JOURNAL OF THE UNITED STATES ARTILLERY

PUBLISHED UNDER DIRECTION OF THE

ARTILLERY BOARD

VOLUME 24
1905

FORT MONROE, VIRGINIA
ARTILLERY SCHOOL PRESS
1905

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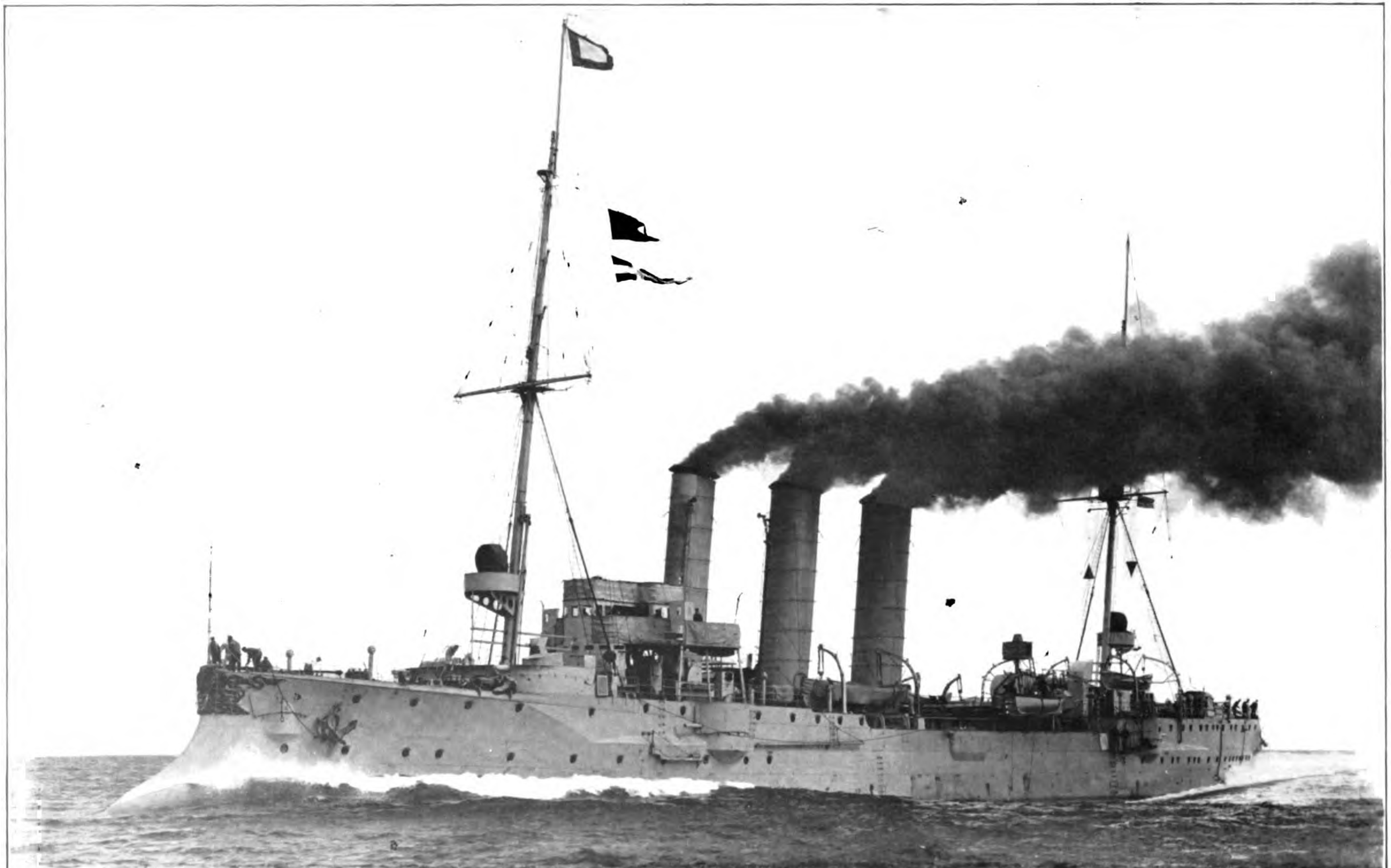

