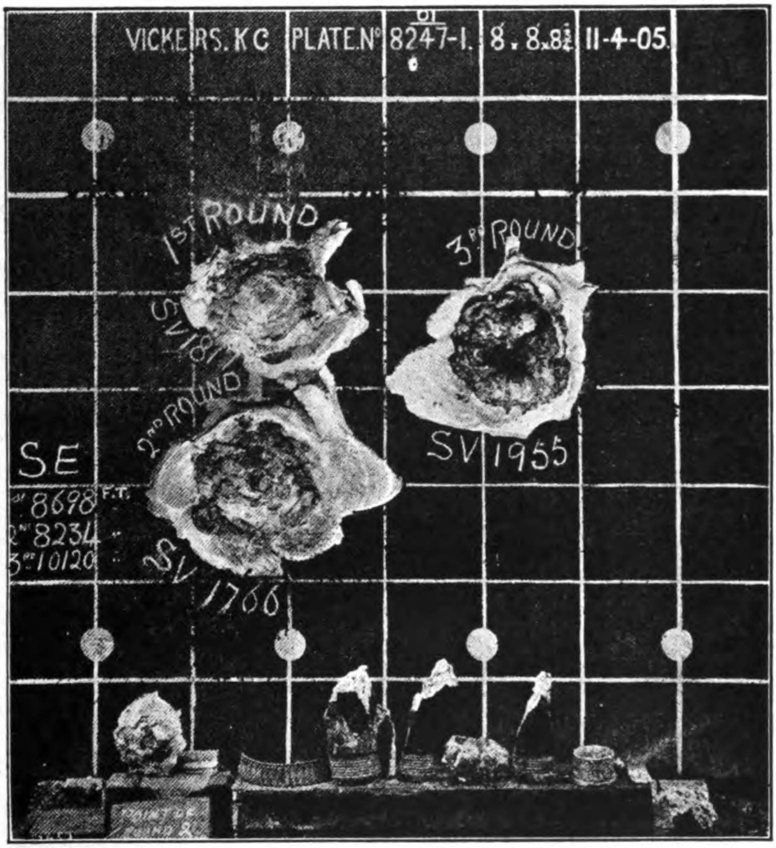

FIG. 1. **Front of 8¾-inch plate after attack by 9.2-inch gun.**

PLATE II.

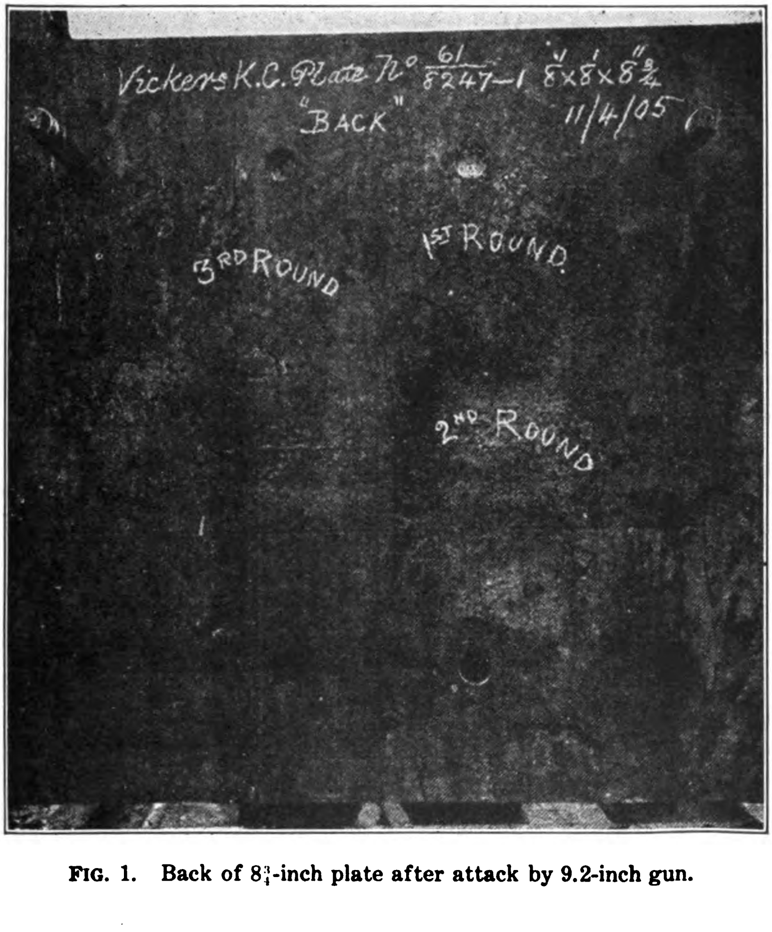

FIG. 1. Back of 8¾-inch plate after attack by 9.2-inch gun.

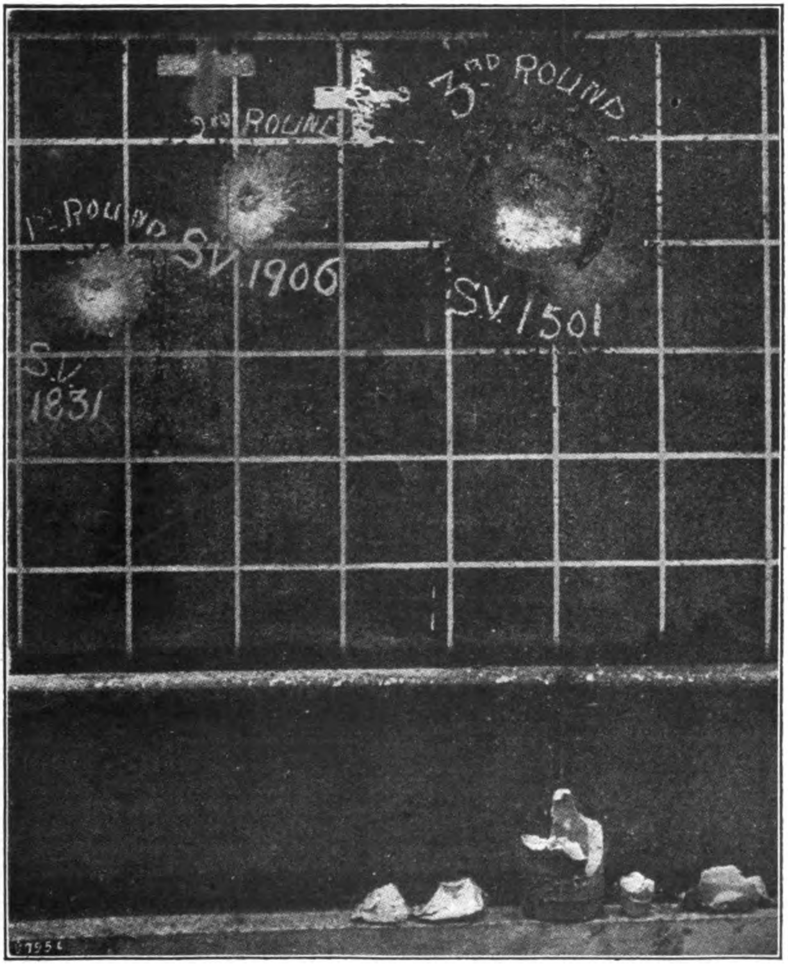

Fig. 1. Front of $2\frac{7}{16}$-inch plate after attack by 6-pounder and 4.7-inch guns.

NUMERICAL DATA

Caliber	7.65 cm.
Length of tube	2.295 m.
Weight of gun with breech-block and parts connecting it to upper carriage	336.0 kg.
Maximum recoil	1.270 m.
Height of line of fire	0.99 m.
Track	1.60 m.
Maximum range	6300.0 m.
Maximum elevation	16°
Maximum depression	10°
Angular breadth of traverse (on the carriage)	3° on either side.
Length of line of sight	1.0 m.
Laying apparatus	Sight with cross-level with removable pointing arc, and telescopic sight.
Muzzle velocity	520.0 m.
Weight of the piece in battery (without limber) with shields 3 mm. thick	950.0 kg.
Weight of piece with limber without the cannoneers	1750.0 kg.
Weight of caisson	1770-1800 kg.
Maximum rate of fire per minute	21 rounds.
Ammunition:	
(a) Shrapnel	weight 6.7 kg.; 320 hard lead balls of 9 gm. each; fuze graduated to 5500 meters.
(b) Explosive shell	weight 6.6 kg.; 260 fragments.

Canister no longer supplied.

Bursting charge: 107 gm. ecrasite with 165 gm. *phosphorantimon*, a smoke-producing compound to facilitate observation of the points of burst in ranging.

All ammunition is fixed: the cartridge contains 530 to 540 gm. nitroglycerine powder.

The detachment for the service of the piece consists of 6 men. When the organization is completed each regiment of artillery will consist of two battalions of three batteries each. A battery consists of 6 guns and 9 caissons.

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FIRING AGAINST SHIELDED GUNS

In 1904 some tests were made of the effect of artillery and infantry fire against guns and caissons provided with shields. First, soft steel shields were tested and then others of hard steel. The caissons were filled with loaded cartridges arranged some with the point of the projectile to the front, some with point to the rear. As regards the small arm projectiles employed, some were lead bullets and others were of hardened steel. The 5 mm. plates stopped the lead bullets at all ranges; the steel bullets, however, perforated them beginning at 500 meters. This result, however, is devoid of all practical signification because of the impossibility of using bullets of this metal on account of the excessive wear they cause in small arm rifles.

In the artillery fire shrapnel and explosive shell were used. The shrapnel balls produced bulges of 4 mm. on the soft steel shields, but flattened out without appreciable effect on the hard steel plates. Both kinds of shields could be perforated by the large fragments, which produced very much larger holes in the soft steel ones. The fuzes (those used in Sweden are aluminum) also perforated the shields at short ranges of burst.

The most interesting result was that there was not a single explosion of the cartridges contained in the caissons although the latter were hit and pierced several times by large fragments, by explosive shell and by shrapnel. None of the cartridges exploded in spite of the fact that some of the fuzes were indented and bent, some of the projectiles damaged, and even some of the cartridge cases torn to the extent that the powder ran out. It seems, then, that the risk of explosion of caissons placed beside the pieces is not as great as has been feared in some armies. However, it should not be forgotten that a caisson did explode in the course of some tests made in 1903 at the Steinfeld polygon in Austria.

—*Jahrbuecher fur die deutsche Armee und Marine.*

An important modification has been published with reference to articles No. 26 and 28 of the German regulations for field artillery fire, with the object of defining exactly the mode of execution of fire against artillery furnished with shields. In general, time fuze shrapnel will be used against shielded guns, because this projectile is by far the most efficient against all the non-protected part of the personnel and because a greater number is carried in the ammunition supply. But when explosive shell are available they will be also used in percussion fire against shielded guns. In case of necessity percussion shrapnel may be employed.

For the field howitzers, explosive shell with percussion fuze have a much greater efficiency than shrapnel with percussion fuze.

It is laid down that the width of the zone covered must be sufficiently extended to include the caisson serving as a shelter or post of observation for the battery commander.

In regard to the use of time fuze and percussion fire, it is to be noted that in Germany ranging with time fuze is considered a much more delicate operation than ranging with percussion fuze, and it is thought that the Russians very often came to grief in the present war from having employed time fuze in ranging.

In the French artillery, however, we are well satisfied with the results obtained by time fuze ranging. Perhaps it may be thought necessary, then, to improve our fuzes or attain greater exactness in the mode of setting them.

—*La France Militaire.*

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AIMING BY TELESCOPIC SIGHT

In the *Internationale Revue* Lieutenant-General H. Rhone, late of the Imperial German Army, publishes the following remarks on the article by by Dr. S. Czapski, "Aiming by Telescopic Sights," a translation of which we printed in our January-February number.

The General says: In the very valuable article by Dr. Czapski, "Aiming by Telescopic Sights Compared with Aiming by Open Sights," its author complains of the lack of any data "as to the amount of the error to be expected in aiming with open sights."

Perhaps the following data may fill the gap mentioned.

A very prominent officer of the German artillery in its best time made the following statement in his "Guide for the Correction of Aiming in Practicing with Rifled Guns:"* "As to the eye of the gunner and its practice, experience shows that in the case of a normal eye and a reasonable amount of practice, according to the remark on page xxxiii of the preface to the range tables for rifled guns, of 1865, the mean error in aiming amounts to 56 seconds, etc."

When I had command of a battery, I observed the results of the aiming drill with much attention, and found that with the open sights the mean error was about 0.2-sixteenths of a degree, or about 45 seconds both in height and laterally. This corresponds to a mean deviation of $45\sqrt{2}$ or about 65 seconds (as the total deviation is the hypotenuse of a right angle triangle, the deviations in height and direction being its sides), which come near enough to the data of the range tables. The probable error then would be 47 or 55, average 51 seconds. This does not contain the *constant* errors which will result from the fact that some men always aim too high, others always too low, whereby the dispersion of hits of the *entire battery* will be increased.

An error of that amount (51 seconds) is not of very great importance in practical work. At a range of 3000 meters it would displace the hitting point 0.7 m., and would result in a mean (50%) dispersion in height of 1.0 m., while this dispersion with the best modern guns is from 3 to 4 m. If all error in aiming could be avoided, there would still remain a mean dispersion in height of from 2.8 to 3.9 m., a very negligeable decrease.

It seems to me that aiming to be accurate will take too much time; 15 seconds at least are necessary, except where men have been taught by special drilling to aim more quickly; but there is hardly any time left for such drilling.

This is my chief argument in favor of telescopic sights for our new field guns; and I fully agree with the author in the desire he expresses at the end of his article for the trials he recommends.

An advantage of the telescopic sights, not pointed out in the article is their *shortness* and *easy handling* (also of the "collimateur" of the French field gun, and of the Grubb sight). When combined with a horizontal quadrant these instruments will allow the use of auxiliary aiming points and their accuracy is at least 15 times that of the aiming plane. By means of the latter, angles can be measured accurately to one degree, while the goniometer of the French field gun measures them accurately to from 3 to 4 minutes ($\frac{1}{1000}$ part of the range) and therefore a correct direction is obtained very much more quickly. An up-to-date field gun without a telescopic sight is certainly not to be thought of.

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GERMAN PLANS FOR A NAVAL BASE IN THE FAR EAST

An imperial order to fortify Kiao-Chau Bay, the German concession in the southern part of the Shan-Tung Peninsula, has been issued. The work will be done under the supervision of the Governor of the protectorate,

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* Anleitung zur Correctur beim Schiessen aus gezogenen Geschuetzen, Berlin, 1869.

Rear Admiral Truppel, and five engineer and fortification officers, Captain Dollman and Lieutenants Hintze, Moslehner, Steffen and Leris. It is probable that the work now contemplated is only the beginning of an extensive plan.

The expense of this work will be provided for this year out of the Kiao-Chau budget, but the fortifying of the bay will doubtless be carried forward after this from successive appropriations to be asked of the Reichstag. As Kiao-Chau is Germany's only station in Far Eastern waters, the Navy Department has desired since its acquisition to make it a safe base for German war vessels. The fortifying of Kiao-Chau at this time, it is said, need not be construed as preparing for its defense against any particular Power, but only as a precautionary measure too long neglected.

Plans for the defense of Kiao-Chau Harbor were drawn up in accordance with Germany's agreement with China, which provided for the fortifying of the harbor. Lack of funds, however, has made impossible the project until now, owing to the great amount of money necessary to cover the cost of building docks, piers and other landing facilities for trading vessels and junks. Having provided excellent facilities for ships of commerce, attention apparently has now been turned to the fortifications. It is possible that certain changes will be made in the plans, but the work will be along the line of the original project.

The appropriation will be used in the construction of forts and their equipment with modern ordnance. The defense will probably be of the same general character as those at Hong Kong or the American base at Guantanamo. A naval base not defended is almost a handicap, and whatever plans for the work have been approved in Berlin are in accordance with the agreement with China.

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ATTACKS UPON FORTIFIED HARBORS

After a very complete study of historical examples of attacks upon fortified harbors from the time of the British operations against Cartagena in 1586 to and including the campaign of Santiago, Lieutenant-Commander W. L. Rodgers, U.S.N., in *Proceedings U. S. Naval Institute*, draws the following conclusions:—

The campaigns which have been described have been selected as representatives of operations against sea ports. Let us now see if we can perceive a general reason which explains why each place was selected as a point of attack.

It is evident that in every case mentioned the attack on the harbor was made with the object of affecting a chain of water communications, either military or civil. Sometimes the attack was for the object of improving or securing the attacker's lines of water routes, sometimes it was to injure the enemy's lines. Sometimes the port was an ocean port, sometines one on interior waters; but in each case the attempt to capture a harbor was dictated by some relation it had to lines of water communication.

Even when the objective was a hostile fleet behind the fortifications the reason for the attack still was to secure one's own communications by destroying the enemy's fleet. If we sketch out a probable course of the campaign in a supposititious war, the harbors which will become a part of the necessary lines of communications for that campaign will be clearly apparent, and the degree of preparation and defense proper for each one will depend upon its relative importance to the operations of the war.

To be sure, raiding and wanton destruction of fortifications and the property near them is always possible, but it is becoming more unlikely every year; not so much on account of the prevalence of humanitarian views, nor of the increasing limitations upon belligerent rights, but because the improvements in the transmission of news and in transportation of every sort makes it unwise to scatter the combatant forces in minor operations. Great defensive works are needed only by those ports which are essential as bases of operations, whether commercial or combatant.

It appears from the examples we have considered of attacks upon fortified harbors that such may take place either by the navy alone or in conjunction with an army. In both cases the operations may include a period of slow approach and preparation on the part of the navy analogous to a military siege, or they may consist only of a sudden attack analogous to a military assault.

In this country the success of Farragut's principal actions and their important consequences have much misled unreflecting opinion; and the fact that his assaults were followed by a passage to the other side of the defenses, has led most persons in this country to think that "forcing the passage," as it is called, is the normal form of naval attack upon a fortified harbor. If we think of the operations before Charleston, we must recognize that when Dupont made his assault he did not think of forcing the passage; and, later, Dahlgren, who relieved him, drew up a memoir justifying himself for not running in. From a comparison of the situations in the Gulf with that at Charleston, it seems clear that Farragut ran inside because by doing so he, in co-operation with the army, completely invested the enemy's position and cut all his lines of supply, while maintaining his own communications intact. At Charleston, on the other hand, a passage of the forts by the navy would have been profitless unless the army had made a simultaneous successful attack on Fort Johnson, for the forts would have kept their own communication while the ships would have been cut off.

Thus we see that "forcing a passage" is not justifiable unless the fleet gain a positive advantage with regard to the enemy without sacrifice of its own lines of communication. These conditions will rarely occur, although they are associated with the most brilliant achievements of the navy.

Having thus glanced at some of the principal conditions which determine the propriety of attack, we must now take up the question of methods to be followed. Let us try to decide what features are fixed and what are variable in the plans and operations we have considered.

The methods of attack are necessarily governed by the means of defense. Not only during the period of three hundred years from which we have drawn our examples, but farther back in history, as far back as the siege of Tyre by Alexander, we may see that there have always been two ways of defending a harbor from a naval attack. The defense may resist by striving either to destroy the lives of the attacking forces, or to delay and injure the ships that carry them. It does not seem that there can be a third way. It has always been feasible for a sufficiently powerful attack to deal successfully with either mode of resistance, and therefore in every age a properly devised system of harbor defense has combined the two plans of resistance so that they might reinforce each other and thus oblige the enemy, in shunning Scylla, to fall into Charybdis.

Ever since the invention of cannon they have been used as the armament of ships and harbor defenses. In both cases they damage a ship's hull and destroy lives on board. Sometimes the ship thus attacked by gun-fire is destroyed by it and always she is more or less damaged. But in the very great majority of cases throughout history the loss of life owing to the gun-fire decides the battle and not the injury that the gun inflicts upon the hull. Usually a new crew only would restore to the ship most of her formidability. Similarly, in using guns against forts more or less damage is inflicted upon the armament within the fort, but in every century it has been a fact that the damage to the materiel is not usually conclusive, but the effect of the fire upon the morale and lives of the defenders is conclusive. The same is true in the case of field artillery, a defeated battery has usually suffered more in its men than in its guns. Thus in spite of frequent efforts of gunners to select certain materiel for their object of destruction, in all ages and under all conditions the effect of artillery fire usually is chiefly upon personnel. Although gun-fire often inflicts very grave injuries upon materiel, yet we have never been justified by history in *predicting* such injuries to be as influential upon the course of battle as the concomitant loss of life. Thus we may regard the gun (in modern times the high-power gun) as a weapon directed against life, its effects upon materiel are incidental only, although often of great importance.