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JOURNAL

OF THE

UNITED STATES ARTILLERY

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

VOL. 24 No. 1 JULY—AUGUST, 1905 WHOLE NO. 74

A REGIMENT OF FIELD ARTILLERY

BY LIEUTENANT-COLONEL A. D. SCHENCK, ARTILLERY CORPS

THE number of regiments of field artillery required for any given army is first of all predicated upon the number of guns required for that army; upon the size of the batteries and of the battalions, and very materially upon the nature of the larger units of the other arms of the service, more especially as to whether these be *corps d'armée*, or large divisions. The General Staff has decided that for our service there shall be, or ought to be, 3.35 guns per thousand muskets, despite the fact that in the military nations this factor is from 4 to 6 guns per thousand infantry muskets; and even the larger factor is the limit not at all because there should not be more guns, but because of the cost, and the refusal of the non-military political power to appropriate the necessary money. It is evident that the maximum number of guns must insure a great advantage in battle, other things being equal.

Again it has always been found that, to insure even reasonable steadiness with green troops, a greater number of guns is required than for disciplined men. As we must fight our wars with green volunteer troops, we should provide for even a greater number of guns than is to be found in any foreign army, instead of a less ratio than is to be found elsewhere. Moreover, being a mounted service, it should be placed upon the same footing as to the proportional number of regiments in the field artillery as is found in our cavalry relative to the infantry. The cavalry strength of 15 regiments provides a powerful brigade of 2400 sabers for each of 7 divisions; and beyond question of doubt there should be organized in the field artillery enough regiments to provide the artillery quota for these 7 divisions, viz., 7 regiments of light, and 7 of heavy field artillery, 4 of horse artillery for service with the cavalry, and the corps and army so-called reserves, and at least one regiment each of siege, and mountain artillery. In other words, the field artillery of our army, if placed upon the same footing as that held at present by our cavalry, would have at least 20 regiments of field artillery such as will presently be indicated.

Because of the manifest superiority of fire of the new so-called R.F. guns, "therefore," the number of guns in the battery has been reduced from 6 to 4, and it seems to be taken for granted that the number of batteries is to be left as before the reduction in guns, The modern magazine rifle is immeasurably superior to the old Brown Bess of four scoreyears ago, but because of this superiority the number of muskets, or of infantry companies or regiments, has not been reduced; on the contrary they have in all detail been increased, both as to the number of men in a company, the number of companies in a regiment, and even to the number of regiments in an army. In other words although the artilleryman should, for tactical reasons, better reduce the number of guns in a battery, there is apparently no valid reason whatever why he should also reduce the total number of guns in an army. On the contrary there is quite as much reason why he should increase the number of his superior modern guns, as there is for the infantryman's so doing because he has found a new rifle vastly more powerful than the old one; unless indeed, our friend the enemy first makes such a reduction, and even then it by no means follows that it is wisdom on our part to follow his foolish lead and for no good reason surrender so manifest a superiority in battle as is insured by a greater number, and if possible better guns.

We are supposed to be making the best possible organization for the smallest army that will enable us to meet at least the first shock of attack quickly, and have, therefore, made provision for a very unusual proportion of cavalry to infantry in our army, for the very simple reason that it is the very first of the "Three Arms" to meet the enemy, and it is fully recognized that it is utterly impossible to improvise cavalry of any kind, even the poorest, that will possess any immediate efficiency in war. It is absolutely incontestable that it takes even more time and care to equip and train that other arm of the mounted service—the field artillery, than is required for cavalry, and the cavalry quota at least of its horse artillery must be prepared to meet the advance of an enemy as quickly as the cavalry itself. Field artillery can no more be improvised than can cavalry; consequently, as is now the fact as to our cavalry, the proportion of field artillery in our army should be even greater as respects the infantry arm than is the cavalry; and, aside from siege and mountain artillery, the field artillery should be sufficient to provide for the 7 above-named infantry divisions, a brigade to each, for which the cavalry is now prepared to furnish a brigade to each of these divisions.

It is to be hoped that soon the organization of our army will be made very much more complete through a thorough and comprehensive organization of its field artillery. It is conceded a principle of the greatest importance even in the most perfectly organized armies of Europe, that the MOUNTED arms of the service must be so organized and maintained in peace as to be able at a moment's notice to take the field for war, completely manned, horsed, armed and equipped, and so maintained throughout a war. For instance, a French or German cavalry regiment on war footing in the field numbers about 600 sabers, with 4 squadrons of 2 troops each. It actually has 5 squadrons of 2 troops each, and in peace these 10 troops are maintained at about 60 men each, with their horses. In the event of war the men and horses of the 5th squadron (depot), are drafted to the other squadrons and the regiment can at once take the field at its full war strength, completely equipped, while the depot squadron, remaining at home, is at once filled up from the reserves, and stands ready to make good at once all war losses of men and horses that its regiment may sustain in the field, from deaths, wounds or sickness.

This system will hardly be accepted in our army organization wherein each unit is supposed to take the field, but there is no reason why we may not, in part at least, avail ourselves of this exceedingly valuable expedient when the organization of our field artillery is being perfected, and the battalions and regiments are given form.

In the first place a battalion of two 4-gun batteries, virtually one Austrian battery of 8 guns, is not likely to be accepted by Congress or other authorities as a real battalion of field artillery, nor will 3 such virtual batteries be accepted as a regiment. Three 6-gun batteries together with the necessary artillery ammunition train, almost universally constitutes a battalion of field; but what is still more to the point, 3 batteries, but without the necessary ammunition train attached thereto, is already prescribed for our service, page 20, Field Service Regulations, U. S. Army, 1905.

To these 3 batteries of 481 enlisted, it is only necessary to add a fourth for the artillery ammunition train. This battery with its personnel as to number, organized precisely as the others except as to number of drivers and cannoneers, will have permanently 29 enlisted noncommissioned officers, cooks, musicians, etc., so that the battalion of 4 batteries will call for a war strength of 510 enlisted, with horses, etc., exclusive of the privates of the train when filled to its war strength also. These 510 enlisted, then, as a peace footing will be divided among the 4 batteries—128 in round numbers to each, together with the appropriate number of horses for the war strength of the three gun batteries, exclusive of the horses for the 29 noncommissioned officers, etc., of the train battery. The number of officers and noncommissioned officers is always maintained at the war strength. Then, in the event of war, all that is necessary to put the GUN batteries on a war footing, is to draft to them from the train battery the necessary men and horses and the gun batteries are, at a moment's notice, completely manned and horsed for war service.

At the same time while the train battery (which is not to become a cadre for a depot battery as in Europe) will not be on a war footing, it will at least have complete that most valuable part, the officers and noncommissioned officers, etc., all trained and disciplined artillerymen, and with about 174 privates and the necessary horses, it will soon be enabled to follow its gun batteries to the field. With its complement of seasoned officers and noncommissioned officers, to lick this train battery into shape will be a very simple affair, compared with what would obtain if we have only gun batteries all on a peace footing, all to be recruited up to the war strength, with no train battery at all provided for. A battery of the train should carry an ammunition supply about equal to that actually carried in the field by the 3 batteries of the battalion, say 36 cassions, forge, stores wagons, etc.; the enlisted war strength being about 29 noncommissioned officers, etc., 114 drivers, 12 spare drivers, and 48 cannoneers to replace, say, 10 per cent losses from battle casualties, sickness, etc.; total 203 enlisted. One-half of this ammunition supply, or one train battery per regiment, should no doubt march immediately with the troops; for the divisional artillery, say, in rear of the divisional trains, and the other half in rear of the corps or army trains; each to be brought to the front of these trains, respectively, when battle is imminent. The batteries of the train will also in time of peace serve the most important functions of collecting and at least partially training recruits and green horses, and thus save the gun batteries much valuable time which can better be devoted to advanced training and practice. These would form a provisional battalion of the train for each regiment commanded by a major, but without a staff other than a provisional detailed one.

A battalion comprising in war 696 men and as many horses, 1392 in all, to say nothing of the 24 guns and great amount of material, most certainly should be commanded by a lieutenant-colonel, with at least one, and better two, majors as assistants; in these days of indirect fire, and the difficulty of fire control, range finding, and many another complication, wholly unknown to the field artilleryman even of the very recent past.

The difficulties connected with the modern range-finding and fire control system account for the war necessity for the increased battalion and regimental staffs and noncommissioned staffs as compared with those of the cavalry and infantry. The indirect fire now practiced by field artillery is a thing which practically found no application even five or ten years ago, but which finds universal use in the present Russo-Japanese war. Regiments, and even brigades—not single batteries or at most battalions in theory—now deliver a concentrated and deadly fire from screened and protected positions a thousand or more yards behind an elevation; directed and controlled by range-finding and fire control officers under the commander perhaps miles away from their guns, just as we find done in our coast artillery fire control, especially with mortars where the gunner never sees his target. For these purposes the commanding officer of the field artillery utilizes all of his staff in battle, and finds the need for even a greater number of officers and men. On the other hand they are all quite necessary for administration purposes in time of peace, even were it not axiomatic that they must exist in times of peace to the end that they may be trained and fitted in time of peace for that of war.