The power of the guns on shore relative to the protection provided for the crews of the ships has not varied greatly through several centuries. The gun of the day has been thought powerful enough when it could pierce the side of a contemporary ship at a moderate range. Moreover, we find that the relation of the gun afloat to the harbor defenses has been constant also, both in size and protection, and further that the gun ashore may be attacked by the gun afloat in two ways, either by a fire of large missiles to disable the gun, or a more rapid fire of small missiles to disable the gun detachment. It also appears that the relative value of a battery on shore to that of one afloat is a function both of the relative degree of protection that each enjoys as well as of the relative volume of fire that each can deliver. Fortifications, ships and cannons have always been so related that the ships have needed a very considerable superiority in volume of fire to engage shore batteries without severe loss, and when ships have suffered little it is more often because the gun detachments are driven away than because the battery is badly injured. With regard to the gun, therefore, we conclude that its use and tactics in the future will be what they have been in past without being much affected by possible changes in guns and armor. The gun's function is primarily to destroy life.*

Next let us consider the means available to the defenders of resisting the ships themselves. These have always been of two kinds, strictly passive obstructions or obstacles, such chain barriers, floating booms, sunken wrecks or piling, etc., and active means of inflicting injury upon the ships. In the latter class fire ships have been employed, but they have been serviceable only under special circumstances. In closed waters they have usually been ineffective so that they have not been generally regarded as important. The submarine mine was the earliest addition of a practical kind to the

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*Of course these remarks do not apply to the use of breaching batteries in siege operations.

ways of injuring the ship, and this was followed by the spar torpedo, the automobile torpedo, and latest, by the submarine boat carrying an automobile torpedo. In these various ways of opposing the ship, as distinct from opposing the crew, we see a progressive change from a bare passive resistance to the advance of the underwater body of the ship, towards an increasingly active attack upon the same underwater body, with the submarine boat and its torpedo as the farthest point of the developement. The submarine boat is now a mechanical success, but experience has not developed proper tactics. In attempting to use it we are in the position of a man who for the first time picks up a sword. He can wound an unskilled opponent with it immediately, but to parry with it or to wound a practiced adversary is a matter calling for much training. Nevertheless, whatever may be our present doubts as to the proper tactics of employing submarines, we may be sure that they have come to stay because they conform to the natural line of progress in harbor defense, which we have seen to be that of increasing the activity and efficacy of resistance to the underwater hulls of ships.

Another means of resistance directed primarily against the structure is the mortar. Although the fire of high-angle artillery has been used a very long time, yet until quite recently it has not been sufficiently accurate to be applicable against moving targets on the water, and therefore it is only within the past few years that mortar batteries have been extensively employed for coast defense. Seacoast mortars endeavor, if possible, to sink ships by complete penetration, and therein lies their peculiarity which classes them apart. High-power guns act principally against life, and mortars principally against materiel. The mortar differs from other weapons whose main action is against the ship in that it is placed upon the land. It also differs from other seacoast guns in that it is generally so placed that it is not as liable to injury from ship fire as high-power guns.

Let us now turn to methods of attack. As was before remarked, through all the centuries a good defense has so combined a plan for injuring the persons of the attacking forces with one for injuring the ships themselves that the two plans shall reinforce each other. Therefore any good plan of attack should endeavor to encounter only one of the two methods of resistance. Throughout the centuries there has been only one sure way of accomplishing this; namely, by making the principal atttack by the shore and not involving the ships themselves to such an extent as to risk serious injury to them. Just here is the point where modern inventions have affected tactics, but in detail only, not in broad principles. In the past the resistance to the ships was passive and immobile, and therefore in the struggle for the possession of a fortified harbor it was the proper sphere of the fleet to use its heavy artillery freely in aiding the force on shore, since the fleet was always at liberty to retire without danger of a counter-attack. At the present time the defense employs to advantage an active mobile counter-attack upon the underwater hull, and it is to be expected that in the future, more than in the past, attack upon fortified harbors will take the form of a military siege, while the navy will act as a covering force.

Indeed we may consider that the late operations against Wei-hai-wei and Santiago, which we have examined and where the navy took suchin active parts in spite of the exclusively naval objectives, we may believe, I say that these campaigns clearly foreshadow future practice. This view is confirmed by the thought that a harbor is attacked because it plays a part in a system of communications. But a fleet's duty is to occupy a region and control the sea communication therein, and so it is poor policy to gain a desirable seaport by the sacrifice of ships which are the very means of utilizing the capture. In other words the ships of fleet should actively assist in the capture of a seaport only when their probable losses will not affect their control of the sea.

Thus a comparison of past operations leads us to the conclusion that the attack on fortified harbors must be, in the future, chiefly a work of an army; and the navy, as a rule, should confine itself to maintaining and protecting the sea communications of the besieging army.

Defense should avail itself of every opportunity for counter-attack. In the past the naval support and supply to the siege operations has always been liable to such a counter-blow; which, when successful, must cause the attack to collapse. But here again is a point of difference between old means and new, and therefore between old and new tactics. Formerly channel obstructions were almost as much an obstacle to the exit of the defenders from the harbor as they were to the entrance of the besiegers; and therefore the counter-blow usually came from the outside. With proper control of the sea on the part of the attack this outside counter-blow, of course, could not come at all. At present, with channel obstructions which do not restrain friendly forces the counter-blow is deliverable from within the harbor where a refuge is at hand after striking. Further, the development of mobility in the means of attack on ship's bottoms has provided a readily available means of delivering a very formidable counter-blow.

As was the case in the past, so in the future, the maintenance of contact between the naval and transport fleets on one hand and the besieging army on the other, will always be the most important feature of the entire campaign, but the defense's newly acquired capability of delivering an effective counter-blow on the water from within the harbor transforms this maintenance of contact to something far from what it used to be, and makes it the vulnerable and critical feature of the operations.

A skilful admiral in performing his part in capturing a harbor will therefore, rather withdraw his heavy ships; holding them in reserve for use against a relieving fleet, and will develop the greatest activity in picket duty on the part of his gunboats, torpedo boats and submarines in order to prevent the similar craft of the enemy from interfering with the transport fleet. He will, if possible, send his light craft, particularly the submarines, inside against the hostile vessels there. The besieging army will regard it as its duty to attack and annoy all hostile shipping inside no less than to advance its siege operations, because the ships of the defense will operate against the besiegers' line of supply, when they go outside to deliver the counter-blow; and when inside, they will very considerably limit the action of the besiegers' field forces within their own lines. The active naval work of the campaign on both sides will therefore largely take the form of picket work, mining and countermining, and minor attacks by gunboats, torpedo boats and submarines.

All classes of work except the last are fairly well known through experience. But with regard to the tactics of submarines we know nothing. Hostile submarines are in the position of two duellists armed with knives and turned loose in a dark room. Both will want to see, and I am inclined to think that submarines will sacrifice much of their invisibility for the sake of acting quickly and with certainty.

But here we are going into the field of speculation. There can be no doubt, however, that they will play an important role, because our historical examination shows us that they are in the line of progress of three hundred years.

Thus, to conclude our study, we may say that, as formerly, so in the future, the seacoast guns of all descriptions and the channel obstruction will be the foundations of harbor defense. But, whereas in former times improbability of any serious counter-blow authorized and required the battle ships to take a more or less prominent part in the reduction of the defense, the new facility the defense has acquired of delivering a counter-blow will oblige the battleships to remain somewhat in retirement while the work of reducing the defenses will fall more exclusively than in the past upon a land force operating in rear of the seacoast forts.

The active work of the navy in these joint operations will be by every means possible to prevent the delivery of the counter-blow upon the water.

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NOTES ON THE DEFENSE OF PORT ARTHUR

Lieutenant Podgourski, who was torpedo officer of the cruiser Bayan, delivered a lecture at St. Petersburg on the defense of Port Arthur, with particular reference to technical details. We make a few extracts from the account given by the *Rousskii Invalid* (No. 94).

The lecturer spoke first of submarine mines. The Russian mines used for forming lines of obstacles contained 250 kg. of high explosive. Those used by the Japanese were very nearly one-half smaller. The Japanese from the very beginning were expert in rapidly planting lines of mines in the outer harbor. Admiral Makaroff was well aware of this, and every night he had torpedo boats and destroyers on guard to prevent their doing so; he also had constructed floating barricades behind which cruisers lay on the watch.

The loss of the Petropavlovsk is easily understood, when it is considered that more than 1500 mines were in the waters of the harbor, Russian as well as Japanese. The Russian mines were arranged at a distance of 3 to 4 km. from the entrance, in three lines with intervals of about 100 to 200 m. They used judgment firing.

The Russians tried various means for dragging for the mines that interfered with their work, but all these operations were very costly and but slightly successful; they had to limit themselves to dragging the channel of egress.

The use of ships' searchlights hindered the attacks of Japanese torpedo boats, but they have the serious disadvantage of revealing the exact location of the ship attacked. Hence in the latter part of the siege, the searchlights were taken off the ships and installed on shore to one side so as to cover the ship and deceive the enemy.

The lecturer confirms the lack of preparedness for war of the land front of the fortress at the beginning of hostilities. In all there were available on that front only three searchlights, one of which was out of commission. There were no wire entanglements, no fougasses, no entrenchments, and only a few guns. Of the six forts only three were armed, and the others were in various stages of completion. They all gave the impression of being unfinished. Everything had to be organized and completed in all haste.

The 40 cm., 75 cm. and 90 cm. searchlights rendered great service in night attacks, not only in revealing the presence of the attackers but also in affecting their morale and causing almost panics amongst them.

Fougasses were used in two ways, either automatic or with electric firing. About 80% of the latter failed to work because the wires had been cut by projectiles, although the lead wires had been buried at depths of from 1 to 1.2 meters. But once broken, they could not be repaired. Much of this work had been badly done on account of the lack of instructed men. The *single company of sappers* of the garrison was not sufficient for the task.

Great use was made of hand grenades, the Japanese being the first to employ them. Charged with high explosive, they produced effects of great violence. Tne Russian grenades weighed about 800 gms. and were charged with guncotton. They also made use of small Chinese bombs of cast iron, weighing up to 3 kg., and small Chinese grenades charged with powder. As many as 1500 grenades a day were used, the soldiers making use of them more willingly than even of their rifles in some cases.

The Russians also employed a kind of large land torpedo (called "globes de mines" by the lecturer). These were difficult to handle on account of their weight, but produced a great effect on the Japanese. In one case, one of these torpedoes weighing 250 kg. was thrown in the midst of the enemy from the Pagoda redoubt and caused a complete panic. They were also successfully used in the recapture of Hill 203. Later they were made much less heavy, only a few kilograms, and the lecturer himself made use of 105, none of which missed fire.

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SUBMARINES

The following are the results of the comparative trials between the submersible boat "Aigrette" and the submarine "Z," which has lately taken place before the special Commission on Submarines at Cherbourg. The "Aigrette" is of the improved "Sirene" type, of which 13 were ordered by M. de Lanessan, but when M. Pelletan became Minister of Marine, only two, the "Aigrette" and "Cicogne," were allowed to be completed. The dimensions of the "Aigrette" are as follows :—Length, 117 feet 6 inches; beam, 12 feet 7 inches; displacement 172 tons; motor, 200-H.P., to give a speed of 10.5 knots. The dimensions of "Z" are :—Length, 135 feet 6 inches: beam, 9 feet 8 inches; displacement 202 tons; motor, 190-H.P., to give a speed of 11 knots. The trials terminated very much sooner than was expected, and the result has been to prove clearly the superiority of the submersible over the submarine for work at sea. The "Aigrette," with much more beam and better distributed weights, showed herself to be much the better sea-boat of the two, and was the drier, although she has no bridges and she answers her helm well, while her habitability is of course far better than that of the submarine, as the men can come up and breathe fresh air in perfect safety; "Z," on the contrary, did not rise to the sea, and laboured a good deal, this being due, it is supposed, to her four torpedo-tubes weighing her down forward; moreover, she does not steer well; while the high bridge with which she has been fitted for navigating purposes, when moving on the surface, has the disadvantage of rendering her visible at a distance.

"Z" ought to have realised a speed of 11 knots on the surface, but she only made 8.3 knots; when submerged she made only 4.1 knots, and it is not believed to be possible to get her up over 6 knots, while the stipulated speed was 7.6 knots. The "Aigrette" made 8.7 knots on the surface, instead of the 9.2 knots promised; when submerged she made 6.3 knots instead of the stipulated 6.7 knots. While "Z" rolled heavily and her crew experienced much discomfort, the roll of the "Aigrette" did not exceed 12°, and the men were able to cook. What caused real astonishment during the trials was the time taken when diving; it was fully expected that "Z" would have dived in much less time than the "Aigrette," as she is an improved and larger "Farfadet," and the "Farfadet" is able to dive in 90 seconds, whilst according to the contract 5 minutes is allowed for the "Aigrette" to dive. Three trials were made under practical conditions at sea with the machinery for running on the surface at work. The result of the three trials were as follows :—

"Aigrette"	"Z"
4m. 30s.	5m. 30s.
4m. 14s.	4m. 30s.
5m. 50s.	10m.

These trials seem clearly to show that the submersible alone presents the necessary qualities for all prolonged navigation at sea; this does not necessarily involve the complete abandonment of the submarine, but it must be adapted to a certain *role*, and more must not be expected from it than it can perform. The submersible is the engine of offense, but the submarine can render useful service for coast defense, that is over a limited field of action. The submarine costs much less than the submersible; it will therefore be advisable to use it for defensive purposes.

Another result of the trial has been to show that "Z," which is a large "Lutin," the plan for the two vessels being by the same designer, has not gained anything by her increased dimensions, whilst the "Aigrette," which is an improved "Narval," has, on the contrary, gained much. The Committee are of opinion that the submersible of the future should have a displacement of 400 tons, and that the useful displacement of the submarine should not exceed 100 tons. It therefore becomes a question of deferring any further work on the new submarines of the "Emeraude" type, which were to have had a displacement of 450 tons, until the whole question has been considered. The Committee before leaving Cherbourg inspected the new submarine station, and expressed their complete satisfaction with it.

It also interesting to note that the Budget Committee also recommends that as regards submersibles, a return should be made to the 1900 programme. Instead of the 44-ton boats which were last ordered, and which are uninhabitable, eleven submarines of the "Aigrette" type should be constructed. The Committee further recommends that sixty-six torpedo boats should be built, the construction to be divided between the dockyards and private yards, as may be most convenient.

The new submarines have been ordered at Cherbourg. These were mentioned originally in the Annexe to the Budget first distributed in the French Chambers as "Q 47" and "Q 48"; but after revision of the Annexe they became "Q 59" and "Q 60." These boats are to be of a modified

"Emeraude" type. They are not to be confused with the "Rubis" and "Topaze," which are precisely of the "Emeraude" type. They will each displace 425 tons; length about 180 feet; beam, 12.8 feet; motor, 1,200-H.P.; speed, 12 knots, cost of the two £145,600. A small submarine for experiments was ordered at Toulon at the end of last year. She was intended to be carried and launched from a larger vessel; some warships now building will have a special provision for doing this when out at sea. The small boat is known as "Q 61." Her displacement is 21 tons; length, 36.5 feet; beam, 6.5 feet; motor, 130-H.P.; cost, £7,200.—*Journal R. U. S. I.*

England possesses at present 17 submarines built and 23 in course of construction. The Admiralty has just created three stations for these boats. 1. Portsmouth, 5 submarines Class B with the gunboat Hazard. The other boats of Class B will gather at Portsmouth as they are completed. 2. Devonport, 5 submarines Class A with the cruiser Forth. The station will be at the place called Cattewater where there there are gasolene reservoirs, docks, and special arrangements for keeping secret the details of the submarines. 3. Sheerness, 5 submarines numbered 1 to 5, with a cruiser to be designated.

The speed of the Class B submarines is 13 knots on the surface and 9 knots submerged; their radius of action is 500 miles on the surface and 90 miles submerged. Their speed in diving is 60 meters a minute at an inclination of 10 degrees.—*Le Yacht.*

The transfer of the mining defenses of our ports from the Army to the Navy probably to some extent accounts for the more vigorous policy to be pursued as regards the construction of submarines. It is of vital importance to us that there should be free ingress and egress to all friendly ships at our ports in time of war. The Russo-Japanese war shows that the use of submarine mines may be as dangerous to friend as to foe. It is more than possible that Russian ships were destroyed by Russian mines, and Japanese ships by Japanese mines, in the operations off Port Arthur. Submarine boats for the defense of ports would probably be less costly and certainly less dangerous to friendly vessels than a mine field, and an equally effective deterrent the ships of the enemy, but as long as the command of the sea is maintained, neither submarine boats nor mines are needed for the defense of ports. Submarine boats to be of real value should be used offensively. Little information is forthcoming as to the trials of British submarines. Nothing that has been published would seem to indicate that the submarine is anything more than an inferior kind of torpedo-boat, and of all the lessons to be drawn from the war none comes out more clearly than this—the torpedo boat, handled though it was with consummate courage and skill by the Japanese, nearly always failed to attain its objective.—*The Naval Annual,* 1905.

BOOK REVIEWS

The Naval Annual, 1905. Edited by T. A. Brassey, A.I.N.A. 8+525p. il. pl. O. Portsmouth. J. Griffin & Co. 2, The Hard. 15s. net.

The new volume of this most valuable annual is in no respects inferior to previous issues. In fact, in some features it surpasses some of them, and, as a whole, it is one of the most interesting that has appeared for several years. The year 1904 has been so fertile in naval events of great importance that it was to be expected they would offer a broad field to those who contribute to its pages. The volume fulfils expectation in this respect, besides having many articles that are instructive as well as interesting.

Among the note-worthy characteristics of this edition may be mentioned the excellent account of the "Russo-Japanese Naval Campaign of 1904" by Admiral Sir Cyprian Bridge; the essay upon "The Imperial German Navy" by J. L. Bashford; and the chapters upon Armor and Ordnance by Captain Tresidder. There is also a thoughtful and instructive article on Naval Tactics contributed by Admiral Sir R. Custance, well worth study by naval officers.

In Part I. the Editor and Mr. Leyland give the usual chapters on the British Navy, Foreign Navies, and Comparative Strength. They contain important particulars of British and foreign warships, and the usual summary of progress which is so useful a feature of this publication. A chapter on "The Navy and the Somaliland Expedition of 1902-4" contains many interesting details illustrating the usefulness and mobility of sea forces for land purposes, "in fulfilling those functions which, though at times unseen and unadvertised, are yet none the less important than the military operations proceeding currently." Mr. Thursfield in the chapter on "The Dogger Bank and its Lessons" gives the whole history of the subject and the conclusions arrived at by the Commission with comments and reasons as to how the mistake came to be made. The "psychological atmosphere" which the Russian Admiral created for his self-delusion seems to explain the blunder quite readily.

Then follows the chapter which no doubt will claim the greatest attention in this issue, that by Admiral Sir Cyprian Bridge on the Russo-Japanese Naval Campaign of 1904. The authority of the author, who personally witnessed many of the incidents of this war, and the importance of the subject, make this chapter of special interest. It comprises 75 pages and should be read in its entirety to be fully appreciated. We can only touch upon some of his conclusions. "Perhaps nothing stands out more clearly in the campaign than the insignificance of the results effected by the locomotive torpedo." He concludes that the torpedo is a weapon of limited efficiency, to be depended upon only in special circumstances of infrequent occurrence. As regards submarines, "full consideration of the conditions revealed by the present war is likely to lead to the conclusion that the adoption of the submarine is no sign of naval progress, but is on the contrary a retrograde step." He also questions the utility of the big armored cruiser. "Is there any justification for the existence of the type?" Of battleships, the author says "the battleship as a type has eminently justified her existence in this campaign. It was Admiral Togo's battle fleet, not his torpedo craft, not the sunken steamers, not the Japanese blockade mines, which really confined the Russians to Port Arthur." Another lesson the author draws is the small tactical and strategical value of speed, and he gives instances in support of this. He concludes by showing the great value of morale in war. Perhaps some of these questions can be answered with more certainty when the details of the last great naval battle between the Russians and Japanese fleets are available, but while there may be difference of opinion on the views expressed the conclusions of the author cannot fail to command respect. His comprehensive review of the present war is one of the most instructive and interesting that has yet appeared.

A chapter on "Manning of the Navy and Mercantile Marine" by Lord Brassey, one on the German Navy, and an appropriate one—for the centennial year of Nelson's victory—on the battle of Trafalgar, complete this part of the book.

The section on Armor and Ordnance has been undertaken by a new writer for the *Annual*, but one well-known to the military and naval world, Captain Tresidder. The subject is ably treated and the chapters contain much valuable matter. We have quoted from this section on previous pages of this issue.

The usual lists of warships of the world, with the plans and illustrations, tables of ordnance, statistics, etc., are given and maintain their completeness and excellence as in former issues.

It may be said that the *Annual* has become invaluable to the coast artillery, as well as to the Navy, both for study and reference. Each succeeding volume maintains its high standard and reputation as one of the most useful books for this purpose.

The Eyes and Ears of the Artillery. Hints on the Education and Training of Artillery Observation Patrols and Ground Scouts. By Colonel C. N. Simpson, R. F. A., with preface by Major-General Sir W. G. Knox, K. C. B. 8+76p. il. D. London: Hugh Rees, Ltd., 124 Pall Mall, S.W. 1905. 1s. 3d. net.

This is a very practical, common-sense little manual on that most important duty in war, observation and reconnaissance, particularly from the artillery point of view. It is not sought to separate artillery from the protective scouting by other troops, but to provide artillery with efficient observation services whose duty it is to collect and transmit to the artillery commander information which by amplifying or corroborating reports from other sources would render that arm secure from dangers of indifferent scouting by others, and at the same time furnish the artillery commander with special data of importance from an artillery standpoint.

It is clearly desirable that artillery should be capable of reconnoitring positions for guns, of searching the ground on the front and flanks of a position, of reconnoitring the enemy's position and of reporting the movements of the enemy and one's own advanced troops, with other information, as for example, the effect of fire on the objective, etc.; and any scheme which will produce a body of men capable of performing these duties with accuracy and dispatch cannot fail to be of the utmost value to an artillery commander.

The author therefore considers the subject of scouting and reconnaissance in so far as it may be held to fall to the lot of an "artillery observation patrol," and points out the principal points which every person who wishes to become an adept in these important duties should bear in mind. He gives a number of practical hints on the subject, including equipment, training, gaining information, map-reading, making reports, judging distances, care and use of telescopes and field glasses, horsemanship, observation of fire, and concludes with a syllabus and a suggested course of outdoor instruction for artillery observation patrols.