It costs to equip and and arm, etc., about $75,000 for a regiment of 1800 infantrymen; $280,000 for a regiment of cavalry, and over $700,000 for regiment of field artillery as herein indicated. A day's rations for the infantry regiment weighs 7,200 pounds, while that for the artillery regiment together with the forage for the horses will weigh 38,340 pounds,—and so it goes through all of the details, as to ammunition, horseshoes, saddlery, harness, carriages, and scores of others; each at times of vital importance, with a situation that requires at the head of each general class a staff officer to supervise, and be accountable for, and a noncommissioned staff sergeant to distribute, and look after the paper work,—which alas, like the poor, the bureau chiefs in the War Department, from their comfortable chairs, compel the poor devils in the field in war,—to "always have with us."

We should have, then, for a field artillery battalion:—

1 Lieutenant-colonel.
1 Major. (or 2 ?)
1 Adjutant, 1st Lieutenant.
1 Quartermaster and Commissary, 1st Lieutenant.
1 Ordnance, Signal and Range Officer, 1st Lieutenant.
1 Veterinarian, 1st or 2nd Lieutenant.
1 Sergeant-major.
1 Sergeant of Ordnance.
1 Quartermaster-sergeant.
1 Commissary-sergeant.
1 Range and Signal Sergeant.
1 Veterinary Sergeant.
1 Standard bearer, (Corporal).
2 Buglers.
4 Mounted Orderlies.
3 Gun Batteries.
1 Train Battery.

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696 total enlisted.
21 total commissioned.
12 Guns.
72 Caissons.
16 other carriages.
1392 men and horses.

And for a regiment of field artillery:—

1 Colonel.
1 Major, commanding train batteries.
1 Adjutant, Captain.
1 Ordnance Officer, Captain.
1 Range and Signal Officer, Captain.
1 Quartermaster, Captain.
1 Commissary, Captain.
1 Veterinarian, Captain.
1 Sergeant-major.
1 Sergeant of Ordnance.
1 Signal and Range Sergeant.
1 Quartermaster-sergeant.
1 Commissary-sergeant.
1 Farrier Sergeant.
1 Saddler Sergeant.
1 Veterinary Sergeant.
2 Color Sergeants.
12 Mounted Orderlies.

1 Chief musician. 1 Chief trumpeter. 1 Principal musician. 1 Drum major. 4 Sergeants. 28 Corporals. 1 Cook. 11 Privates.	Band.

2 Battalions.

1440 total enlisted.
49 total commissioned.
2880 total men and horses.
24 Guns.
144 Caissons.
32 other carriages.

The total commissioned for a regiment of cavalry or infantry is 50. The prospects for regimental promotion for the future in time of peace may become evident from the following table:

RELATIVE NUMBER OF OFFICERS TO A COLONEL IN DIFFERENT BRANCHES OF SERVICE.

	Navy	Corps Eng.	Cavalry	Infantry	Field Artillery	Including Staff*
Colonel	1.0	1.0	1	1	1	1.00
Lieutenant-Colonel	1.6	1.6	1	1	2	1.00
Major	2.4	3.2	3	3	3	2.46
Captain	4.2	4.3	15	15	13	9.54
1st Lieutenant	1.1	4.3	15	15	14	8.50
2nd Lieutenant	1.7	4.3	15	15	16	8.50
Totals	12.0	18.7	50	50	49	31.

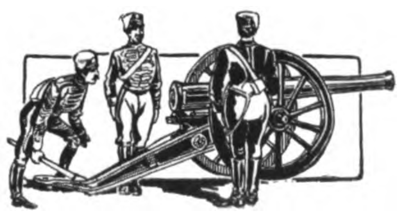
* Exclusive of the Ordnance, details to it chiefly probably from Artillery Corps.