The notes here compiled afford an excellent opportunity of a study of the duties that will be required from such patrols, and will be found of much practical utility as a system of training.

Staff Rides, with Hints on Writing Appreciations and Reconnaissance Reports. By Captain A. A. Marindin, The Black Watch. 55p. S. London: Hugh Rees, Ltd., 124 Pall Mall, S.W. 1905. 2s. net.

In this convenient pocket volume Captain Marindin gives a concise account of Staff Rides and the nature of the work done on them. The meaning of the term Staff Ride has been but little understood by regimental officers, hence the object of the book is to define their purpose and give same of the details that an officer who has never been on one may wish to know.

It gives a clear description of how a Ride is carried out at the Staff College, the nature and division of the duties of the officers engaged, followed by a chapter on details as to schemes, number of officers participating, etc. The chapters on Appreciation of a Situation and Reconnaissance Reports contain many sensible remarks for the guidance of officers in this work.

The method laid down is altogether practical and it is evident that much valuable instruction can be given officers, both line and staff, with little expense and without the use of troops. The author says, "it will easily be understood that a Staff Ride is really hard work from start to finish for everybody," but it is also evident from his book that it is most excellent practice and the results undoubtedly should give a good insight into the fitness of officers for staff duty.

Wellington's Campaigns: Peninsula-Waterloo, 1808-15. Also Moore's Campaign of Corunna (for Military Students). By Major-Gen. C. W. Robinson, C. B. Part I. 1808-9-10, Roleia to Busaco. 149p. maps and plans. O. London: Hugh Rees, Ltd., 124 Pall Mall, S.W. 1906. 3s 6d. net.

Fully appreciating the value of Wellington's campaigns as a foundation for the study of military history by British officers and military students in general, General Robinson in this capital book gives a concise account of all the more important incidents of them from Roleia to Busaco, with full comments designed especially for military students and as an aid to the study of military history generally. Any exhaustive examination into the details of Wellington's battles and sieges would fill, not one volume but several, hence the scope of the book is limited; its chief aim being to facilitate the study of all the main British operations, giving critical remarks upon them and general observations in reference to the history and practice of war. It is, however, not a mere precis, but a readable and instructive account that traverses the ground in a clear and intelligent manner.

The introductory chapters explain first the origin of the war and then the principles of war and influence of topography on military operations and the topography of the Peninsular. Then follows Wellesley's campaign in the Peninsular, 1808; Moore's campaign, 1808-9; and Wellington's second series of operations ending with his withdrawal behind the defensive lines of Torres Vedras. The account of the successive campaigns is concise, definite and accurate. With respect to battles, their distinctive character is given, also the object with which each was fought, the general character of the positions taken up, the main features of the battles described, and their results. The comments in each case are valuable and instructive both as explanations of the operations themselves and as an aid in the study of the art of war. The book is well supplied with excellent maps and plans, which add to its value.

The campaigns of Wellington teach many valuable lessons and remain to this day models for study by military students. This book can be cordially commended for the purpose.

History of the War in the Peninsula and in the South of France from the Year 1807 to the Year 1814. By Major-General Sir W. F. P. Napier, K.C.B., Colonel 27th Regiment. Three volumes. Kansas City, Mo. Hudson-Kimberly Publishing Co. 1904.

This edition of an English and a military classic is particularly welcome to the army, as it places in their hands at a reasonable price one of the most instructive military histories published.

The work is too well known in general literature to require any special comment as to its value to the general reader. It has been long recognized as a classic, both on account of the author's inimitable and vigorous style and his admirable descriptions of sieges and of battles.

Napier is regarded to-day as the best military historian England has produced. In the first place, he was an officer of note in the army, and an eye-witness of the scenes he describes, but more than that, he possessed a peculiarly appropriate literary style, which enabled him to light up uninteresting details with natural eloquence and vivid imagination, without destroying the accuracy or truthfulness of the general picture.

The accuracy of the account in its main features has stood the test of time. Wellington himself gave much assistance to the author, and handed over to him the whole of Joseph Bonaparte's correspondence which had been taken in the battle of Vitoria. Recently, however, Professor Oman of Oxford, England, who has had access to the Spanish official reports and documents, has undertaken a new history (has yet completed) which modifies the statements of Napier on *political* subjects very materially, but does not affect the *military* account very seriously, and Napier's peculiarly attractive style has not been approached.

The work is well printed, the maps are numerous and quite satisfactory, and an excellent index makes this edition more useful than any preceding one.

The United States: A History of Three Centuries. W. E. Chancellor and F. W. Hewes. In Ten Parts. **Part II: Colonial Union, 1698-1774.** New York: G. P. Putnam's Sons. 1905. Pp. 539.

The second volume of this comprehensive work, the opening volume of which we have already reviewed* fulfills the promise of the earlier volume, and indicates that the entire work will be for the general reader, one of the most complete and satisfactory histories that has yet appeared.

The development of our country and our institutions is traced in *all* the different spheres of action: industry, commerce, civilization, education, literature and social life, as well as in those usually considered in histories, namely, war and politics. The space allotted to political and military events is, in consequence, somewhat reduced, but the work has thereby gained in in completness and proper balance.

The authors are both recognized authorities in their respective departments of history. Their story is told in fascinating language, vividly, and with all the interest that properly attaches to the history of our nation. The statistical and economic part is novel and exceptional in a work of this kind, and adds greatly to the practical value of the history.

Part II. (the present second volume of the complete work) comprises the period of *Colonial Union*, 1698-1774, and is a record of the Development of the Several English Colonies and of the Rise of the Spirit of Revolution.

The volume opens with an account of the growth of population in general from 1697-1760, and particularly of the slave trade and the negro population during this period; the western movement of population is next discussed, the Colonial Governments are described and the political histories of the different colonies are traced; the progress of New France and of New Spain are outlined, and the development of the spirit of revolution is presented in clear and graphic pen-pictures.

The section on *War* contains accounts of Queen Anne's War, the English-Spanish in Georgia and Florida, King George's War, the French and Indian War and the Conspiracy of Pontiac; that on *Industry* treats especially of the progress in agriculture, colonial manufacture, iron and steel, shipbuilding and fisheries, textiles, paper and books, trade, transportation and finance; and that on *Civilization* contains articles on religion and morality, education, literature and social life. A final chapter on contemporaneous European history completes the pictures presented. This volume contains five large maps, five diagrams showing historical perspectives of various kinds, and 87 smaller maps scattered through the text.

A few extracts will illustrate the general mode of treatment of the subject and the character of the work:

The fall of Quebec is treated as a triumph of the new sea-power of England:

"In England, William Pitt has become supreme, a man who by believing in the glory of England helped her make herself glorious. A great enthusiast, he woke in British hearts a kindred enthusiasm. He was now to oppose to French distrust English faith, and was thereby to change the fortunes of the American War (1754-1763). To prevent reinforcements from reaching New France, he launched the English navy against the French. Sir Edward Hawkes intercepted and drove ashore a fleet of transports sailing from Rochefort with troops for America, while Admiral Osborn, cruis-

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* See JOURNAL, November-December 1904, p. 384.

ing between Spain and Africa, barred the passage of the Straits of Gibraltar, which was irresolutely attempted by ships from Toulon. Her own fleets England sent unmolested across the sea. * *

"In 1763, the fearful European war was brought to an end by the Treaty of Paris; by its terms France ceded to Great Britain all her North American possessions save New Orleans and the region west of the Mississippi. * * Even more humiliating terms would probably have been exacted from France by England, if Pitt had then held the chief power; but enough had been gained. The navy by winning for England the overlordship of the sea, had made the 'tight little island' the home of the chief nation of the world."

In the discussion of the growth of population, we find the following pertinent remarks:

"Government alone, not soil, not quality of people, explains the success of Pennsylvania in comparison with either Virginia or New York. Massachusetts had to contend with a harsh climate and poor soil, yet in her white population she surpassed every colony; and all, excepting New Hampshire and Rhode Island, had superior geographical advantages. Let those who argue (as many do) that laws make but little difference in the prosperity and the morality, the happiness and the progress, of a people, study patiently the story of the American colonies in the first six decades of the seventeenth century. * * * * * *

"By the year 1760, the social tone of the Southern Colonies was already determined. There was a political aristocracy based upon an economic aristocracy. It is this that, more than anything else, explains the fact that the western-moving tide of American migration began not in New England, New York or Pennsylvania, but in Virginia and the Carolinas. In the aristocracy founded upon negro slavery, there was but little room for the free but poor white wage-earner. The land and slave-lords owned most of the land, and needed to hire but little labor. As the white bondmen served out their time, and as their children grew to manhood and womanhood, in a contracted labor market they could find but limited opportunities for work and wages. The result was the western migration, one of whose earliest leaders was the immortal Washington."

The scope of the work and its philosophic character are here cleary indicated. It is a rich storehouse of information and portrays the life-history of the nation in all its spheres of action.

Taschenbuch der Kriegsflotten, VI. Jahrgang, 1905. By B. Weyer, Kapitanleutnant a. D. 348p. 359 sketches and pictures of ships. S. München: J. F. Lehmann's Verlag 1905. Price Mk. 4.

This excellent little Naval Pocket Book, now in its 6th year, improves with each issue. Revised in consequence of the Russo-Japanese war, the opportunity was taken to make a number of other improvements also. The list of ships have been carefully gone over, brought up to date according to latest information, and 50 new pictures and plans have been added. Cruisers have been subdivided and rearranged under the heads : armored cruisers (vertical waterline armor), protected cruisers (protective deck only), and unprotected cruisers (without protective deck)—a better arrangement than before. Two of the minor chapters, one on International Signals and one on Birthdays of Rulers and National Holidays, have been omitted, without loss to the book.

One suggestion we would make. At present on opening the book the data given in the lists of ships of various navies run across both pages, left and right. Where the alignment is exact this causes no trouble, but in several cases in the present book, the matter on the right hand page, say, is above or below that on the left, making it difficult for the eye to follow across on the same line. On pages 100 and 101, for example, the information on page 101 is a whole line below that of the ship to which it pertains given on page 100, in fact comes opposite that of the next ship on the list. If this could be avoided in some way, it would add to the convenience of the book for reference.

The illustrations are particularly good in this edition and very complete. Part II. gives the comparative strength, naval programs, etc., of the principal Powers; Part III. tables of naval and coast guns; Part IV. miscellaneous information, principally concerning the German navy; and Part V. conversion tables, tables of distances, etc.

It is really a very complete and satisfactory little book, and with its fund of information on the navies of the world given in convenient and concise form, it will be found a handy and useful reference book for all interested in naval matters.

In the exceedingly able **Presidential Address of Mr. R. A. Hadfield** to the Iron and Steel Institute, will be found a very complete history of iron and steel manufacture, with many interesting remarks on subjects connected therewith, and indications of the probabilities of the future. It fills a pamphlet of 82 pages with several plates, and is a valuable contribution to the literature of the subject. We must content ourselves with quoting some of his remarks on War Material:

In armor plates, the advance from those of wrought iron to the modern cemented hard-face type has been marvellous. Armor of to-day has a figure of merit not far from three times that of wrought iron; and this, as will be readily understood, has meant in itself a revolution in the building of war vessels. Compound plates for a time struggled hard against mild or tough steel, but it was Harvey, the American, who introduced the bold idea of applying, and improving, the old process of cementation to the production of armor having a hard face, practically impenetrable to any type of projectiles excepting those with caps. Then Ehrensberger and Schmitz of Krupp's works, with all the wonderful resources of that great establishment at their disposal, perfected this system, and improved the steel of which the plates were made to such a degree that Harvey plates in their turn had to give way to what is now known universally as "K.C." or Krupp-cemented armor.

As an example of the great superiority of this new description of armor, it may be mentioned that a 6-inch plate affords equal resistance to more than 18 inches of wrought iron. It will be seen from this what a revolution has been produced in the designing of warships by the saving of weight devoted to protection; and this, again, is due to the metallurgist.

The problem of suddenly arresting armor-piercing projectiles, striking in some cases with 30,000 foot-tons of energy, has not been an easy one, as will be readily understood; therefore the greatest credit is due to the firms of Krupp, Brown, Vickers, Cammell, Beardmore, Armstrong, Schneider, Terni, Wittkowitz, Carnegie, and Bethlehem, who have gradually brought their work to that state of perfection that an uncapped projectile can be stopped in its more than "mad career" with ruin to itself, whilst the plate passes successfully through this trying ordeal, unperforated, and with nothing more than a few face cracks. Messrs. Schneider, in November last, rolled a nickel-chromium steel armor plate weighing 65 tons, the ingot having been 4 feet across and 9 feet in length.

Having said so much for armor, what shall be said of the latest type of projectiles, which, by means of a cap, has enabled this remarkable armor to be readily perforated? In one case a 12-inch armor-piercing shell was fired at a 12-inch Krupp-cemented plate at a velocity of about 2000 foot-seconds, the plate being completely perforated, and the projectile, after passing through this trying ordeal, being found in the rear of the plate in a condition for bursting.

With the complex stresses involved in such a trial, both to the plate and to the projectile, it will be seen that the problem of producing the most suitable material for the purpose is one demanding a very high order of skill and knowledge.

There still remain many problems to be solved in plate and projectile manufacture, and also in the production of steel used in modern high-velocity guns, but out of chaos order is being evolved.

In the construction of guns, carbon steel has long held its own. Naturally, the risk of the gun bursting has necessitated great caution in the production of the material to be used. Special steels have been regarded with suspicion, but there is now a growing disposition to consider the question of using a special steel having higher efficiency as regards resistance to the severe stresses met with, and also to erosion. Attention is also being given to the means for avoiding "streaky" steel, which in the past has given much trouble.

In order to afford an exact idea of the enormous energies which have to be dealt with, it may be mentioned that a 12-inch breech-loading gun has been fired in this country with a muzzle velocity of close upon 2700 foot-seconds. This means a striking energy of 42,220 foot-tons. The projectile, if uncapped, would be capable of perforating 44 inches of wrought iron, 34 inches mild steel, 19 inches of Krupp-cemented armor; if a capped projectile were used, about 23 inches of Krupp-cemented armor would be pierced. As may be imagined, the inner tubes of guns, at such velocities, are soon worn out; in fact, in large caliber guns, an improved steel for these inner tubes is a matter much to be desired.

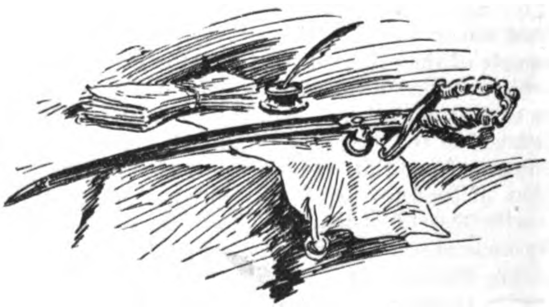

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TABLE I.

$\varphi = 30°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
° ′					° ′				
31 0	1.6678	171	1.1900	86	34 0	1.2042	96	0.9549	49
5	1.6507	168	1.1814	84	5	1.1946	94	0.9500	49
10	1.6339	164	1.1730	83	10	1.1852	92	0.9451	48
15	1.6175	162	1.1647	81	15	1.1760	91	0.9403	48
20	1.6013	158	1.1566	80	20	1.1669	90	0.9355	47
25	1.5855	156	1.1486	79	25	1.1579	88	0.9308	46
30	1.5699	153	1.1407	78	30	1.1491	87	0.9262	46
35	1.5546	151	1.1329	76	35	1.1404	86	0.9216	46
40	1.5395	148	1.1253	74	40	1.1318	85	0.9170	45
45	1.5247	145	1.1179	73	45	1.1233	84	0.9125	45
50	1.5102	143	1.1106	72	50	1.1149	83	0.9080	44
55	1.4959	142	1.1034	71	55	1.1066	82	0.9036	44
32 0	1.4817	139	1.0963	70	35 0	1.0984	81	0.8992	43
5	1.4678	136	1.0893	68	5	1.0903	79	0.8949	43
10	1.4542	133	1.0825	67	10	1.0824	78	0.8906	42
15	1.4409	131	1.0758	66	15	1.0746	77	0.8864	42
20	1.4278	129	1.0692	65	20	1.0669	76	0.8822	41
25	1.4149	126	1.0627	65	25	1.0593	76	0.8781	41
30	1.4023	125	1.0562	64	30	1.0517	74	0.8740	40
35	1.3898	123	1.0498	62	35	1.0443	73	0.8700	40
40	1.3775	121	1.0436	61	40	1.0370	72	0.8660	39
45	1.3654	119	1.0375	60	45	1.0298	71	0.8621	39
50	1.3535	118	1.0315	60	50	1.0227	70	0.8582	39
55	1.3427	116	1.0255	59	55	1.0157	70	0.8543	38
33 0	1.3301	114	1.0196	58	36 0	1.0087	137	0.8505	75
5	1.3187	112	1.0138	57	10	0.9950	132	0.8430	73
10	1.3075	111	1.0081	56	20	0.9818	129	0.8357	72
15	1.2964	109	1.0025	56	30	0.9689	126	0.8285	70
20	1.2855	107	0.9969	55	40	0.9563	123	0.8215	69
25	1.2748	104	0.9914	54	50	0.9440	121	0.8146	67
30	1.2644	103	0.9860	54	37 0	0.9319	118	0.8079	66
					10	0.9201	115	0.8013	64
35	1.2541	102	0.9806	53	20	0.9086	112	0.7949	63
40	1.2439	101	0.9753	52	30	0.8974	110	0.7886	62
45	1.2338	100	0.9701	51	40	0.8864	107	0.7824	61
50	1.2238	99	0.9650	51	50	0.8757	105	0.7763	59
55	1.2139	97	0.9599	50	38 0	0.8652	102	0.7704	58
34 0	1.2042	96	0.9549	49					

TABLE I. (Continued.)

$\varphi = 30°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
38° 0′	0.8652	102	0.7704	58	46° 0′	0.5252	50	0.5668	32
10	0.8550	101	0.7646	58	10	0.5202	50	0.5636	32
20	0.8449	98	0.7588	57	20	0.5152	49	0.5604	32
30	0.8351	96	0.7531	56	30	0.5103	48	0.5572	32
40	0.8255	95	0.7475	55	40	0.5055	48	0.5540	31
50	0.8160	93	0.7420	52	50	0.5007	47	0.5509	31
39 0	0.8067	91	0.7368	52	47 0	0.4960	47	0.5478	31
10	0.7976	89	0.7316	51	10	0.4913	46	0.5447	31
20	0.7887	88	0.7265	51	20	0.4867	46	0.5416	30
30	0.7799	86	0.7214	50	30	0.4821	45	0.5386	30
40	0.7713	84	0.7164	49	40	0.4776	45	0.5356	30
50	0.7629	83	0.7115	49	50	0.4731	45	0.5326	30
40 0	0.7546	82	0.7066	48	48 0	0.4686	44	0.5296	30
10	0.7464	80	0.7018	47	10	0.4642	44	0.5266	29
20	0.7384	78	0.6971	46	20	0.4598	43	0.5237	29
30	0.7306	78	0.6925	46	30	0.4555	43	0.5208	29
40	0.7228	76	0.6879	45	40	0.4512	42	0.5179	29
50	0.7152	75	0.6834	45	50	0.4470	42	0.5150	28
41 0	0.7077	74	0.6789	44	49 0	0.4428	42	0.5122	28
10	0.7003	72	0.6745	43	10	0.4386	41	0.5094	28
20	0.6931	72	0.6702	43	20	0.4345	41	0.5066	28
30	0.6859	70	0.6659	42	30	0.4304	40	0.5038	27
40	0.6789	70	0.6617	42	40	0.4264	40	0.5011	27
50	0.6719	69	0.6575	41	50	0.4224	40	0.4984	27
42 0	0.6650	68	0.6534	41	50 0	0.4184	39	0.4957	27
10	0.6582	66	0.6493	40	10	0.4145	39	0.4930	26
20	0.6516	66	0.6453	40	20	0.4106	39	0.4904	26
30	0.6450	64	0.6413	39	30	0.4067	38	0.4878	26
40	0.6386	64	0.6374	39	40	0.4029	38	0.4852	26
50	0.6322	63	0.6335	38	50	0.3991	38	0.4826	26
43 0	0.6259	62	0.6297	38	51 0	0.3953	37	0.4800	26
10	0.6197	61	0.6259	37	10	0.3916	37	0.4774	25
20	0.6136	60	0.6222	37	20	0.3879	37	0.4749	25
30	0.6076	60	0.6185	37	30	0.3842	36	0.4724	25
40	0.6016	59	0.6148	36	40	0.3806	36	0.4699	25
50	0.5957	58	0.6112	36	50	0.3770	36	0.4674	25
44 0	0.5899	58	0.6076	36	52 0	0.3734	35	0.4649	25
10	0.5841	57	0.6040	35	10	0.3699	35	0.4624	25
20	0.5784	56	0.6005	35	20	0.3664	35	0.4599	25
30	0.5728	56	0.5970	35	30	0.3629	35	0.4574	25
40	0.5672	54	0.5935	34	40	0.3594	34	0.4549	24
50	0.5618	54	0.5901	34	50	0.3560	34	0.4525	24
45 0	0.5564	54	0.5867	34	53 0	0.3526	34	0.4501	25
10	0.5510	53	0.5833	33	10	0.3492	33	0.4476	24
20	0.5457	52	0.5800	33	20	0.3459	33	0.4452	24
30	0.5405	52	0.5767	33	30	0.3426	33	0.4428	24
40	0.5353	51	0.5734	33	40	0.3393	33	0.4404	24
50	0.5302	50	0.5701	33	50	0.3360	32	0.4380	24
46 0	0.5252	50	0.5668	32	54 0	0.3328	32	0.4356	24

$\varphi = 30°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
54° 0′	0.3328	32	0.4356	24	62° 0′	0.2021	24	0.3311	21
10	0.3296	32	0.4332	24	10	0.1997	23	0.3290	20
20	0.3264	31	0.4308	23	20	0.1974	22	0.3270	20
30	0.3233	32	0.4285	24	30	0.1952	23	0.3250	21
40	0.3201	31	0.4261	23	40	0.1929	22	0.3229	20
50	0.3170	31	0.4238	23	50	0.1907	22	0.3209	20
55 0	0.3139	31	0.4215	24	63 0	0.1885	22	0.3189	20
10	0.3108	30	0.4191	23	10	0.1863	22	0.3169	20
20	0.3078	30	0.4168	22	20	0.1841	22	0.3149	20
30	0.3048	30	0.4146	23	30	0.1819	22	0.3129	20
40	0.3018	30	0.4123	23	40	0.1797	22	0.3109	20
50	0.2988	29	0.4100	22	50	0.1775	21	0.3089	20
56 0	0.2959	30	0.4078	23	64 0	0.1754	22	0.3069	20
10	0.2929	29	0.4055	22	10	0.1732	21	0.3049	20
20	0.2900	28	0.4033	22	20	0.1711	20	0.3029	20
30	0.2872	29	0.4011	23	30	0.1691	21	0.3009	20
40	0.2843	29	0.3988	22	40	0.1670	21	0.2989	20
50	0.2814	28	0.3966	22	50	0.1649	20	0.2969	19
57 0	0.2786	28	0.3944	22	65 0	0.1629	21	0.2950	20
10	0.2758	28	0.3922	22	10	0.1608	20	0.2930	20
20	0.2730	28	0.3900	22	20	0.1588	20	0.2910	19
30	0.2702	28	0.3878	22	30	0.1568	20	0.2891	20
40	0.2674	27	0.3856	22	40	0.1548	20	0.2871	20
50	0.2647	27	0.3834	21	50	0.1528	19	0.2851	19
58 0	0.2620	27	0.3813	22	66 0	0.1509	20	0.2832	20
10	0.2593	27	0.3791	21	10	0.1489	19	0.2812	19
20	0.2566	26	0.3770	21	20	0.1470	19	0.2893	19
30	0.2540	27	0.3749	22	30	0.1451	20	0.2774	20
40	0.2513	26	0.3727	21	40	0.1431	19	0.2754	19
50	0.2487	26	0.3706	21	50	0.1412	19	0.2735	19
59 0	0.2461	26	0.3685	22	67 0	0.1393	20	0.2716	20
10	0.2435	26	0.3663	21	10	0.1373	19	0.2696	20
20	0.2409	25	0.3642	20	20	0.1354	18	0.2676	19
30	0.2384	26	0.3622	22	30	0.1336	19	0.2657	20
40	0.2358	25	0.3600	21	40	0.1317	18	0.2637	19
50	0.2333	24	0.3579	20	50	0.1299	18	0.2618	19
60 0	0.2309	25	0.3559	22	68 0	0.1281	18	0.2599	20
10	0.2284	25	0.3537	21	10	0.1263	18	0.2579	20
20	0.2259	24	0.3516	20	20	0.1245	18	0.2559	19
30	0.2235	25	0.3496	21	30	0.1227	18	0.2540	20
40	0.2210	24	0.3475	21	40	0.1209	18	0.2520	19
50	0.2186	24	0.3454	20	50	0.1191	17	0.2501	19
61 0	0.2162	24	0.3434	21	69 0	0.1174	18	0.2482	20
10	0.2138	24	0.3413	21	10	0.1156	17	0.2462	19
20	0.2114	23	0.3392	20	20	0.1139	17	0.2443	19
30	0.2091	24	0.3372	21	30	0.1122	17	0.2424	20
40	0.2067	23	0.3351	20	40	0.1105	17	0.2404	19
50	0.2044	23	0.3331	20	50	0.1088	16	0.2385	18
62 0	0.2021	24	0.3311	21	70 0	0.1072	17	0.2367	20

TABLE I. (Continued.

$\varphi = 30°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
70° 0′	0.1072	17	0.2367	20	78° 0′	0.0410	11	0.1444	20
10	0.1055	16	0.2347	19	10	0.0399	11	0.1424	19
20	0.1039	16	0.2328	18	20	0.0388	10	0.1405	19
30	0.1023	16	0.2310	20	30	0.0378	11	0.1386	20
40	0.1007	16	0.2290	19	40	0.0367	10	0.1366	19
50	0.0991	16	0.2271	18	50	0.0357	10	0.1347	18
71 0	0.0975	16	0.2253	20	79 0	0.0347	10	0.1329	20
10	0.0959	16	0.2233	19	10	0.0337	10	0.1309	20
20	0.0943	16	0.2214	19	20	0.0327	10	0.1289	19
30	0.0927	16	0.2195	20	30	0.0317	10	0.1270	20
40	0.0911	15	0.2175	19	40	0.0307	9	0.1250	20
50	0.0896	15	0.2156	19	50	0.0298	9	0.1230	19
72 0	0.0881	16	0.2137	20	80 0	0.0289	10	0.1211	20
10	0.0865	15	0.2117	19	10	0.0279	9	0.1191	20
20	0.0850	15	0.2098	19	20	0.0270	8	0.1171	19
30	0.0835	15	0.2079	20	30	0.0262	9	0.1152	20
40	0.0820	15	0.2059	19	40	0.0253	9	0.1132	20
50	0.0805	14	0.2040	18	50	0.0244	8	0.1112	19
73 0	0.0791	15	0.2022	20	81 0	0.0236	9	0.1093	20
10	0.0776	15	0.2002	19	10	0.0227	8	0.1073	20
20	0.0761	14	0.1983	19	20	0.0219	8	0.1053	19
30	0.0747	14	0.1964	20	30	0.0211	8	0.1034	20
40	0.0733	14	0.1944	19	40	0.0203	8	0.1014	19
50	0.0719	14	0.1925	19	50	0.0195	7	0.0995	19
74 0	0.0705	14	0.1906	20	82 7	0.0188	8	0.0976	20
10	0.0691	14	0.1886	19	10	0.0180	7	0.0956	19
20	0.0677	13	0.1867	19	20	0.0173	7	0.0937	19
30	0.0664	14	0.1848	20	30	0.0166	7	0.0918	20
40	0.0650	13	0.1828	19	40	0.0159	7	0.0898	19
50	0.0637	13	0.1809	18	50	0.0152	6	0.0879	19
75 0	0.0624	14	0.1791	20	83 0	0.0146	7	0.0860	20
10	0.0610	13	0.1771	19	10	0.0139	7	0.0840	20
20	0.0597	12	0.1752	19	20	0.0132	6	0.0820	20
30	0.0585	13	0.1733	20	30	0.0126	6	0.0800	20
40	0.0572	12	0.1713	19	40	0.0120	6	0.0780	20
50	0.0560	12	0.1694	19	50	0.0114	6	0.0760	20
76 0	0.0548	12	0.1675	20	84 0	0.0108	6	0.0740	20
10	0.0536	12	0.1655	19	10	0.0102	6	0.0720	20
20	0.0524	12	0.1636	19	20	0.0096	5	0.0700	20
30	0.0512	12	0.1617	20	30	0.0091	6	0.0680	20
40	0.0500	12	0.1597	19	40	0.0085	5	0.0660	20
50	0.0488	11	0.1578	19	50	0.0080	4	0.0640	21
77 0	0.0477	12	0.1559	20	85 0	0.0076	5	0.0619	20
10	0.0465	11	0.1539	19	10	0.0071	5	0.0599	20
20	0.0454	11	0.1520	19	20	0.0066	4	0.0579	21
30	0.0443	12	0.1501	20	30	0.0062	5	0.0558	20
40	0.0431	11	0.1481	19	40	0.0057	4	0.0538	20
50	0.0420	10	0.1462	18	50	0.0053	4	0.0518	21
78 0	0.0410	11	0.1444	20	86 0	0.0049	4	0.0497	20

$\varphi = 30°$

i	ξ	Δ	T′	Δ
86° 0′	0.0049	4	0.0497	20
10	0.0045	4	0.0477	20
20	0.0041	3	0.0457	21
30	0.0038	4	0.0436	20
40	0.0034	3	0.0416	20
50	0.0031	3	0.0396	21
87 0	0.0028		0.0375	

$\varphi = 35°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
° ′					° ′				
36 0	1.6763	186	1.4538	186	38 0	1.3179	118	1.1406	86
5	1.6577	182	1.4352	179	5	1.3061	116	1.1320	83
10	1.6395	177	1.4173	173	10	1.2945	113	1.1237	81
15	1.6218	174	1.4000	168	15	1.2832	112	1.1156	79
20	1.6044	171	1.3832	163	20	1.2720	110	1.1077	78
25	1.5873	168	1.3669	157	25	1.2610	108	1.0999	76
30	1.5705	165	1.3512	152	30	1.2502	106	1.0923	74
35	1.5540	161	1.3360	147	35	1.2396	105	1.0849	72
40	1.5379	155	1.3213	142	40	1.2291	103	1.0777	71
45	1.5224	154	1.3071	137	45	1.2188	101	1.0706	69
50	1.5070	153	1.2934	133	50	1.2087	99	1.0637	67
55	1.4917	151	1.2801	129	55	1.1988	98	1.0570	64
37 0	1.4766	147	1.2672	124	39 0	1.1890	96	1.0506	63
5	1.4619	144	1.2548	120	5	1.1794	95	1.0443	62
10	1.4475	140	1.2428	115	10	1.1699	94	1.0381	60
15	1.4335	138	1.2313	113	15	1.1605	92	1.0321	59
20	1.4197	135	1.2200	110	20	1.1513	91	1.0262	58
25	1.4062	133	1.2090	107	25	1.1422	89	1.0204	58
30	1.3929	131	1.1983	104	30	1.1333	88	1.0146	57
35	1.3798	128	1.1879	101	35	1.1245	87	1.0089	55
40	1.3670	126	1.1778	97	40	1.1158	85	1.0034	52
45	1.3544	123	1.1681	94	45	1.1073	84	0.9982	53
50	1.3421	122	1.1587	92	50	1.0989	83	0.9929	51
55	1.3299	120	1.1495	89	55	1.0906	82	0.9878	50
38 0	1.3179	118	1.1406	86	40 0	1.0824	81	0.9828	49

TABLE I. (Continued.)

$\varphi = 35°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
40° 0′	1.0824	81	0.9828	49	45° 0′	0.7398	83	0.7710	54
5	1.0743	79	0.9779	48	10	0.7315	80	0.7656	53
10	1.0664	78	0.9731	48	20	0.7235	79	0.7603	53
15	1.0586	77	0.9683	47	30	0.7156	78	0.7550	52
20	1.0509	76	0.9636	46	40	0.7078	78	0.7498	51
25	1.0433	75	0.9590	45	50	0.7000	77	0.7447	50
30	1.0358	74	0.9545	44	46 0	0.6923	75	0.7397	50
					10	0.6848	74	0.7347	49
35	1.0284	73	0.9501	44	20	0.6774	72	0.7298	49
40	1.0211	72	0.9457	44	30	0.6702	72	0.7249	48
45	1.0139	71	0.9413	43	40	0.6630	70	0.7201	48
50	1.0068	70	0.9370	42	50	0.6560	70	0.7153	47
55	0.9998	70	0.9328	40	47 0	0.6490	68	0.7106	46
41 0	0.9928	69	0.9288	40	10	0.6422	68	0.7060	46
5	0.9859	68	0.9248	39	20	0.6354	66	0.7014	46
10	0.9791	66	0.9209	39	30	0.6288	66	0.6968	45
15	0.9725	65	0.9170	39	40	0.6222	65	0.6923	45
20	0.9660	65	0.9131	39	50	0.6157	64	0.6878	44
25	0.9595	64	0.9092	38	48 0	0.6093	64	0.6834	43
30	0.9531	63	0.9054	38	10	0.6029	62	0.6791	43
					20	0.5967	62	0.6748	43
35	0.9468	62	0.9016	37	30	0.5905	61	0.6705	42
40	0.9406	62	0.8979	37	40	0.5844	60	0.6663	42
45	0.9344	61	0.8942	37	50	0.5784	60	0.6621	41
50	0.9283	60	0.8905	37	49 0	0.5724	59	0.6580	41
55	0.9223	59	0.8868	36	10	0.5665	58	0.6539	40
42 0	0.9164	117	0.8832	71	20	0.5607	58	0.6499	40
10	0.9047	114	0.8761	70	30	0.5549	57	0.6459	40
20	0.8933	111	0.8691	69	40	0.5492	56	0.6419	39
30	0.8822	109	0.8622	68	50	0.5436	55	0.6380	39
40	0.8713	106	0.8554	67	50 0	0.5381	55	0.6341	39
50	0.8607	104	0.8487	65	10	0.5326	54	0.6302	38
43 0	0.8503	101	0.8422	64	20	0.5272	54	0.6264	38
10	0.8402	100	0.8358	63	30	0.5218	53	0.6226	38
20	0.8302	97	0.8295	63	40	0.5165	53	0.6188	37
30	0.8205	96	0.8232	62	50	0.5112	52	0.6151	37
40	0.8109	95	0.8170	61	51 0	0.5060	51	0.6114	37
50	0.8014	92	0.8109	59	10	0.5009	51	0.6077	37
44 0	0.7922	91	0.8050	58	20	0.4958	50	0.6040	36
10	0.7831	89	0.7992	58	30	0.4908	50	0.6004	36
20	0.7742	88	0.7934	57	40	0.4858	49	0.5968	36
30	0.7654	86	0.7877	56	50	0.4809	49	0.5932	35
40	0.7568	86	0.7821	56	52 0	0.4760	48	0.5897	35
50	0.7482	84	0.7765	55	10	0.4712	48	0.5862	35
45 0	0.7398	83	0.7710	54	20	0.4664	47	0.5827	35
					30	0.4617	47	0.5792	34
					40	0.4570	47	0.5758	34
					50	0.4523	46	0.5724	34
					53 0	0.4477	45	0.5690	34

$\varphi = 35°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
53° 0′	0.4477	45	0.5690	34	61° 0′	0.2686	31	0.4260	27
10	0.4432	45	0.5656	33	10	0.2655	30	0.4233	27
20	0.4387	45	0.5623	33	20	0.2625	30	0.4206	26
30	0.4342	44	0.5590	33	30	0.2595	30	0.4180	27
40	0.4298	44	0.5557	33	40	0.2565	30	0.4153	26
50	0.4254	43	0.5524	33	50	0.2535	29	0.4127	26
54 0	0.4211	43	0.5491	32	62 0	0.2506	30	0.4101	26
10	0.4168	43	0.5459	32	10	0.2476	29	0.4075	26
20	0.4125	42	0.5427	32	20	0.2447	28	0.4049	26
30	0.4083	42	0.5395	32	30	0.2419	29	0.4023	26
40	0.4041	41	0.5363	32	40	0.2390	28	0.3997	26
50	0.4000	41	0.5331	31	50	0.2362	28	0.3971	26
55 0	0.3959	40	0.5300	32	63 0	0.2334	28	0.3945	26
10	0,3919	40	0.5268	31	10	0.2306	28	0.3919	26
20	0.3879	40	0.5237	30	20	0.2278	27	0.3893	26
30	0.3839	40	0.5207	31	30	0.2251	28	0.3867	26
40	0.3799	39	0.5176	31	40	0.2223	27	0.3841	26
50	0.3760	39	0.5145	30	50	0.2196	27	0.3815	25
56 0	0.3721	39	0.5115	30	64 0	0.2169	27	0.3790	26
10	0.3682	38	0.5085	30	10	0.2142	27	0.3764	25
20	0.3644	38	0.5055	30	20	0.2115	26	0.3739	25
30	0.3606	38	0.5025	30	30	0.2089	27	0.3714	26
40	0.3568	38	0.4995	30	40	0.2062	26	0.3688	25
50	0.3530	37	0.4965	30	50	0.2036	26	0.3663	25
57 0	0.3493	37	0.4935	30	65 0	0.2010	26	0.3638	26
10	0.3456	36	0.4905	29	10	0.1984	26	0.3612	25
20	0.3420	36	0.4876	29	20	0.1958	25	0.3587	24
30	0.3384	36	0.4847	29	30	0.1933	26	0.3563	25
40	0.3348	36	0.4818	29	40	0.1907	25	0.3538	25
50	0.3312	35	0.4789	28	50	0.1882	24	0.3513	24
58 0	0.3277	35	0.4761	29	66 0	0.1858	25	0.3489	25
10	0.3242	35	0.4732	29	10	0.1833	24	0.3464	25
20	0.3207	34	0.4703	28	20	0.1809	24	0.3439	24
30	0.3173	34	0.4675	28	30	0.1785	24	0.3415	25
40	0.3139	34	0.4647	28	40	0.1761	24	0.3390	25
50	0.3105	34	0.4619	28	50	0.1737	24	0.3365	24
59 0	0.3071	34	0.4591	28	67 0	0.1713	24	0.3341	25
10	0.3037	33	0.4563	28	10	0.1689	23	0.3316	25
20	0.3004	33	0.4535	28	20	0.1666	23	0.3291	24
30	0.2971	33	0.4507	28	30	0.1643	24	0.3267	25
40	0.2938	32	0.4479	28	40	0.1619	23	0.3242	25
50	0.2906	32	0.4451	28	50	0.1596	22	0.3217	24
60 0	0.2874	32	0.4423	28	68 0	0.1574	23	0.3193	25
10	0.2842	32	0.4395	27	10	0.1551	22	0.3168	25
20	0.2810	31	0.4368	27	20	0.1529	22	0.3143	24
30	0.2779	32	0.4341	28	30	0.1507	22	0.3119	25
40	0.2747	31	0.4313	27	40	0.1485	22	0.3094	24
50	0.2716	30	0.4286	26	50	0.1463	22	0.3070	24
61 0	0.2686	31	0.4260	27	69 0	0.1441	22	0.3046	25

TABLE I. (Continued.)

$\varphi = 35°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
69° 0′	0.1441	22	0.3046	25	77° 0′	0.0580	14	0.1901	24
10	0.1419	21	0.3021	24	10	0.0566	14	0.1877	24
20	0.1398	21	0.2997	24	20	0.0552	14	0.1853	23
30	0.1377	22	0.2973	24	30	0.0538	14	0.1830	24
40	0.1355	21	0.2949	24	40	0.0524	13	0.1806	24
50	0.1334	20	0.2925	24	50	0.0511	13	0.1782	23
70 0	0.1314	21	0.2901	24	78 0	0.0498	14	0.1759	24
10	0.1293	20	0.2877	24	10	0.0484	13	0.1735	24
20	0.1273	20	0.2853	24	20	0.0471	12	0.1711	23
30	0.1253	20	0.2829	24	30	0.0459	13	0.1688	24
40	0.1233	20	0.2805	24	40	0.0446	12	0.1664	24
50	0.1213	20	0.2781	24	50	0.0434	12	0.1640	23
71 0	0.1193	20	0.2757	24	79 0	0.0422	12	0.1617	24
10	0.1173	20	0.2733	24	10	0.0410	12	0.1593	24
20	0.1153	19	0.2709	24	20	0.0398	12	0.1569	24
30	0.1134	20	0.2685	24	30	0.0386	12	0.1545	24
40	0.1114	19	0.2661	24	40	0.0374	12	0.1521	24
50	0.1095	18	0.2637	23	50	0.0362	11	0.1497	24
72 0	0.1077	19	0.2614	24	80 0	0.0351	12	0.1473	24
10	0.1058	19	0.2590	24	10	0.0339	11	0.1449	23
20	0.1039	18	0.2566	24	20	0.0328	10	0.1426	24
30	0.1021	18	0.2542	24	30	0.0318	11	0.1402	24
40	0.1003	18	0.2518	24	40	0.0307	10	0.1378	24
50	0.0985	18	0.2494	23	50	0.0297	10	0.1354	24
73 0	0.0967	18	0.2471	24	81 0	0.0287	10	0.1330	24
10	0.0949	18	0.2447	24	10	0.0277	10	0.1306	24
20	0.0931	18	0.2423	24	20	0.0267	10	0.1282	24
30	0.0913	18	0.2399	24	30	0.0257	10	0.1258	24
40	0.0895	17	0.2375	24	40	0.0247	9	0.1234	24
50	0.0878	17	0.2351	23	50	0.0238	9	0.1210	24
74 0	0.0861	17	0.2328	24	82 0	0.0229	10	0.1186	24
10	0.0844	17	0.2304	24	10	0.0219	9	0.1162	23
20	0.0827	16	0.2280	24	20	0.0210	8	0.1139	24
30	0.0811	17	0.2256	24	30	0.0202	9	0.1115	24
40	0.0794	16	0.2232	24	40	0.0193	8	0.1091	24
50	0.0778	16	0.2208	23	50	0.0185	8	0.1067	24
75 0	0.0762	16	0.2185	24	83 0	0.0177	8	0.1043	24
10	0.0746	16	0.2161	24	10	0.0169	8	0.1019	24
20	0.0730	16	0.2137	23	20	0.0161	8	0.0995	24
30	0.0714	16	0.2114	24	30	0.0153	8	0.0971	24
40	0.0698	15	0.2090	24	40	0.0145	8	0.0947	25
50	0.0683	15	0.2066	23	50	0.0137	6	0.0922	24
76 0	0.0668	16	0.2043	24	84 0	0.0131	7	0.0898	24
10	0.0652	15	0.2019	24	10	0.0124	7	0.0874	25
20	0.0637	14	0.1995	23	20	0.0117	6	0.0849	24
30	0.0623	15	0.1972	24	30	0.0111	7	0.0825	25
40	0.0608	14	0.1948	24	40	0.0104	6	0.0800	25
50	0.0594	14	0.1924	23	50	0.0098	6	0.0775	24
77 0	0.0580	14	0.1901	24	85 0	0.0092	6	0.0751	25

TABLE I. (Continued.)