Considering the chances of promotion in the Navy as compared with that of regimental promotion in the Army, it is very evident that a "hump" in promotion for the latter is inevitable, and will be very much greater than it ever has been in the Navy. One certain aid to promotion, though a small one, would be to make every battalion commander in the line a lieutenant-colonel, with at least one, and better, two majors as his assistants. Three field officers are certainly not too many to fight 500 or 600 men in extended order in the infantry, or 800 men and horses in the cavalry. Assuredly it will not be found too many for over 1300 men and horses with a dozen guns in a field artillery battalion. But granted this aid, it would still be just as difficult for a large number of officers even to reach the grade of colonel, though a greater number would reach that of lieutenant-colonel. To insure efficiency, it is not alone necessary to insure promotion to the grades of field officers at suitable ages in each grade, as is done by the compulsory retirement feature of the Personnel Bill for the Navy, but it is equally important that promotion should be such that officers can serve a reasonable time in each grade successively, but especially in the grades of field officers before retirement for age. If it has been found absolutely necessary to apply the present drastic law for the Navy, where the chances for promotion are more than double those in the Army, it can readily be seen that it is absolutely necessary to apply to the regiments of the Army compulsory elimination for age, at least in the grades above that of captain, as was done in the English army, coupled with a provision for an increase in the number of majors and lieutenant-colonels. If peace conditions continue for even a few years longer, the "hump" in regimental promotion will develop to large proportions, and this drastic remedy will have to be applied or we shall again have even the lists of captains and lieutenants loaded with grandfathers. If the remedy be applied at once while regimental officers are reasonably young for their grades, they will be kept so and with the minimum of hardship to the fewest possible number of officers, but if not applied until the "hump" is fully developed, the hardship will be inflicted by wholesale and to the maximum number of officers in the harshest possible manner.

Certainly the remedy should be applied to the field artillery regiments at the time of there organization; then, if care be taken to appoint to these regiments officers of suitable age for the grades they are to hold, which can readily be done, the few who will reach an age too great for the grade they hold will be at once eliminated, and not permitted to block promotion and create the "hump," which would then grow at an ever increasing rate until an efficient service would be hopeless.

Incidentally it may be remarked that if we are to have a proper and efficient organization for the field artillery, most certainly a chief of this artillery, as is found in every army organization, and wholly disconnected from the Artillery Corps for coast defense, is an essential of the utmost importance. A chief of artillery is necessary and important chiefly as a fighting head, but there is also another reason, among many, in the fact that it is a mounted service. The deplorable inefficiency for want of such a chief during our Civil War is only too well remembered. And the same held good for the cavalry also. It is readily recalled that General Stanley was made chief of cavalry in the Army of the Cumberland, and Pleasanton of the Army of the Potomac, and probably the same for other armies. This was made necessary mainly by reason of the phenomenal wastage of horses during that war, and the consequent failure to secure an adequate number of remounts within any reasonable time; matters of such vital importance to the efficiency of the cavalry. These difficulties had, more than anything else, to do with the appointment of chiefs of cavalry in the field armies, and had there been a superior to these on duty in Washington he would have been of vastly more value to that branch of the service than "much cavalry with banners," even had his duties been restricted to the securing of, and shipment of, proper remounts alone.

The counterpart for the infantry of what such chiefs were to the artillery and cavalry, was found in the provost marshal general of the Army, who was charged with the recruitment thereof. These chiefs were found to be absolutely necessary as proved by the long and bloody experiences of that war, as well as by all great wars of recent times, and it appears passing strange that when we so recently expended so much effort to perfect our army organization, no provision was made for a provost marshal general, a chief of cavalry or a chief of field artillery, officers who are not only wanted but who must be had the moment that war begins, if we are to wage it efficiently, successfully and not at an extravagant cost in blood and treasure, as was the case in our Civil War. It would be a wise thing for our Army and Nation if some of the lessons like these, that we learned during that war, were applied now and our Army made ready in every respect for the next war.



TORPEDO COMPANIES AND COMPANY ELECTRICIANS

By Captain HENRY C. DAVIS, Artillery Corps

THE last five years have shown such an advance in methods and material of our coast defense that the personnel of the coast artillery has been obliged to work hard to keep abreast of the course of development. With so many active minds engaged in solving the various problems that have arisen there has been necessarily a considerable lack of co-ordination, but this difficulty has been largely overcome by the establishment on a firm basis of the Artillery School and School of Submarine Defense. These schools, by directing the individual efforts of officers in certain lines lines, have accomplished so much good that it seems very desirable so to co-ordinate their work that better results still may be obtained.

Experience as an instructor for four years in the Artillery School and as commander of a torpedo company from the time it was so designated, has offered valuable opportunities for observing in what respect improvement, it is thought, can be made in existing conditions.