$\varphi = 35°$

i	ξ	Δ	T′	Δ
85° 0′	0.0092	6	0.0751	25
10	0.0086	6	0.0726	25
20	0.0080	5	0.0701	24
30	0.0075	6	0.0677	25
40	0.0069	5	0.0652	25
50	0.0064	4	0.0627	24
86 0	0.0060	5	0.0603	25
10	0.0055	5	0.0578	25
20	0.0050	4	0.0553	24
30	0.0046	5	0.0529	25
40	0.0041	4	0.0504	25
50	0.0037	4	0.0479	25
87 0	0.0033		0.0454	

$\varphi = 40°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
° ′					° ′				
41 0	1.6679	222	1.4450	114	43 0	1.2748	119	1.2168	78
5	1.6457	216	1.4336	112	5	1.2629	116	1.2090	77
10	1.6241	210	1.4224	110	10	1.2513	114	1.2013	75
15	1.6031	203	1.4114	108	15	1.2399	112	1.1938	74
20	1.5828	197	1.4006	106	20	1.2287	111	1.1894	73
25	1.5631	190	1.3900	105	25	1.2176	109	1.1821	71
30	1.5441	185	1.3795	103	30	1.2067	107	1.1750	70
35	1.5256	180	1.3692	102	35	1.1960	105	1.1680	70
40	1.5076	175	1.3590	100	40	1.1855	102	1.1610	69
45	1.4901	170	1.3490	98	45	1.1753	101	1.1511	68
50	1.4731	165	1.3392	97	50	1.1652	99	1.1443	67
55	1.4566	160	1.3295	95	55	1.1553	98	1.1376	66
42 0	1.4406	157	1.3200	94	44 0	1.1455	96	1.1310	65
5	1.4249	153	1.3106	92	5	1.1359	94	1.1245	64
10	1.4096	148	1.3014	90	10	1.1265	92	1.1181	63
15	1.3948	145	1.2924	89	15	1.1173	91	1.1118	63
20	1.3803	142	1.2835	88	20	1.1082	90	1.1055	61
25	1.3661	138	1.2747	86	25	1.0992	88	1.0994	60
30	1.3523	136	1.2661	85	30	1.0904	87	1.0934	59
35	1.3387	134	1.2576	84	35	1.0817	86	1.0875	59
40	1.3253	131	1.2492	83	40	1.0731	84	1.0816	58
45	1.3122	128	1.2409	82	45	1.0647	83	0.0758	57
50	1.2994	125	1.2327	80	50	1.0564	82	0.0701	56
55	1.2869	121	1.2247	79	55	1.0482	82	0.0645	56
43 0	1.2748	119	1.2168	78	45 0	1.0400	80	0.0589	55

TABLE I. (Continued.)

$\varphi = 40°$

i	ξ	Δ	T′	Δ
45° 0	1.0400	80	1.0589	55
5	1.0320	79	1.0534	54
10	1.0241	77	1.0480	53
15	1.0164	76	1.0427	52
20	1.0088	75	1.0375	52
25	1.0013	75	1.0323	51
30	0.9938	74	1.0272	50
35	0.9864	72	1.0222	50
40	0.9792	70	1.0172	49
45	0.9722	70	1.0123	49
50	0.9652	69	1.0074	48
55	0.9583	67	1.0026	47
46 0	0.9516	132	0.9979	93
10	0.9384	129	0.9886	91
20	0.9255	126	0.9795	89
30	0.9129	123	0.9706	87
40	0.9006	119	0.9619	85
50	0.8887	117	0.9534	82
47 0	0.8770	114	0.9452	80
10	0.8656	111	0.9372	79
20	0.8545	109	0.9293	77
30	0.8436	106	0.9216	76
40	0.8330	105	0.9140	75
50	0.8225	103	0.9065	73
48 0	0.8122	101	0.8992	72
10	0.8021	99	0.8920	71
20	0.7922	97	0.8849	70
30	0.7825	95	0.8779	69
40	0.7730	94	0.8710	68
50	0.7636	92	0.8642	66
49 0	0.7544	90	0.8576	65
10	0.7454	89	0.8511	65
20	0.7365	88	0.8446	64
30	0.7277	86	0.8382	63
40	0.7191	84	0.8319	62
50	0.7107	84	0.8257	61
50 0	0.7023	82	0.8196	60
10	0.6941	81	0.8136	59
20	0.6860	79	0.8079	59
30	0.6781	78	0.8020	58
40	0.6703	78	0.7962	58
50	0.6625	76	0.7904	56
51 0	0.6549	75	0.7848	55
51° 0	0.6549	75	0.7848	55
10	0.6474	74	0.7793	54
20	0.6400	72	0.7739	54
30	0.6328	72	0.7685	53
40	0.6256	70	0.7632	53
50	0.6186	70	0.7579	52
52 0	0.6116	69	0.7527	52
10	0.6047	68	0.7475	51
20	0.5979	67	0.7424	51
30	0.5912	66	0.7373	51
40	0.5846	66	0.7322	50
50	0.5780	64	0.7272	49
53 0	0.5716	64	0.7223	49
10	0.5652	62	0.7174	49
20	0.5590	62	0.7125	48
30	0.5528	61	0.7077	47
40	0.5467	61	0.7029	47
50	0.5406	60	0.6982	46
54 0	0.5346	60	0.6936	46
10	0.5286	58	0.6890	46
20	0.5228	57	0.6844	45
30	0.5171	57	0.6799	45
40	0.5114	57	0.6754	45
50	0.5057	56	0.6709	44
55 0	0.5001	55	0.6665	46
10	0.4946	54	0.6619	44
20	0.4892	54	0.6575	44
30	0.4838	54	0.6531	43
40	0.4784	53	0.6488	42
50	0.4731	52	0.6446	41
56 0	0.4679	52	0.6405	40
10	0.4627	52	0.6365	40
20	0.4575	50	0.6325	39
30	0.4525	50	0.6286	40
40	0.4475	50	0.6246	39
50	0.4425	50	0.6207	39
57 0	0.4375	49	0.6158	40
10	0.4326	48	0.6118	39
20	0.4278	48	0.6079	39
30	0.4230	47	0.6040	40
40	0.4183	47	0.6000	39
50	0.4136	46	0.5961	39
58 0	0.4090	46	0.5922	39
10	0.4044	46	0.5883	38
20	0.3998	45	0.5845	38
30	0.3953	45	0.5807	38
40	0.3908	45	0.5769	38
50	0.3863	44	0.5731	37
59 0	0.3819	44	0.5694	38

$\varphi = 40°$

i	ξ	Δ	T′	Δ	*i*	ξ	Δ	T′	Δ
59° 0′	0.3819	44	0.5694	38	67° 0′	0.2091	30	0.4073	32
10	0.3775	43	0.5656	37	10	0.2061	29	0.4041	31
20	0.3732	43	0.5619	37	20	0.2032	28	0.4010	31
30	0.3689	42	0.5582	37	30	0.2004	29	0.3979	31
40	0.3647	42	0.5545	37	40	0.1975	29	0.3948	31
50	0.3605	42	0.5508	36	50	0.1946	28	0.3917	30
60 0	0.3563	42	0.5472	36	68 0	0.1918	28	0.3887	31
10	0.3521	41	0.5436	36	10	0.1890	28	0.3856	31
20	0.3480	41	0.5400	36	20	0.1862	27	0.3825	30
30	0.3439	40	0.5364	36	30	0.1833	28	0.3795	31
40	0.3399	40	0.5328	36	40	0.1807	27	0.3764	31
50	0.3359	39	0.5292	35	50	0.1780	27	0.3733	30
61 0	0.3320	40	0.5257	36	69 0	0.1753	27	0.3703	31
10	0.3280	39	0.5221	35	10	0.1726	26	0.3672	30
20	0.3241	38	0.5186	34	20	0.1700	26	0.3642	30
30	0.3203	38	0.5152	35	30	0.1674	26	0.3612	30
40	0.3165	38	0.5117	35	40	0.1648	26	0.3582	30
50	0.3127	37	0.5082	34	50	0.1622	26	0.3552	30
62 0	0.3090	38	0.5048	34	70 0	0.1596	26	0.3522	30
10	0.3052	37	0.5014	34	10	0.1570	25	0.3492	30
20	0.3015	36	0.4980	34	20	0.1545	24	0.3462	30
30	0.2979	37	0.4946	34	30	0.1521	25	0.3432	30
40	0.2942	36	0.4912	34	40	0.1496	25	0.3402	30
50	0.2906	36	0.4878	33	50	0.1471	24	0.3372	29
63 0	0.2870	36	0.4845	34	71 0	0.1447	24	0.3343	30
10	0.2834	35	0.4811	33	10	0.1423	24	0.3313	30
20	0.2799	34	0.4778	33	20	0.1399	24	0.3283	29
30	0.2765	35	0.4745	34	30	0.1375	24	0.3254	30
40	0.2730	35	0.4711	33	40	0.1351	23	0.3224	29
50	0.2695	34	0.4678	32	50	0.1328	23	0.3195	29
64 0	0.2661	34	0.4646	33	72 0	0.1305	23	0.3166	30
10	0.2627	33	0.4613	33	10	0.1282	23	0.3136	29
20	0.2594	33	0.4580	32	20	0.1259	22	0.3107	29
30	0.2561	34	0.4548	33	30	0.1237	23	0.3078	30
40	0.2527	33	0.4515	32	40	0.1214	22	0.3048	29
50	0.2494	32	0.4483	32	50	0.1192	22	0.3019	29
65 0	0.2462	32	0.4451	32	73 0	0.1170	22	0.2990	30
10	0.2430	32	0.4419	32	10	0.1148	21	0.2960	29
20	0.2398	32	0.4387	32	20	0.1126	21	0.2931	29
30	0.2366	32	0.4355	32	30	0.1105	22	0.2902	30
40	0.2334	31	0.4323	31	40	0.1083	21	0.2872	29
50	0.2303	31	0.4292	31	50	0.1062	20	0.2843	29
66 0	0.2272	31	0.4261	32	74 0	0.1042	21	0.2814	30
10	0.2241	30	0.4229	31	10	0.1021	21	0.2784	29
20	0.2211	30	0.4198	31	20	0.1000	20	0.2755	29
30	0.2181	30	0.4167	32	30	0.0980	20	0.2726	30
40	0.2151	30	0.4135	31	40	0.0960	20	0.2696	29
50	0.2121	30	0.4104	31	50	0.0940	19	0.2667	28
67 0	0.2091	30	0.4073	32	75 0	0.0921	20	0.2639	30

TABLE I. (Continued.)

$\varphi = 40°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
75° 0′	0.0921	20	0.2639	30	83° 0′	0.0212	10	0.1250	29
10	0.0901	19	0.2609	29	10	0.0202	9	0.1221	29
20	0.0882	19	0.2580	29	20	0.0193	9	0.1192	29
30	0.0863	19	0.2551	30	30	0.0184	10	0.1163	30
40	0.0844	19	0.2521	29	40	0.0174	9	0.1133	29
50	0.0825	18	0.2492	28	50	0.0165	8	0.1104	29
76 0	0.0807	18	0.2464	30	84 0	0.0157	8	0.1075	30
10	0.0789	18	0.2434	29	10	0.0149	8	0.1045	29
20	0.0771	18	0.2405	28	20	0.0141	8	0.1016	29
30	0.0753	18	0.2377	29	30	0.0133	8	0.0987	29
40	0.0735	17	0.2348	29	40	0.0125	8	0.0967	29
50	0.0718	17	0.2319	28	50	0.0117	7	0.0928	29
77 0	0.0701	18	0.2291	30	85 0	0.0110	7	0.0899	30
10	0.0683	17	0.2261	29	10	0.0103	7	0.0869	29
20	0.0666	16	0.2232	28	20	0.0096	6	0.0840	30
30	0.0650	17	0.2204	29	30	0.0090	7	0.0810	30
40	0.0633	16	0.2175	29	40	0.0083	6	0.0780	29
50	0.0627	16	0.2146	28	50	0.0077	6	0.0751	30
78 0	0.0601	16	0.2118	30	86 0	0.0071	6	0.0721	30
10	0.0585	16	0.2088	29	10	0.0065	5	0.0691	29
20	0.0569	15	0.2059	28	20	0.0060	5	0.0662	30
30	0.0554	16	0.2031	29	30	0.0055	6	0.0632	30
40	0.0538	15	0.2002	29	40	0.0049	5	0.0602	29
50	0.0523	15	0.1963	28	50	0.0044	4	0.0573	30
79 0	0.0508	15	0.1945	30	87 0	0.0040		0.0543	
10	0.0493	14	0.1915	29					
20	0.0479	14	0.1886	28					
30	0.0465	14	0.1858	29					
40	0.0451	14	0.1829	29					
50	0.0437	14	0.1800	29					
80 0	0.0423	14	0.1771	29					
10	0.0409	13	0.1742	29					
20	0.0396	13	0.1713	29					
30	0.0383	13	0.1648	29					
40	0.0370	13	0.1655	29					
50	0.0357	12	0.1626	29					
81 0	0.0345	12	0.1597	29					
10	0.0333	12	0.1568	29					
20	0.0321	12	0.1539	28					
30	0.0309	12	0.1511	29					
40	0.0297	11	0.1482	29					
50	0.0286	11	0.1453	29					
82 0	0.0275	11	0.1424	29					
10	0.0264	11	0.1395	29					
20	0.0253	10	0.1366	29					
30	0.0243	11	0.1337	29					
40	0.0232	10	0.1308	29					
50	0.0222	10	0.1279	29					
83 0	0.0212	10	0.1250	29					

$\varphi = 45°$

i		*ξ*	*Δ*	T′	*Δ*	*i*		*ξ*	*Δ*	T′	*Δ*
°	′					°	′				
46	0	1.6036	231	1.5744	149	49	0	1.0765	95	1.1930	72
	5	1.5805	223	1.5595	146		5	1.0670	93	1.1858	72
	10	1.5582	216	1.5449	143		10	1.0577	91	1.1786	71
	15	1.5366	208	1.5306	140		15	1.0486	90	1.1715	70
	20	1.5158	201	1.5166	137		20	1.0396	89	1.1645	68
	25	1.4957	194	1.5029	133		25	1.0307	87	1.1577	67
	30	1.4763	189	1.4896	131		30	1.0220	86	1.1510	66
	35	1.4574	185	1.4765	128		35	1.0134	84	1.1444	65
	40	1.4389	180	1.4637	125		40	1.0050	82	1.1379	64
	45	1.4209	175	1.4512	123		45	0.9968	81	1.1315	63
	50	1.4034	170	1.4389	120		50	0.9887	80	1.1252	61
	55	1.3864	164	1.4269	118		55	0.9807	79	1.1191	60
47	0	1.3700	160	1.4151	115	50	0	0.9728	77	1.1131	59
	5	1.3540	155	1.4036	113		5	0.9651	76	1.1072	58
	10	1.3385	151	1.3923	110		10	0.9575	74	1.1014	58
	15	1.3234	147	1.3813	108		15	0.9501	73	1.0956	57
	20	1.3087	143	1.3705	106		20	0.9428	72	1.0899	56
	25	1.2944	139	1.3599	104		25	0.9356	71	1.0843	55
	30	1.2805	133	1.3495	102		30	0.9285	69	1.0788	55
	35	1.2672	129	1.3393	100		35	0.9216	68	1.0733	54
	40	1.2543	124	1.3293	97		40	0.9148	68	1.0679	52
	45	1.2419	123	1.3196	95		45	0.9080	68	1.0627	52
	50	1.2296	122	1.3101	94		50	0.9012	67	1.0575	52
	55	1.2174	122	1.3007	92		55	0.8945	66	1.0523	51
48	0	1.2052	119	1.2915	91	51	0	0.8879	127	1.0472	99
	5	1.1933	116	1.2824	89		5	0.8752	124	1.0373	98
	10	1.1817	114	1.2735	88		10	0.8628	122	1.0275	95
	15	1.1703	112	1.2647	86		15	0.8506	119	1.0180	94
	20	1.1591	110	1.2561	84		20	0.8387	117	1.0086	92
	25	1.1481	108	1.2477	82		25	0.8270	113	0.9994	89
	30	1.1373	106	1.2395	81		30	0.8157	111	0.9905	88
	35	1.1267	104	1.2314	79		35	0.8046	110	0.9817	86
	40	1.1163	102	1.2235	78		40	0.7936	107	0.9731	85
	45	1.1061	100	1.2157	77		45	0.7829	105	0.9646	84
	50	1.0961	99	1.2080	76		50	0.7724	102	0.9562	82
	55	1.0862	97	1.2004	74		55	0.7622	101	0.9480	81
49	0	1.0765	95	1.1930	72	52	0	0.7521	98	0.9399	80

TABLE I. (Continued.)

$\varphi = 45°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
52° 0′	0.7521	98	0.9399	80	60° 0′	0.4128	52	0.6517	48
10	0.7423	97	0.9319	78	10	0.4076	51	0.6469	47
20	0.7326	95	0.9241	77	20	0.4025	50	0.6422	46
30	0.7231	93	0.9164	76	30	0.3975	50	0.6376	47
40	0.7138	92	0.9088	74	40	0.3925	50	0.6329	46
50	0.7046	90	0.9014	73	50	0.3875	49	0.6283	46
53 0	0.6956	89	0.8941	72	61 0	0.3826	49	0.6237	46
10	0.6867	87	0.8869	71	10	0.3777	48	0.6191	46
20	0.6780	86	0.8798	70	20	0.3729	48	0.6145	45
30	0.6694	84	0.8728	69	30	0.3681	47	0.6100	45
40	0.6610	83	0.8659	69	40	0.3634	47	0.6055	45
50	0.6527	82	0.8590	68	50	0.3587	46	0.6010	44
54 0	0.6445	80	0.8522	67	62 0	0.3541	46	0.5966	44
10	0.6365	79	0.8455	66	10	0.3495	45	0.5922	44
20	0.6286	78	0.8389	65	20	0.3450	45	0.5878	44
30	0.6208	77	0.8324	64	30	0.3405	44	0.5834	44
40	0.6131	76	0.8260	64	40	0.3361	44	0.5790	44
50	0.6055	74	0.8196	62	50	0.3317	44	0.5746	43
55 0	0.5981	74	0.8134	62	63 0	0.3273	44	0.5703	43
10	0.5907	72	0.8072	61	10	0.3229	42	0.5660	43
20	0.5835	72	0.8011	60	20	0.3186	42	0.5617	42
30	0.5763	71	0.7951	60	30	0.3144	42	0.5575	42
40	0.5692	70	0.7891	59	40	0.3102	42	0.5533	42
50	0.5622	68	0.7832	58	50	0.3060	41	0.5491	42
56 0	0.5554	68	0.7774	58	64 0	0.3019	41	0.5449	42
10	0.5486	68	0.7716	58	10	0.2978	41	0.5407	41
20	0.5418	66	0.7658	56	20	0.2937	40	0.5366	40
30	0.5352	66	0.7602	56	30	0.2897	40	0.5326	42
40	0.5286	64	0.7546	56	40	0.2857	39	0.5284	41
50	0.5222	64	0.7490	54	50	0.2818	39	0.5243	40
57 0	0.5158	63	0.7436	54	65 0	0.2779	39	0.5203	40
10	0.5095	62	0.7382	54	10	0.2740	38	0.5162	40
20	0.5033	61	0.7328	54	20	0.2702	38	0.5122	40
30	0.4972	61	0.7274	53	30	0.2664	38	0.5082	40
40	0.4911	60	0.7221	54	40	0.2626	38	0.5042	40
50	0.4851	59	0.7167	52	50	0.2588	37	0.5002	40
58 0	0.4792	59	0.7115	52	66 0	0.2551	37	0.4962	40
10	0.4733	58	0.7063	52	10	0.2514	37	0.4922	40
20	0.4675	57	0.7011	51	20	0.2477	36	0.4882	39
30	0.4618	57	0.6960	51	30	0.2441	36	0.4843	40
40	0.4561	56	0.6909	50	40	0.2405	36	0.4803	39
50	0.4505	55	0.6859	50	50	0.2369	35	0.4764	39
59 0	0.4450	56	0.6809	50	67 0	0.2334	35	0.4725	39
10	0.4394	54	0.6759	50	10	0.2299	35	0.4686	39
20	0.4340	54	0.6709	48	20	0.2264	34	0.4647	38
30	0.4286	54	0.6661	48	30	0.2230	34	0.4609	39
40	0.4232	52	0.6613	48	40	0.2196	34	0.4570	39
50	0.4180	52	0.6565	48	50	0.2162	33	0.4531	38
60 0	0.4128	52	0.6517	48	68 0	0.2129	34	0.4493	38

TABLE I. (Continued.)

$\varphi = 45°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
68° 0′	0.2129	34	0.4493	38	76° 0′	0.0840	21	0.2749	36
10	0.2095	33	0.4455	38	10	0.0819	21	0.2713	35
20	0.2062	32	0.4417	37	20	0.0798	20	0.2678	35
30	0.2030	32	0.4380	38	30	0.0778	20	0.2644	36
40	0.1998	32	0.4342	38	40	0.0758	20	0.2608	35
50	0.1966	32	0.4304	37	50	0.0738	19	0.2573	34
69 0	0.1934	32	0.4267	38	77 0	0.0719	20	0.2539	36
10	0.1902	31	0.4229	37	10	0.0699	19	0.2503	35
20	0.1871	30	0.4192	37	20	0.0680	18	0.2468	34
30	0.1841	31	0.4155	38	30	0.0662	18	0.2434	36
40	0.1810	30	0.4117	37	40	0.0644	18	0.2398	35
50	0.1780	30	0.4080	37	50	0.0626	18	0.2363	34
70 0	0.1750	30	0.4043	38	78 0	0.0608	18	0.2329	36
10	0.1720	29	0.4005	37	10	0.0590	18	0.2293	35
20	0.1691	29	0.3968	36	20	0.0572	17	0.2258	34
30	0.1662	30	0.3932	37	30	0.0555	17	0.2224	36
40	0.1632	29	0.3895	36	40	0.0538	17	0.2188	35
50	0.1603	28	0.3859	36	50	0.0521	16	0.2153	34
71 0	0.1575	28	0.3823	37	79 0	0.0505	16	0.2119	36
10	0.1547	28	0.3786	37	10	0.0489	16	0.2083	35
20	0.1519	27	0.3749	36	20	0.0473	16	0.2048	34
30	0.1492	28	0.3713	37	30	0.0457	16	0.2014	36
40	0.1464	27	0.3676	36	40	0.0441	15	0.1978	35
50	0.1437	27	0.3640	36	50	0.0426	14	0.1943	34
72 0	0.1410	27	0.3604	36	80 0	0.0412	15	0.1909	36
10	0.1383	26	0.3568	36	10	0.0397	14	0.1873	35
20	0.1357	26	0.3532	36	20	0.0383	14	0.1838	34
30	0.1331	26	0.3496	36	30	0.0369	14	0.1804	36
40	0.1305	26	0.3460	36	40	0.0355	14	0.1769	35
50	0.1279	25	0.3424	36	50	0.0341	13	0.1734	34
73 0	0.1254	26	0.3388	36	81 0	0.0328	14	0.1700	36
10	0.1228	25	0.3352	36	10	0.0314	13	0.1665	35
20	0.1203	24	0.3316	36	20	0.0301	12	0.1630	34
30	0.1179	24	0.3280	36	30	0.0289	12	0.1596	36
40	0.1155	24	0.3244	36	40	0.0277	12	0.1561	35
50	0.1131	24	0.3208	36	50	0.0265	12	0.1526	34
74 0	0.1107	24	0.3172	36	82 0	0.0253	12	0.1492	35
10	0.1083	23	0.3136	35	10	0.0241	11	0.1457	35
20	0.1060	23	0.3101	35	20	0.0230	10	0.1422	35
30	0.1037	23	0.3066	36	30	0.0220	12	0.1387	36
40	0.1014	23	0.3030	35	40	0.0208	11	0.1351	35
50	0.0991	22	0.2995	35	50	0.0197	10	0.1316	35
75 0	0.0969	22	0.2960	36	83 0	0.0187	10	0.1281	35
10	0.0947	22	0.2924	35	10	0.0177	10	0.1246	35
20	0.0925	22	0.2889	35	20	0.0167	9	0.1211	35
30	0.0903	22	0.2854	36	30	0.0158	10	0.1176	36
40	0.0881	21	0.2818	35	40	0.0148	9	0.1140	35
50	0.0860	20	0.2783	34	50	0.0139	8	0.1105	35
76 0	0.0840	21	0.2749	36	84 0	0.0131	9	0.1070	36

TABLE I. (Continued.)

$\varphi = 45°$

i	ξ	Δ	T′	Δ
° ′				
84 0	0.0131	9	0.1070	36
10	0.0122	8	0.1034	35
20	0.0114	8	0.0999	35
30	0.0106	8	0.0964	35
40	0.0098	7	0.0929	35
50	0.0091	7	0.0894	36
85 0	0.0084	7	0.0858	35
10	0.0077	6	0.0823	36
20	0.0071	6	0.0787	35
30	0.0065	6	0.0752	35
40	0.0059	6	0.0747	36
50	0.0053	6	0.0681	36
86 0	0.0047		0.0645	

$\varphi = 50°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
° ′					° ′				
51 0	1.4332	186	1.6164	148	53 0	1.0940	105	1.3343	91
5	1.4146	181	1.6016	145	5	1.0835	104	1.3252	90
10	1.3965	177	1.5871	142	10	1.0731	102	1.3162	88
15	1.3788	172	1.5729	139	15	1.0629	100	1.3074	86
20	1.3616	167	1.5590	137	20	1.0529	98	1.2988	85
25	1.3449	163	1.5453	133	25	1.0431	96	1.2903	84
30	1.3286	158	1.5320	130	30	1.0335	95	1.2819	83
35	1.3128	154	1.5190	127	35	1.0240	93	1.2736	81
40	1.2974	151	1.5063	125	40	1.0147	92	1.2655	80
45	1.2823	147	1.4938	122	45	1.0055	90	1.2575	79
50	1.2676	143	1.4816	119	50	0.9965	88	1.2496	77
55	1.2533	139	1.4697	117	55	0.9877	87	1.2419	76
52 0	1.2394	136	1.4580	115	54 0	0.9790	86	1.2343	75
5	1.2258	133	1.4465	112	5	0.9704	84	1.2268	74
10	1.2125	129	1.4353	110	10	0.9620	82	1.2194	73
15	1.1996	127	1.4243	108	15	0.9538	81	1.2121	71
20	1.1869	125	1.4135	106	20	0.9457	81	1.2050	71
25	1.1744	122	1.4029	103	25	0.9376	80	1.1979	70
30	1.1622	120	1.3926	102	30	0.9296	79	1.1909	69
35	1.1502	117	1.3824	100	35	0.9217	77	1.1840	68
40	1.1385	115	1.3724	98	40	0.9140	75	1.1772	67
45	1.1270	113	1.3626	96	45	0.9065	74	1.1705	66
50	1.1157	110	1.3530	94	50	0.8991	74	1.1639	65
55	1.1047	107	1.3436	93	55	0.8917	73	1.1574	64
53 0	1.0940	105	1.3343	91	55 0	0.8844	143	1.1510	126

TABLE I. (Continued.)

$\varphi = 50°$

i		ξ	Δ	T′	Δ	i		ξ	Δ	T′	Δ
55°	0′	0.8844	143	1.1510	126	63°	0′	0.4438	62	0.7451	62
	10	0.8701	138	1.1384	123		10	0.4376	61	0.7389	62
	20	0.8563	135	1.1261	119		20	0.4315	60	0.7327	60
	30	0.8428	132	1.1142	117		30	0.4255	60	0.7267	60
	40	0.8296	129	1.1025	115		40	0.4195	58	0.7207	60
	50	0.8167	125	1.0910	111		50	0.4137	58	0.7147	59
56	0	0.8042	123	1.0799	110	64	0	0.4079	58	0.7089	58
	10	0.7919	120	1.0689	107		10	0.4021	56	0.7031	58
	20	0.7799	116	1.0582	103		20	0.3965	56	0.6973	57
	30	0.7683	115	1.0479	103		30	0.3909	56	0.6916	57
	40	0.7568	111	1.0376	98		40	0.3853	54	0.6859	57
	50	0.7457	109	1.0278	98		50	0.3799	54	0.6802	56
57	0	0.7348	107	1.0180	96	65	0	0.3745	54	0.6746	56
	10	0.7241	104	1.0084	94		10	0.3691	53	0.6690	56
	20	0.7137	102	0.9990	92		20	0.3638	52	0.6634	55
	30	0.7034	100	0.9898	91		30	0.3586	52	0.6579	55
	40	0.6934	99	0.9807	90		40	0.3534	52	0.6524	54
	50	0.6835	98	0.9717	88		50	0.3482	50	0.6470	54
58	0	0.6737	96	0.9629	87	66	0	0.3432	50	0.6416	54
	10	0.6641	93	0.9542	86		10	0.3382	50	0.6362	54
	20	0.6548	92	0.9456	84		20	0.3332	49	0.6308	53
	30	0.6456	90	0.9372	83		30	0.3283	49	0.6255	53
	40	0.6366	89	0.9289	82		40	0.3234	48	0.6202	53
	50	0.6277	87	0.9207	81		50	0.3186	47	0.6149	52
59	0	0.6190	86	0.9126	80	67	0	0.3139	48	0.6097	52
	10	0.6104	85	0.9046	78		10	0.3091	46	0.6045	52
	20	0.6019	83	0.8968	78		20	0.3045	46	0.5993	51
	30	0.5936	82	0.8890	77		30	0.2999	46	0.5942	52
	40	0.5854	80	0.8813	76		40	0.2953	46	0.5890	51
	50	0.5774	80	0.8737	74		50	0.2907	44	0.5839	50
60	0	0.5694	78	0.8663	74	68	0	0.2863	45	0.5789	51
	10	0.5616	78	0.8589	73		10	0.2818	44	0.5738	50
	20	0.5538	76	0.8516	72		20	0.2774	43	0.5688	50
	30	0.5462	75	0.8444	72		30	0.2731	43	0.5638	50
	40	0.5387	74	0.8372	70		40	0.2688	43	0.5588	50
	50	0.5313	72	0.8302	69		50	0.2645	42	0.5538	49
61	0	0.5241	72	0.8233	69	69	0	0.2603	42	0.5489	50
	10	0.5169	71	0.8164	68		10	0.2561	42	0.5439	49
	20	0.5098	70	0.8096	67		20	0.2519	41	0.5390	48
	30	0.5028	69	0.8029	67		30	0.2478	41	0.5342	49
	40	0.4959	68	0.7962	66		40	0.2437	40	0.5293	48
	50	0.4891	67	0.7896	65		50	0.2397	40	0.5245	48
62	0	0.4824	66	0.7831	65	70	0	0.2357	40	0.5197	48
	10	0.4758	66	0.7766	63		10	0.2317	39	0.5149	48
	20	0.4692	65	0.7703	64		20	0.2278	38	0.5101	48
	30	0.4627	64	0.7639	64		30	0.2240	38	0.5053	48
	40	0.4563	63	0.7575	62		40	0.2202	38	0.5005	47
	50	0.4500	62	0.7513	62		50	0.2164	37	0.4958	47
63	0	0.4438	62	0.7451	62	71	0	0.2127	37	0.4911	47

TABLE I. (Continued.)

$\varphi = 50°$

i	ξ	Δ	T′	Δ	*i*	ξ	Δ	T′	Δ
71° 0′	0.2127	37	0.4911	47	79° 0′	0.0730	21	0.2792	43
10	0.2090	37	0.4864	47	10	0.0708	21	0.2749	43
20	0.2053	36	0.4817	46	20	0.0687	20	0.2706	42
30	0.2017	36	0.4771	47	30	0.0667	21	0.2664	43
40	0.1981	36	0.4724	46	40	0.0646	20	0.2621	42
50	0.1945	35	0.4678	46	50	0.0626	20	0.2579	42
72 0	0.1910	35	0.4632	46	80 0	0.0606	20	0.2537	43
10	0.1875	34	0.4586	46	10	0.0586	19	0.2494	42
20	0.1841	34	0.4540	45	20	0.0567	19	0.2452	42
30	0.1807	34	0.4495	46	30	0.0548	19	0.2410	42
40	0.1773	33	0.4449	45	40	0.0529	18	0.2368	42
50	0.1740	33	0.4404	44	50	0.0511	18	0.2326	42
73 0	0.1707	33	0.4360	46	81 0	0.0493	18	0.2284	42
10	0.1674	33	0.4314	45	10	0.0475	17	0.2242	42
20	0.1641	32	0.4269	44	20	0.0458	17	0.2200	42
30	0.1609	32	0.4225	45	30	0.0441	17	0.2158	42
40	0.1577	32	0.4180	45	40	0.0424	16	0.2116	42
50	0.1545	31	0.4135	44	50	0.0408	16	0.2074	42
74 0	0.1514	31	0.4091	45	82 0	0.0392	16	0.2032	42
10	0.1483	30	0.4046	44	10	0.0376	16	0.1990	42
20	0.1453	30	0.4002	44	20	0.0360	15	0.1948	42
30	0.1423	30	0.3958	45	30	0.0345	15	0.1906	42
40	0.1393	29	0.3913	44	40	0.0330	14	0.1864	42
50	0.1364	29	0.3869	44	50	0.0316	14	0.1822	42
75 0	0.1335	29	0.3825	44	83 0	0.0302	14	0.1780	42
10	0.1306	29	0.3781	44	10	0.0288	14	0.1738	42
20	0.1277	28	0.3737	43	20	0.0274	13	0.1696	42
30	0.1249	28	0.3694	44	30	0.0261	13	0.1654	42
40	0.1221	27	0.3650	44	40	0.0248	13	0.1612	42
50	0.1194	27	0.3606	43	50	0.0235	12	0.1570	42
76 0	0.1167	27	0.3563	44	84 0	0.0223	12	0.1528	42
10	0.1140	26	0.3519	43	10	0.0211	12	0.1486	42
20	0.1114	26	0.3476	42	20	0.0199	11	0.1444	42
30	0.1088	26	0.3434	44	30	0.0188	11	0.1402	42
40	0.1062	26	0.3390	43	40	0.0177	11	0.1360	43
50	0.1036	25	0.3347	42	50	0.0166	10	0.1317	42
77 0	0.1011	25	0.3305	44	85 0	0.0156	10	0.1275	42
10	0.0986	25	0.3261	43	10	0.0146	10	0.1233	42
20	0.0961	24	0.3218	42	20	0.0136	10	0.1191	42
30	0.0937	24	0.3176	43	30	0.0126	10	0.1149	42
40	0.0913	24	0.3133	43	40	0.0116	9	0.1107	43
50	0.0889	24	0.3090	42	50	0.0107	8	0.1064	42
78 0	0.0865	24	0.3048	43	86 0	0.0099	8	0.1022	42
10	0.0841	23	0.3005	43	10	0.0091	8	0.0980	42
20	0.0818	22	0.2962	42	20	0.0083	7	0.0938	42
30	0.0796	22	0.2920	43	30	0.0076	7	0.0896	42
40	0.0774	22	0.2877	43	40	0.0069	7	0.0854	43
50	0.0752	22	0.2834	42	50	0.0062	6	0.0811	42
79 0	0.0730	21	0.2792	43	87 0	0.0056		0.0769	

$\varphi = 55°$

i	ξ	Δ	T′	Δ	*i*	ξ	Δ	T′	Δ
° ′					° ′				
56 0	1.2852	160	1.7232	201	59 0	0.8687	82	1.2609	83
5	1.2692	156	1.7031	194	5	0.8605	80	1.2526	82
10	1.2536	153	1.6837	187	10	0.8525	79	1.2444	80
15	1.2383	150	1.6650	180	15	0.8446	78	1.2364	79
20	1.2233	147	1.6470	173	20	0.8368	77	1.2285	77
25	1.2086	144	1.6297	167	25	0.8291	76	1.2208	76
30	1.1942	141	1.6130	163	30	0.8215	75	1.2132	75
35	1.1801	138	1.5967	159	35	0.8140	73	1.2057	74
40	1.1663	136	1.5808	156	40	0.8067	72	1.1983	73
45	1.1527	132	1.5652	152	45	0.7995	72	1.1910	72
50	1.1395	130	1.5500	148	50	0.7923	70	1.1838	71
55	1.1265	127	1.5352	143	55	0.7853	69	1.1767	69
57 0	1.1138	125	1.5209	140	60 0	0.7784	136	1.1698	137
5	1.1013	123	1.5069	137	10	0.7648	131	1.1561	134
10	1.0890	121	1.4932	133	20	0.7517	129	1.1427	129
15	1.0769	119	1.4799	130	30	0.7388	124	1.1298	127
20	1.0650	117	1.4669	127	40	0.7264	122	1.1171	124
25	1.0533	114	1.4542	123	50	0.7142	120	1.1047	122
30	1.0419	111	1.4419	120	61 0	0.7022	115	1.0927	119
					10	0.6907	113	1.0808	115
35	1.0308	110	1.4299	118	20	0.6794	111	1.0693	113
40	1.0198	108	1.4181	115	30	0.6685	108	1.0580	112
45	1.0090	105	1.4066	112	40	0.6575	107	1.0468	108
50	0.9985	103	1.3954	110	50	0.6468	104	1.0360	107
55	0.9882	101	1.3844	107	62 0	0.6364	102	1.0253	105
58 0	0.9781	99	1.3737	105	10	0.6262	100	1.0148	104
5	0.9682	98	1.3632	103	20	0.6162	98	1.0044	102
10	0.9584	96	1.3529	100	30	0.6064	96	0.9942	100
15	0.9488	95	1.3429	98	40	0.5968	95	0.9842	99
20	0.9393	94	1.3331	96	50	0.5873	93	0.9743	98
25	0.9299	92	1.3235	95	63 0	0.5780	90	0.9645	96
30	0.9207	90	1.3140	93	10	0.5989	90	0.9549	96
					20	0.5599	88	0.9453	94
35	0.9117	89	1.3047	91	30	0.5511	87	0.9359	92
40	0.9028	88	1.2956	89	40	0.5424	85	0.9267	91
45	0.8940	86	1.2867	88	50	0.5339	84	0.9176	89
50	0.8854	84	1.2779	86	64 0	0.5255	82	0.9087	88
55	0.8770	83	1.2693	84	10	0.5173	81	0.8999	87
59 0	0.8687	82	1.2609	83	20	0.5092	80	0.8912	86
					30	0.5012	78	0.8826	84
					40	0.4934	77	0.8742	84
					50	0.4857	76	0.8658	82
					65 0	0.4781	75	0.8576	82

$\varphi = 55°$

i	ξ	Δ	T′	Δ	*i*	ξ	Δ	T′	Δ
65° 0′	0.4781	75	0.8576	82	73° 0′	0.2090	41	0.5340	58
10	0.4706	74	0.8494	80	10	0.2049	41	0.5282	58
20	0.4632	72	0.8414	80	20	0.2008	40	0.5224	57
30	0.4560	72	0.8334	79	30	0.1968	40	0.5167	58
40	0.4488	70	0.8255	78	40	0.1929	39	0.5109	57
50	0.4418	70	0.8177	77	50	0.1889	38	0.5052	56
66 0	0.4348	68	0.8100	77	74 0	0.1851	38	0.4996	57
10	0.4280	68	0.8023	76	10	0.1813	38	0.4939	56
20	0.4212	67	0.7947	75	20	0.1775	38	0.4883	56
30	0.4145	66	0.7872	74	30	0.1737	37	0.4827	56
40	0.4079	65	0.7798	74	40	0.1700	37	0.4771	56
50	0.4014	64	0.7724	73	50	0.1663	36	0.4715	55
67 0	0.3950	64	0.7651	73	75 0	0.1627	36	0.4660	56
10	0.3886	62	0.7578	72	10	0.1591	35	0.4604	55
20	0.3824	62	0.7506	72	20	0.1556	35	0.4549	54
30	0.3762	62	0.7434	70	30	0.1521	34	0.4495	55
40	0.3700	60	0.7364	70	40	0.1487	34	0.4440	55
50	0.3640	59	0.7294	69	50	0.1453	34	0.4385	54
68 0	0.3581	59	0.7225	69	76 0	0.1419	33	0.4331	54
10	0.3522	58	0.7156	68	10	0.1386	33	0.4377	54
20	0.3464	57	0.7088	68	20	0.1353	32	0.4223	54
30	0.3407	56	0.7020	68	30	0.1321	32	0.4169	54
40	0.3351	56	0.6952	67	40	0.1289	32	0.4115	53
50	0.3295	55	0.6885	66	50	0.1257	31	0.4061	53
69 0	0.3240	55	0.6819	66	77 0	0.1226	31	0.4008	54
10	0.3185	54	0.6753	66	10	0.1195	30	0.3954	53
20	0.3131	53	0.6687	64	20	0.1165	30	0.3901	53
30	0.3078	52	0.6622	64	30	0.1135	30	0.3848	53
40	0.3026	52	0.6558	64	40	0.1105	29	0.3795	53
50	0.2974	52	0.6494	64	50	0.1076	29	0.3742	52
70 0	0.2922	51	0.6430	63	78 0	0.1047	28	0.3690	53
10	0.2871	50	0.6367	63	10	0.1019	28	0.3637	53
20	0.2821	50	0.6304	62	20	0.0991	28	0.3584	52
30	0.2771	49	0.6242	62	30	0.0963	28	0.3532	53
40	0.2732	48	0.6180	62	40	0.0935	27	0.3479	53
50	0.2674	48	0.6118	62	50	0.0908	26	0.3426	52
71 0	0.2626	48	0.6056	62	79 0	0.0882	26	0.3374	52
10	0.2578	47	0.5994	61	10	0.0856	26	0.3322	52
20	0.2531	46	0.5933	60	20	0.0830	25	0.3270	52
30	0.2485	46	0.5873	60	30	0.0805	25	0.3218	52
40	0.2439	46	0.5813	60	40	0.0780	25	0.3166	52
50	0.2393	45	0.5753	60	50	0.0755	24	0.3114	52
72 0	0.2348	44	0.5693	60	80 0	0.0731	24	0.3062	52
10	0.2304	44	0.5633	59	10	0.0707	23	0.3010	52
20	0.2260	43	0.5574	58	20	0.0684	23	0.2958	52
30	0.2217	43	0.5516	59	30	0.0661	23	0.2906	52
40	0.2174	42	0.5457	59	40	0.0638	22	0.2854	51
50	0.2132	42	0.5398	58	50	0.0616	22	0.2803	51
73 0	0.2090	41	0.5340	58	81 0	0.0594	22	0.2752	52

TABLE I. (Continued.)

$\varphi = 55°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
° ′					° ′				
81 0	0.0594	22	0.2752	52	84 0	0.0268	14	0.1833	51
10	0.0572	21	0.2700	51	10	0.0254	14	0.1782	51
20	0.0551	20	0.2649	51	20	0.0240	14	0.1731	50
30	0.0531	20	0.2598	52	30	0.0226	14	0.1681	51
40	0.0511	20	0.2546	51	40	0.0212	13	0.1630	51
50	0.0491	20	0.2495	50	50	0.0199	12	0.1579	50
82 0	0.0471	19	0.2445	52	85 0	0.0187	12	0.1529	52
10	0.0452	18	0.2393	51	10	0.0175	12	0.1477	51
20	0.0434	18	0.2342	51	20	0.0163	11	0.1426	50
30	0.0416	18	0.2291	51	30	0.0152	11	0.1376	51
40	0.0398	18	0.2240	51	40	0.0141	11	0.1325	51
50	0.0380	17	0.2189	50	50	0.0130	10	0.1274	50
83 0	0.0363	17	0.2139	52	86 0	0.0120	10	0.1224	51
10	0.0346	16	0.2087	51	10	0.0110	9	0.1173	51
20	0.0330	16	0.2036	51	20	0.0101	9	0.1122	50
30	0.0314	16	0.1985	51	30	0.0092	8	0.1072	51
40	0.0298	15	0.1934	51	40	0.0084	8	0.1021	51
50	0.0283	15	0.1883	50	50	0.0076	8	0.0970	50
84 0	0.0268	14	0.1833	51	87 0	0.0068		0.0920	

$\varphi = 60°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
61 0	1.1482	166	1.7362	191	63 0	0.8419	96	1.3834	108
5	1.1316	162	1.7171	186	5	0.8323	94	1.3726	107
10	1.1154	158	1.6985	181	10	0.8229	91	1.3619	105
15	1.0996	154	1.6804	176	15	0.8138	89	1.3514	104
20	1.0842	151	1.6628	172	20	0.8049	88	1.3410	104
25	1.0691	147	1.6456	168	25	0.7961	87	1.3306	103
30	1.0544	143	1.6288	164	30	0.7874	85	1.3203	101
35	1.0401	140	1.6124	160	35	0.7789	83	1.3102	99
40	1.0261	137	1.5964	155	40	0.7706	82	1.3003	96
45	1.0124	133	1.5809	152	45	0.7624	80	1.2907	94
50	0.9991	130	1.5657	149	50	0.7544	79	1.2813	53
55	0.9861	127	1.5508	146	55	0.7465	78	1.2720	92
62 0	0.9734	124	1.5362	143	64 0	0.7387	77	1.2628	89
5	0.9610	120	1.5219	140	5	0.7310	75	1.2539	87
10	0.9490	117	1.5079	136	10	0.7235	74	1.2452	84
15	0.9373	115	1.4943	134	15	0.7161	73	1.2368	84
20	0.9258	113	1.4809	131	20	0.7088	72	1.2284	84
25	0.9145	110	1.4678	128	25	0.7016	70	1.2200	83
30	0.9035	108	1.4550	126	30	0.6946	69	1.2117	81
35	0.8927	106	1.4424	123	35	0.6877	69	1.2036	81
40	0.8821	103	1.4301	121	40	0.6808	67	1.1955	80
45	0.8718	101	1.4180	118	45	0.6741	65	1.1875	78
50	0.8617	100	1.4062	115	50	0.6676	65	1.1797	77
55	0.8517	98	1.3947	113	55	0.6611	63	1.1720	76
63 0	0.8419	96	1.3834	108	65 0	0.6548	124	1.1644	147

TABLE I. (Continued.)

$\varphi = 60°$

i	ξ	Δ	T′	Δ	*i*	ξ	Δ	T′	Δ
65° 0′	0.6548	124	1.1644	147	73° 0′	0.2627	54	0.6696	78
10	0.6424	121	1.1497	142	10	0.2573	54	0.6618	78
20	0.6303	120	1.1355	141	20	0.2519	53	0.6540	76
30	0.6183	116	1.1214	138	30	0.2466	52	0.6464	76
40	0.6067	113	1.1076	135	40	0.2414	52	0.6388	76
50	0.5954	112	1.0941	132	50	0.2362	50	0.6312	75
66 0	0.5842	109	1.0809	130	74 0	0.2312	50	0.6237	75
10	0.5733	107	1.0679	129	10	0.2262	50	0.6162	75
20	0.5626	104	1.0550	124	20	0.2212	48	0.6087	74
30	0.5522	102	1.0426	122	30	0.2164	48	0.6013	74
40	0.5420	101	1.0304	122	40	0.2116	47	0.5939	73
50	0.5320	98	1.0182	119	50	0.2069	46	0.5866	73
67 0	0.5222	96	1.0063	116	75 0	0.2023	46	0.5793	72
10	0.5126	94	1.9947	115	10	0.1977	46	0.5721	72
20	0.5032	92	0.9832	112	20	0.1931	44	0.5649	72
30	0.4940	90	0.9720	110	30	0.1887	44	0.5577	71
40	0.4850	89	0.9610	109	40	0.1843	43	0.5506	71
50	0.4761	87	0.9501	108	50	0.1800	42	0.5435	70
68 0	0.4674	86	0.9393	106	76 0	0.1758	42	0.5365	70
10	0.4588	84	0.9287	105	10	0.1716	42	0.5295	70
20	0.4504	82	0.9182	102	20	0.1674	41	0.5225	70
30	0.4422	81	0.9080	100	30	0.1633	40	0.5155	70
40	0.4341	79	0.8980	100	40	0.1593	40	0.5085	69
50	0.4262	78	0.8880	99	50	0.1553	39	0.5016	68
69 0	0.4184	76	0.8781	96	77 0	0.1514	39	0.4948	68
10	0.4108	74	0.8685	94	10	0.1475	38	0.4880	68
20	0.4034	74	0.8591	92	20	0.1437	38	0.4812	67
30	0.3960	73	0.8499	92	30	0.1399	38	0.4745	68
40	0.3887	72	0.8407	92	40	0.1361	36	0.4677	67
50	0.3815	70	0.8315	92	50	0.1325	36	0.4610	67
70 0	0.3745	70	0.8223	90	78 0	0.1289	36	0.4543	68
10	0.3675	68	0.8133	89	10	0.1253	35	0.4775	67
20	0.3607	68	0.8044	88	20	0.1218	34	0.4408	66
30	0.3539	67	0.7956	89	30	0.1184	34	0.4342	67
40	0.3472	66	0.7867	89	40	0.1150	34	0.4275	66
50	0.3406	65	0.7778	88	50	0.1116	33	0.4209	66
71 0	0.3341	64	0.7690	87	79 0	0.1083	33	0.4143	66
10	0.3277	63	0.7603	86	10	0.1050	32	0.4077	66
20	0.3214	62	0.7517	84	20	0.1018	31	0.4011	65
30	0.3152	62	0.7433	84	30	0.0987	31	0.3946	66
40	0.3090	60	0.7349	84	40	0.0956	30	0.3880	65
50	0.3030	60	0.7265	82	50	0.0926	30	0.3815	65
72 0	0.2970	59	0.7183	83	80 0	0.0896	30	0.3750	65
10	0.2911	58	0.7100	83	10	0.0866	29	0.3685	64
20	0.2833	58	0.7017	82	20	0.0837	28	0.3621	64
30	0.2795	57	0.6935	81	30	0.0809	28	0.3557	65
40	0.2738	56	0.6854	80	40	0.0781	28	0.3492	64
50	0.2682	55	0.6774	78	50	0.0753	26	0.3428	64
73 0	0.2627	54	0.6696	78	81 0	0.0727	26	0.3364	64

$\varphi = 60°$

i	ξ	Δ	T′	Δ	*i*	ξ	Δ	T′	Δ
° ′					° ′				
81 0	0.0727	26	0.3364	64	84 0	0.0325	18	0.2232	63
10	0.0701	26	0.3300	64	10	0.0307	17	0.2169	62
20	0.0675	26	0.3236	63	20	0.0290	16	0.2107	62
30	0.0649	26	0.3173	64	30	0.0274	16	0.2045	62
40	0.0623	24	0.3109	63	40	0.0258	16	0.1983	62
50	0.0599	24	0.3046	63	50	0.0242	15	0.1921	62
82 0	0.0575	24	0.2983	64	85 0	0.0227	15	0.1859	62
10	0.0551	23	0.2919	63	10	0.0212	14	0.1797	62
20	0.0528	22	0.2856	62	20	0.0198	14	0.1735	62
30	0.0506	22	0.2794	63	30	0.0184	14	0.1673	62
40	0.0484	21	0.2731	63	40	0.0170	13	0.1611	62
50	0.0463	21	0.2668	62	50	0.0157	12	0.1549	62
83 0	0.0442	20	0.2606	63	86 0	0.0145	12	0.1487	62
10	0.0422	20	0.2543	62	10	0.0133	12	0.1425	62
20	0.0402	20	0.2481	62	20	0.0121	10	0.1363	62
30	0.0382	20	0.2419	63	30	0.0111	10	0.1301	62
40	0.0362	19	0.2356	62	40	0.0101	10	0.1239	62
50	0.0343	18	0.2294	62	50	0.0091	9	0.1177	61
84 0	0.0325	18	0.2232	63	87 0	0.0082		0.1116	

$\varphi = 65°$

66 0	0.9760	159	1.7708	228	68 0	0.6877	88	1.3657	122
5	0.9601	155	1.7480	221	5	0.6789	86	1.3535	119
10	0.9446	150	1.7259	213	10	0.6703	83	1.3416	116
15	0.9296	147	1.7046	207	15	0.6620	83	1.3300	114
20	0.9149	143	1.6839	201	20	0.6537	81	1.3186	111
25	0.9006	139	1.6638	196	25	0.6456	78	1.3075	109
30	0.8867	136	1.6442	191	30	0.6378	77	1.2966	107
35	0.8731	133	1.6251	186	35	0.6301	76	1.2859	105
40	0.8598	129	1.6065	180	40	0.6225	75	1.2754	103
45	0.8469	125	1.5885	175	45	0.6150	73	1.2651	101
50	0.8344	122	1.5710	171	50	0.6077	72	1.2550	98
55	0.8222	120	1.5539	168	55	0.6005	70	1.2452	96
67 0	0.8102	117	1.5371	164	69 0	0.5935	69	1.2356	94
5	0.7985	113	1.5207	160	5	0.5866	68	1.2262	93
10	0.7872	110	1.5047	155	10	0.5798	66	1.2169	91
15	0.7762	108	1.4892	152	15	0.5732	66	1.2078	90
20	0.7654	105	1.4740	147	20	0.5666	65	1.1988	89
25	0.7549	103	1.4593	143	25	0.5601	63	1.1899	88
30	0.7446	100	1.4450	140	30	0.5538	63	1.1811	88
35	0.7346	98	1.4310	137	35	0.5475	62	1.1723	86
40	0.7248	96	1.4173	133	40	0.5413	61	1.1637	85
45	0.7152	94	1.4040	130	45	0.5352	61	1.1552	85
50	0.7058	92	1.3910	127	50	0.5291	60	1.1467	83
55	0.6966	89	1.3783	123	55	0.5231	58	1.1384	82
68 0	0.6877	88	1.3657	122	70 0	0.5173	116	1.1302	163

TABLE I. (Continued.)

$\varphi = 65°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
70° 0′	0.5173	116	1.1302	163	78° 0′	0.1636	46	0.5761	90
10	0.5057	112	1.1139	160	10	0.1590	46	0.5671	89
20	0.4945	109	1.0979	155	20	0.1544	45	0.5582	88
30	0.4836	107	1.0824	153	30	0.1499	45	0.5494	88
40	0.4729	104	1.0671	149	40	0.1454	44	0.5406	87
50	0.4625	101	1.0522	146	50	0.1400	42	0.5319	87
71 0	0.4524	98	1.0376	145	79 0	0.1368	42	0.5232	86
10	0.4426	97	1.0231	141	10	0.1326	42	0.5146	86
20	0.4329	95	1.0090	137	20	0.1284	40	0.5060	85
30	0.4234	94	0.9953	137	30	0.1244	40	0.4975	86
40	0.4140	90	0.9816	133	40	0.1204	39	0.4889	85
50	0.4050	89	0.9683	131	50	0.1165	38	0.4804	84
72 0	0.3961	87	0.9552	129	80 0	0.1127	38	0.4720	84
10	0.3874	85	0.9423	127	10	0.1089	37	0.4636	84
20	0.3789	84	0.9296	126	20	0.1052	36	0.4552	83
30	0.3705	82	0.9170	123	30	0.1016	36	0.4469	84
40	0.3623	81	0.9047	121	40	0.0980	35	0.4385	83
50	0.3542	80	0.8926	120	50	0.0945	34	0.4302	82
73 0	0.3462	78	0.8806	118	81 0	0.0911	34	0.4220	82
10	0.3384	76	0.8688	116	10	0.0877	33	0.4138	82
20	0.3308	75	0.8572	115	20	0.0844	32	0.4056	82
30	0.3233	74	0.8457	113	30	0.0812	32	0.3974	82
40	0.3159	72	0.8344	111	40	0.0780	30	0.3892	81
50	0.3087	71	0.8233	110	50	0.0750	30	0.3811	81
74 0	0.3016	70	0.8123	109	82 0	0.0720	30	0.3730	80
10	0.2946	68	0.8014	108	10	0.0690	29	0.3650	80
20	0.2878	67	0.7906	107	20	0.0661	28	0.3570	80
30	0.2811	66	0.7799	106	30	0.0633	28	0.3490	80
40	0.2745	64	0.7693	105	40	0.0605	27	0.3410	80
50	0.2681	64	0.7588	104	50	0.0578	26	0.3330	80
75 0	0.2617	62	0.7484	102	83 0	0.0552	26	0.3250	79
10	0.2555	62	0.7382	102	10	0.0526	26	0.3171	79
20	0.2493	60	0.7280	100	20	0.0500	25	0.3092	78
30	0.2433	60	0.7180	100	30	0.0475	24	0.3014	79
40	0.2373	58	0.7080	99	40	0.0451	24	0.2935	79
50	0.2315	57	0.6981	98	50	0.0427	22	0.2856	78
76 0	0.2258	56	0.6883	98	84 0	0.0405	22	0.2778	78
10	0.2202	56	0.6785	96	10	0.0383	22	0.2700	78
20	0.2146	55	0.6680	95	20	0.0361	21	0.2622	78
30	0.2091	54	0.6594	94	30	0.0340	20	0.2544	78
40	0.2037	53	0.6499	94	40	0.0320	20	0.2466	78
50	0.1984	52	0.6405	94	50	0.0300	19	0.2388	78
77 0	0.1932	52	0.6311	94	85 0	0.0281	19	0.2310	78
10	0.1880	50	0.6217	93	10	0.0262	18	0.2232	77
20	0.1830	49	0.6124	92	20	0.0244	17	0.2155	77
30	0.1781	49	0.6032	92	30	0.0227	16	0.2078	78
40	0.1732	48	0.5941	90	40	0.0211	16	0.2000	78
50	0.1684	48	0.5851	90	50	0.0195	15	0.1922	77
78 0	0.1636	46	0.5761	90	86 0	0.0180	15	0.1845	78

$\varphi = 65°$

i	ξ	Δ	T′	Δ
86° 0′	0.0180	15	0.1845	78
10	0.0165	14	0.1767	77
20	0.0151	13	0.1690	77
30	0.0138	13	0.1613	78
40	0.0125	12	0.1535	77
50	0.0113	11	0.1458	76
87 0	0.0102		0.1382	

$\varphi = 70°$

i	ξ	Δ	T′	Δ	i	ξ	Δ	T′	Δ
° ′					° ′				
71 0	0.7613	130	1.7207	223	73 0	0.5189	76	1.3112	128
5	0.7483	127	1.6984	217	5	0.5113	74	1.2984	126
10	0.7356	124	1.6767	211	10	0.5039	73	1.2858	124
15	0.7232	121	1.6556	205	15	0.4966	72	1.2734	123
20	0.7111	118	1.6351	200	20	0.4894	71	1.2611	121
25	0.6993	116	1.6151	195	25	0.4823	69	1.2490	118
30	0.6877	113	1.5956	190	30	0.4754	68	1.2372	117
35	0.6764	110	1.5766	185	35	0.4686	67	1.2255	115
40	0.6654	108	1.5581	181	40	0.4619	66	1.2140	113
45	0.6546	105	1.5400	177	45	6.4553	65	1.2027	112
50	0.6441	103	1.5223	173	50	0.4488	63	1.1915	110
55	0.6338	101	1.5050	168	55	0.4425	62	1.1805	108
72 0	0.6237	98	1.4882	165	74 0	0.4563	60	1.1697	107
5	0.6139	96	1.4717	162	5	0.4303	60	1.1590	105
10	0.6043	93	1.4555	158	10	0.4243	60	1.1485	103
15	0.5950	92	1.4397	154	15	0.4183	58	1.1382	103
20	0.5858	90	1.4243	151	20	0.4125	57	1.1279	100
25	0.5768	88	1.4092	149	25	0.4068	57	1.1179	98
30	0.5680	86	1.3943	146	30	0.4011	55	1.1081	97
35	0.5594	84	1.3797	143	35	0.3956	55	1.0984	96
40	0.5510	83	1.3654	139	40	0.3901	55	1.0888	94
45	0.5427	81	1.3515	137	45	0.3846	53	1.0794	94
50	0.5346	79	1.3378	134	50	0.3793	52	1.0700	92
55	0.5267	78	1.3244	132	55	0.3741	52	1.0608	91
73 0	0.5189	76	1.3112	128	75 0	0.3689	50	1.0517	90

$\varphi = 70°$

i	ξ	Δ	T'	Δ	i	ξ	Δ	T'	Δ
° '					° '				
75 0	0.3689	50	1.0517	90	81 0	0.1196	46	0.5536	113
5	0.3639	50	1.0427	89	10	0.1150	44	0.5423	112
10	0.3589	50	1.0338	87	20	0.1106	43	0.5311	112
15	0.3539	48	1.0251	87	30	0.1063	42	0.5199	112
20	0.3491	48	1.0164	86	40	0.1021	42	0.5087	111
25	0.3443	48	1.0078	85	50	0.0979	40	0.4976	110
30	0.3395	47	0.9993	85	82 0	0.0939	40	0.4866	109
					10	0.0899	38	0.4757	108
35	0.3348	46	0.9908	84	20	0.0861	37	0.4649	108
40	0.3302	46	0.9824	82	30	0.0824	37	0.4541	107
45	0.3256	45	0.9742	83	40	0.0787	36	0.4434	107
50	0.3211	45	0.9659	82	50	0.0751	35	0.4327	107
55	0.3166	45	0.9577	80	83 0	0.0716	34	0.4220	106
76 0	0.3121	87	0.9497	160	10	0.0682	34	0.4114	105
10	0.3034	85	0.9337	157	20	0.0648	32	0.4009	105
20	0.2949	82	0.9180	153	30	0.0616	32	0.3904	104
30	0.2867	81	0.9027	152	40	0.0584	30	0.3800	104
40	0.2786	79	0.8875	149	50	0.0554	30	0.3696	104
50	0.2707	77	0.8726	146	84 0	0.0524	29	0.3592	104
77 0	0.2630	75	0.8580	144	10	0.0495	28	0.3488	103
10	0.2555	74	0.8436	143	20	0.0467	27	0.3385	103
20	0.2481	72	0.8293	141	30	0.0440	26	0.3282	102
30	0.2409	71	0.8152	138	40	0.0414	26	0.3180	102
40	0.2338	69	0.8014	137	50	0.0388	25	0.3078	101
50	0.2269	68	0.7877	134	85 0	0.0363	24	0.2977	102
78 0	0.2201	66	0.7743	133	10	0.0339	23	0.2875	101
10	0.2135	66	0.7610	132	20	0.0316	22	0.2774	100
20	0.2069	64	0.7478	131	30	0.0294	21	0.2674	100
30	0.2005	62	0.7347	128	40	0.0273	20	0.2574	100
40	0.1943	61	0.7219	128	50	0.0253	20	0.2474	100
50	0.1882	60	0.7091	126	86 0	0.0233	19	0.2374	100
79 0	0.1822	58	0.6965	125	10	0.0214	18	0.2274	100
10	0.1764	58	0.6840	125	20	0.0196	18	0.2174	100
20	0.1706	56	0.6715	124	30	0.0178	16	0.2074	100
30	0.1650	55	0.6591	121	40	0.0162	16	0.1974	99
40	0.1595	54	0.6470	121	50	0.0146	15	0.1875	99
50	0.1541	52	0.6349	120	87 0	0.0131		0.1776	
80 0	0.1489	52	0.6229	118					
10	0.1438	50	0.6111	117					
20	0.1387	49	0.5994	114					
30	0.1338	48	0.5880	115					
40	0.1290	48	0.5765	115					
50	0.1242	46	0.5650	114					
81 0	0.1196	46	0.5536	113					

$\varphi = 75$

i	ξ	Δ	T'	Δ	i	ξ	Δ	T,	Δ
° ′					° ′				
76 0	0.5495	111	1.6793	266	79 0	0.2739	51	1.0444	119
5	0.5384	107	1.6527	259	5	0.2688	50	1.0325	117
10	0.5277	104	1.6268	252	10	0.2638	50	1.0208	116
15	0.5173	102	1.6016	244	15	0.2588	49	1.0092	114
20	0.5071	100	1.5772	237	20	0.2539	48	0.9978	113
25	0.4971	98	1.5535	230	25	0.2491	46	0.9865	111
30	0.4873	96	1.5305	224	30	0.2445	46	0.9754	110
35	0.4777	93	1.5081	218	35	0.2399	45	0.9644	108
40	0.4684	92	1.4863	211	40	0.2354	45	0.9536	107
45	0.4592	90	1.4652	206	45	0.2309	44	0.9429	106
50	0.4502	87	1.4446	201	50	0.2265	43	0.9323	105
55	0.4415	85	1.4245	195	55	0.2222	43	0.9218	193
77 0	0.4330	83	1.4050	190	80 0	0.2179	82	0.9115	204
5	0.4247	82	1.3860	186	10	0.2097	81	0.8911	201
10	0.4165	81	1.3674	181	20	0.2016	78	0.8710	195
15	0.4084	78	1.3493	177	30	0.1938	75	0.8515	192
20	0.4006	76	1.3316	173	40	0.1863	73	0.8323	189
25	0.3930	75	1.3143	169	50	0.1790	72	0.8134	186
30	0.3855	73	1.2974	165	81 0	0.1718	69	0.7948	184
					10	0.1649	67	0.7764	181
35	0.3782	72	1.2809	162	20	0.1582	66	0.7583	178
40	0.4710	71	1.2647	159	30	0.1516	64	0.7405	175
45	0.3639	69	1.2488	155	40	0.1452	61	0.7230	173
50	0.3571	67	1.2333	152	50	0.1391	60	0.7057	170
55	0.3504	67	1.2180	148	82 0	0.1331	59	0.6887	168
78 0	0.3437	64	1.2032	145	10	0.1272	57	0.6719	166
5	0.3373	63	1.1887	143	20	0.1215	55	0.6552	163
10	0.3310	63	1.1744	141	30	0 1160	54	0.6389	162
15	0.3247	60	1.1603	138	40	0.1106	53	0.6227	161
20	0.3187	60	1.1465	135	50	0.1053	51	0.6066	159
25	0.3127	59	1.1330	133	83 0	0.1002	49	0.5907	157
30	0.3068	57	1.1197	131	10	0.0953	48	0.5750	156
					20	0.0905	47	0.5594	154
35	0.3011	56	1.1066	128	30	0.0858	45	0.5440	153
40	0.2955	56	1.0938	126	40	0.0813	44	0.5287	152
45	0.2899	54	1.0812	124	50	0.0769	42	0.5135	151
50	0.2845	53	1.0688	123	84 0	0.0727	41	0.4984	150
55	0.2792	53	1.0565	121	10	0.0686	40	0.4834	148
79 0	0.2739	51	1.0444	119	20	0.0646	39	0.4686	148
					30	0.0607	37	0.4538	146
					40	0.0570	36	0.4392	146
					50	0.0534	34	0.4246	144
					85 0	0.0500	33	0.4102	145

TABLE I. (Continued.)

$\varphi = 75$

i		ξ	Δ	T′	Δ
°	′				
85	0	0.0500	33	0.4102	145
	10	0.0467	32	0.3957	144
	20	0.0435	30	0.3813	143
	30	0.0405	29	0.3670	143
	40	0.0376	29	0.3527	142
	50	0.0347	27	0.3386	140
86	0	0.0320	26	0.3246	138
	10	0.0294	25	0.3108	138
	20	0.0269	24	0.2970	138
	30	0.0245	24	0.2832	138
	40	0.0221	22	0.3694	136
	50	0.0199	21	0.2558	136
87	0	0.0178		0.2422	

TABLE II.

$\varphi = 30^\circ$									$\varphi = 35^\circ$							
i		ω		Δ	i		ω		i		ω		i		ω	
°	′	°	′		°	′	°	′	°	′	°	′	°	′	°	′
31	0	65	28	39	51	0	38	20	36	0	70	22	56	0	43	26
	10	64	49	37	52	0	37	50		10	69	47	57	0	42	55
	20	64	12	36	53	0	37	23		20	69	12	58	0	42	25
	30	63	36	35	54	0	36	57		30	68	38	59	0	41	56
	40	63	1	34	55	0	36	32		40	68	5	60	0	41	28
	50	62	27	34	56	0	36	9		50	67	33	61	0	41	2
32	0	61	53	33	57	0	35	47	37	0	67	0	62	0	40	37
	10	61	20	32	85	0	35	26		10	66	29	63	0	40	13
	20	60	48	30	59	0	35	6		20	65	59	64	0	39	50
	30	60	18	30	60	0	34	46		30	65	29	65	0	39	29
	40	59	48	29	61	0	34	28		40	65	0	66	0	39	8
	50	59	19	29	62	0	34	10		50	64	32	67	0	38	49
33	0	58	50	28	63	0	33	53	38	0	64	5	68	0	38	30
	10	58	22	27	64	0	33	37		10	63	38	69	0	38	12
	20	57	55	27	65	0	33	21		20	63	12	70	0	37	55
	30	57	28	26	66	0	33	6		30	62	46	71	0	37	38
	40	57	2	25	67	0	32	52		40	62	21	72	0	37	22
	50	56	37	23	68	0	32	38		50	61	57	73	0	37	6
34	0	56	14	24	69	0	32	25	39	0	61	34	74	0	36	50
	10	55	50	23	70	0	32	12		10	61	11	75	0	36	36
	20	55	27	23	71	0	32	0		20	60	49	76	0	36	23
	30	55	4	22	72	0	31	40		30	60	27	77	0	36	13
	40	54	42	22	73	0	31	38		40	60	6	78	0	36	4
	50	54	20	21	74	0	31	28		50	59	45	79	0	35	56
35	0	53	59	60	75	0	31	18	40	0	59	24	80	0	35	50
	30	52	59	56	76	0	31	9		30	58	27	81	0	35	45
36	0	52	3	52	77	0	31	0	41	0	57	34	82	0	35	40
	30	51	11	48	78	0	30	53		30	56	45	83	0	35	36
37	0	50	23	45	79	0	30	46	42	0	55	57	84	0	35	32
	30	49	38	43	80	0	30	40		30	55	12	85	0	35	28
38	0	48	55		81	0	30	35	43	0	54	29	86	0	35	24
	30	48	15		82	0	30	30		30	53	49	87	0	35	20
39	0	47	37		83	0	30	27	44	0	53	11				
	30	47	2		84	0	30	24		30	52	36				
40	0	46	28		85	0	30	22	45	0	52	2				
	30	45	55		86	0	30	20		30	51	28				
41	0	45	24		87	0	30	19	46	0	50	56				
	30	44	45							30	50	25				
42	0	44	26						47	0	49	55				
43	0	43	33						48	0	49	0				
44	0	42	44						49	0	48	8				
45	0	41	58						50	0	47	20				
46	0	41	16						51	0	46	34				
47	0	40	36						52	0	45	52				
48	0	39	59						53	0	45	12				
49	0	39	23						54	0	44	35				
50	0	38	50						55	0	44	0				
51	0	38	20						56	0	43	26				

TABLE II. (Continued.)

$\varphi = 40°$

i °	′	ω °	′	*i* °	′	ω °	′
41	0	73	39	56	0	51	7
	10	73	8	57	0	50	23
	20	72	37	58	0	49	43
	30	72	8	59	0	49	4
	40	71	39	60	0	48	26
	50	71	10	61	0	47	52
42	0	70	42	62	0	47	19
	10	70	14	63	0	46	47
	20	69	47	64	0	46	16
	30	69	22	65	0	45	48
	40	68	56	66	0	45	21
	50	68	31	67	0	44	55
43	0	68	6	68	0	44	30
	30	66	55	69	0	44	7
44	0	65	49	70	0	43	45
	30	64	46	71	0	43	23
45	0	63	47	72	0	43	3
	30	62	52	73	0	42	44
46	0	62	0	74	0	42	26
	30	61	11	75	0	42	10
47	0	60	25	76	0	41	54
48	0	59	0	77	0	41	40
	30	58	20	78	0	41	26
49	0	57	43	79	0	41	15
	30	57	7	80	0	41	4
50	0	56	32	81	0	40	53
51	0	55	28	82	9	40	45
52	0	54	28	83	0	40	38
53	0	53	32	84	0	40	32
54	0	52	40	85	0	40	26
55	0	51	52	86	0	40	23
56	0	51	7	87	0	40	20

$\varphi = 45°$

i °	′	ω °	′	*i* °	′	ω °	′
46	0	77	5	56	0	59	15
	10	76	31	57	0	58	17
	20	75	58	58	0	57	22
	30	75	27	59	0	56	31
	40	74	56	60	0	55	43
	50	74	26	61	0	54	57
47	0	73	56	62	0	54	14
	10	73	27	63	0	53	34
	20	72	59	64	0	52	55
	30	72	33	65	0	52	18
	40	72	7	66	0	51	43
	50	71	42	67	0	51	10
48	0	71	17	68	0	50	38
	20	70	53	69	0	50	8
	20	70	30	70	0	49	40
	30	70	7	71	0	49	14
	40	69	45	72	0	48	48
	50	69	24	73	0	48	23
49	0	69	3	74	0	48	0
	30	68	3	75	0	47	38
50	0	67	7	76	0	47	19
	30	66	15	77	0	47	2
51	0	65	27	78	0	46	45
	30	64	42	79	0	46	29
52	0	64	0	80	0	46	14
	30	63	19	81	0	46	0
53	0	62	39	82	0	45	48
	30	62	1	83	0	45	39
54	0	61	25	84	0	45	32
	30	60	51	85	0	45	27
55	0	60	18	86	0	45	23
	30	59	46	87	0	45	20

$\varphi = 50°$

i °	′	ω °	′	*i* °	′	ω °	′
51	0	79	44	53	0	73	53
	10	79	9		10	73	29
	20	78	35		20	73	6
	30	78	2		30	72	45
	40	77	30		40	72	24
	50	76	59		50	72	3
52	0	76	30	54	0	71	43
	10	76	2		30	70	45
	20	75	35	55	0	69	52
	30	75	8		30	69	4
	40	74	42	56	0	68	19
	50	74	17		30	67	37
53	0	72	53	57	0	66	56

$\varphi = 55°$

i °	′	ω °	′	*i* °	′	ω °	′
56	0	80	38	58	0	75	41
	10	80	9		10	75	20
	20	79	41		20	75	0
	30	79	13		30	74	41
	40	78	47		40	74	22
	50	78	21		50	74	4
57	0	77	56	59	0	73	46
	10	77	32		30	72	56
	20	77	9	60	0	72	8
	30	76	46		30	71	23
	40	76	24	61	0	70	41
	50	76	2		30	70	2
58	0	75	41	62	0	69	24

TABLE II. (Continued.)

$\varphi = 50°$				$\varphi = 55°$				$\varphi = 60°$				$\varphi = 65°$			
i		ω		i		ω		i		ω		i		ω	
°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′
57	0	66	56	62	0	69	24	61	0	81	41	66	0	83	37
	30	66	18		30	68	48		10	81	15		10	83	2
58	0	65	41	63	0	68	13		20	80	51		20	83	29
	30	65	5		30	67	39		30	80	28		30	81	58
59	0	64	31	64	0	67	7		40	80	5		40	81	29
	30	63	58	65	0	66	6		50	79	42		50	81	2
60	0	63	25	66	0	65	9	62	0	79	20	67	0	80	38
61	0	62	25	67	0	64	16		10	78	58		10	80	16
62	0	61	29	68	0	63	26		20	78	37		20	79	55
63	0	60	37	69	0	62	40		30	78	16		30	79	35
64	0	59	47	70	0	61	56		40	77	56		40	79	16
65	0	59	1	71	0	61	16		50	77	37		50	78	57
66	0	58	17	72	0	60	37	63	0	77	18	68	0	78	39
67	0	57	35	73	0	60	0		30	76	25		30	77	51
68	0	56	56	74	0	59	25	64	0	75	34	69	0	77	7
69	0	56	18	75	0	58	53		30	74	46		30	76	26
70	0	55	43	76	0	58	24	65	0	74	2	70	0	75	47
71	0	55	9	77	0	57	58		30	73	22		30	75	10
72	0	54	38	78	0	57	33	66	0	72	43	71	0	74	34
73	0	54	8	79	0	57	8		30	72	6		30	74	0
74	0	53	40	80	0	56	46	67	0	71	31	72	0	73	28
75	0	53	14	81	0	56	26		30	70	57		30	72	57
76	0	52	50	82	0	56	10	68	7	70	24	73	0	72	27
77	0	52	28	83	0	55	56		30	69	53		30	71	59
78	0	52	7	84	0	55	45	69	0	69	24	74	0	71	32
79	0	51	47	85	0	55	34		30	68	57		30	71	7
80	0	51	28	86	0	55	23	70	0	68	30	75	0	70	43
81	0	51	12	87	0	55	13	71	0	67	38		30	70	20
82	0	51	1					72	0	66	48	76	0	69	58
83	0	50	51					73	0	66	2	77	0	69	16
84	0	50	41					74	0	65	20	78	0	68	38
85	0	50	34					75	0	64	41	79	0	68	3
86	0	50	36					76	0	64	5	80	0	67	32
87	0	50	20					77	0	63	32	81	0	67	3
								78	0	63	1	82	0	66	38
								79	0	62	32	83	0	66	16
								80	0	62	6	84	0	65	57
								81	0	61	43	85	0	65	41
								82	0	61	22	86	0	65	27
								83	0	61	4	87	0	65	14
								84	0	60	49				
								85	0	60	37				
								86	0	60	26				
								87	0	60	14				

TABLE II. (Continued.)

$\varphi = 70°$				$\varphi = 75°$			
i		ω		i		ω	
°	′	°	′	°	′	°	′
71	0	83	32	76	0	84	38
	30	82	33		30	83	43
72	0	81	38	77	0	82	52
	30	80	48		30	82	6
73	0	80	1	78	0	81	23
	30	79	18		30	80	46
74	0	78	37	79	0	80	11
	30	77	58		30	79	39
75	0	77	23	80	0	79	10
	30	76	49		39	78	43
76	0	76	19	81	0	78	19
	30	75	50		30	77	56
77	0	75	23	82	0	77	35
	30	74	57		30	77	16
78	0	74	32	83	0	76	58
	30	74	9		30	76	41
79	0	73	47	84	0	76	26
	30	73	27		30	76	13
80	0	73	7	85	0	76	0
81	0	72	31		30	75	48
82	0	71	59	86	0	75	37
83	0	71	31		30	75	29
84	0	71	8	87	0	75	22
85	0	70	48				
86	0	70	32				
87	0	70	18				

TABLE III.

$\varphi = 30°$

i		ζ
°	′	
35	0	0.24134
39	0	0.15945
43	0	0.11560
47	0	0.08705
51	0	0.06669
55	0	0.05130
57	0	0.04489
59	0	0.03918
61	0	0.03398
63	0	0.02931
65	0	0.02507
67	0	0.02125
69	0	0.01773
71	0	0.01462
73	0	0.01177
75	0	0.00923
77	0	0.00700
79	0	0.00509
81	0	0.00345
83	0	0.00215
85	0	0.00113
87	0	0.00043

$\varphi = 35°$

i		ζ
°	′	
39	0	0.32988
43	0	0.20855
47	0	0.14723
51	0	0.10849
55	0	0.08125
57	0	0.07037
59	0	0.06084
61	0	0.05235
63	0	0.04487
65	0	0.03814
67	0	0.03215
69	0	0.02671
71	0	0.02191
73	0	0.01759
75	0	0.01374
77	0	0.01041
79	0	0.00753
81	0	0.00510
83	0	0.00316
85	0	0.00166
87	5	0.00061

$\varphi = 40°$

i		ζ
°	′	
43	0	0.44268
47	0	0.26252
51	0	0.17954
55	0	0.12880
57	0	0.10982
59	0	0.09371
61	0	0.07979
63	0	0.06773
65	0	0.05712
67	0	0.04780
69	0	0.03948
71	0	0.03220
73	0	0.02573
75	0	0.02003
77	0	0.01512
79	0	0.01089
81	0	0.00735
83	0	0.00453
85	0	0.00235
87	0	0.00087

$\varphi = 45°$

i		ζ
°	′	
47	0	0.59753
51	0	0.32190
55	0	0.21141
57	0	0.17553
59	0	0.14666
61	0	0.12280
63	0	0.10279
65	0	0.18570
67	0	0.07100
69	0	0.05818
71	0	0.04710
73	0	0.03740
75	0	0.02897
77	0	0.02177
79	0	0.01561
81	0	0.01050
83	0	0.00644
85	0	0.00332
87	0	0.00122

$\varphi = 50°$

i		ζ
°	′	
55	0	0.38782
57	0	0.30214
59	0	0.24196
61	0	0.19643
63	0	0.16060
65	0	0.13144
67	0	0.10726
69	0	0.08684
71	0	0.06949
73	0	0.05477
75	0	0.04213
77	0	0.03146
79	0	0.02244
81	0	0.01502
83	0	0.00916
85	0	0.00472
87	0	0.00172

$\varphi = 55°$

i		ζ
°	′	
57	0	0.67742
59	0	0.46363
61	0	0.34696
63	0	0.26945
65	0	0.21277
67	0	0.16908
69	0	0.13413
71	0	0.10572
73	0	0.08215
75	0	0.06252
77	0	0.04627
79	0	0.03277
81	0	0.02181
83	0	0.01320
85	0	0 00678
87	0	0.00245

$\varphi = 60°$

i		ζ
°	′	
63	0	0.55520
65	0	0.39277
67	0	0.29276
69	0	0.22259
71	0	0.17102
73	0	0.12923
75	0	0.09664
77	0	0.07051
79	0	0.04940
81	0	0.03259
83	0	0.01957
84	0	0.00999
85	0	0.00999
87	0	0.00360

$\varphi = 65°$

i		ζ
°	′	
67	0	0.68142
69	0	0.44070
71	0	0.31095
73	0	0.22351
75	0	0.16133
77	0	0.11467
79	0	0.07882
81	0	0.05126
83	0	0.03043
85	0	0.01538
87	0	0.00551

$\varphi = 70°$

i		ζ
°	′	
73	0	0.49449
75	0	0.31829
77	0	0.21186
79	0	0.13959
81	0	0.08818
83	0	0.05127
85	0	0.02554
87	0	0.00907

$\varphi = 75°$

i		ζ
°	′	
77	0	0.56532
79	0	0.31330
81	0	0.18160
83	0	0.10036
85	0	0.04841
87	0	0.01687

TABLE IV.

Supplement to A

			56°		57°		58°	
$\frac{V}{\sqrt{C}}$	$\frac{V}{\sqrt{C}}$	$\frac{V}{X}$	$\frac{V^2}{X}$	D	$\frac{V^2}{X}$	D	$\frac{V^2}{X}$	D
100	460	39.	43.27	36	43.92	37	44.66	38
110	470	39.	43.63	37	44.29	37	45.04	38
120	480	40.	44.00	37	44.66	38	45.42	39
130	490	40.	44.37	37	45.04	39	45.81	39
140	500	40.	44.74	38	45.43	39	46.20	40
150	510	41.	45.12	39	45.82	40	46.60	40
160	520	41.	45.51	39	46.22	40	47.00	41
170	530	41.	45.90	40	46.62	41	47.41	41
180	540	42.	46.30	41	47.03	41	47.82	42
190	550	42.	46.71	42	47.44	42	48.24	43
200	560	42.	47.13	42	47.86	43	48.67	43
210	570	43.	47.55	43	48.29	43	49.10	44
220	580	43.	47.98	43	48.72	44	49.54	45
230	590	44.	48.41	44	49,16	44	49.99	45
240	600	44.	48.85	44	49.60	45	50.44	46
250	610	44.	49.29	45	50.05	46	50.90	46
260	620	45.	49.74	46	50.51	46	51.36	47
270	630	45.	50.20	46	50.97	47	51.83	48
280	640	46.	50.66	47	51.44	48	52.31	49
290	650	46.	51.13	48	51.92	49	52.80	49
300	660	46.	51.61	48	52.41	49	53.29	50
310	670	47.	52.09	49	52.90	50	53.79	51
320	680	47.	52.58	50	53.40	50	54.30	51
330	690	48.	53.08	50	53.90	51	54.81	52
340	700	48.	53.58	51	54.41	52	55.33	52
350	710	49.	54.09	51	54.93	52	55.85	53
360	720	49.	54.60	52	55.45	53	56.38	54
370	730	49.	55.12	52	55.98	53	56.92	55
380	740	50.	55.64	53	56.51	54	57.47	56
390	750	50.	56.17	54	57.05	55	58.03	56
400	760	51.	56.71	54	57.60	56	58.59	57
410	770	51.	57.25	55	58.16	56	59.16	57
420	780	52.	57.80	55	58.72	57	59.73	58
430	790	52.	58.35	56	59.29	57	60.31	58
440	800	53.	58.91	57	59.86	58	60.89	59
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