1. The Department of Electricity at the Artillery School and the Department of Electricity, Mines and Mechanism at Fort Totten are largely duplicates. The capacity for instruction at the former is at present 50 and at the latter is, I believe, 10 or 12. The Artillery School curriculum pertains to the general duties of the artillery officer, while that of the School of Submarine Defense is more restricted and specialized. For these reasons it seems that the latter might well become a post-graduate school for the former, those officers showing most fitness for the electrical and mechanical work at the former being detailed for the course at the latter. Such graduates would be very valuable to artillery district commanders as artillery engineers.

When both schools are working to their utmost capacity and when the mass of uninstructed material is so great, it seems criminal not to work the two schools together and so to the best advantage.

The theoretical and electrical features of submarine mining are not difficult and are all taught at the Artillery School, so that by taking the good graduates from that school for the advanced course, the work at Fort Totten could be devoted to mines proper, i. e., planting, operating, experimenting with and firing. In this manner a much greater number of men could be put through than at present. Also there would be offered a distinction far the capable graduate of the Artillery School.

2. My experience with the torpedo company and as artillery engineer of the district leads me to believe that these two offices should be combined with that of the commander of the torpedo planter and be given to a captain of some rank, or, if the district be important, to a major. Although there is no connection between a post power plant or a searchlight and the submarine work, I think it may be shown that all of these may well be combined under one head and that the attendants should come from the same organization. There are now four torpedo planters and four torpedo companies. The lieutenants of these companies would be selected from the best of the Artillery School graduates. The graduates of this school are familiar with all the principles of electricity as well as with the handling of all machines needed in the submarine mine work. In my work with the torpedo company I had no difficulty with the instruction of the men when assisted by graduates of the Artillery School.

The desirability of having the planter and the torpedo company under one head is, I believe, evident to all who have had the experience, and I think the reports of the officers on the planters now giving instruction will bear out the truth of the assumption. I do not refer to any rivalry that may arise, but to the inherent weakness of any system of instruction having two separate and co-ordinate heads. The captain of the company is, or should be, responsible for the instruction of his company and should decide how much is to be given and when to give it, independently of the captain of the planter.

The duties of the captain of the torpedo planter would then be well defined; his headquarters would be at the post where his company is stationed; his work would be to instruct his company in the duties of planting mines, not only at the home station but in all the harbors of the district placed under his charge. He and his men will become familiar, through experience, with the peculiarities of all the waters he may be called upon to mine. This I believe to be very important.

This system lends itself to the proposition of the Torpedo Board that the torpedo company take charge of all the *central* power plants in the district. It is an excellent idea and is a step in the direction of obtaining specialized enlisted men without robbing the gun companies of their best men, a process which naturally antagonizes the gun company captains. I have used the term "central" plants advisedly, because where the plant is concerned with the supply of electrical power to but one battery it should undoubtedly be under the supervision of the battery commander and should be manned from his company exclusively. For a similar reason I do not recommend that the torpedo company have anything to do the details of the communications.

Considering the care and preservation of submarine mine material at posts other than at headquarters of the torpedo planter, it seems logical that the personnel of the detachment should also come from the torpedo company. If drawn from the gun companies there results a breaking up of the manning tables of the latter and the men so detached are required to learn two independent specialties. In my two years' experience in this work, I have had no difficulty in teaching these details to prepare, test and plant a mines in shallow water but no sooner done than they were lost to me by going back to their companies. The care of the mining material during periods of non-instruction is quite simple and may well be left to the central plant and searchlight detail of the torpedo company at the post.

The captain of the torpedo company (who is, by orders, also the artillery engineer, when practicable) would, if also commander of the planter, have the whole matter in his own hands. With the planter he can transport his details and material, can inspect his different detachments, and give instruction to his company, varied by practice in the different channels assigned to him, Being directly under the district commander, the whole system becomes unified and under one command.

Although specialized work the handling of the submarine defense is no more so than the handling of the gun defense, and any of our artillery officers who have taken the courses at the Artillery School and at Fort Totten with credit are amply equipped for either service. That some will do one better than the other is largely a matter of personal taste and characteristics and not because of greater inherent difficulty in either the one or the other. It would be poor policy to separate the two services. With the effect of having more than one corps interested in the coast defense we are all familiar.

If the torpedo company is to take the role here laid down, it will have to be organized according to the requirements of the district to which it is assigned. A lieutenant should be in immediate command of the torpedo planter while the detachments at the several posts should each be under a lieutenant or a sergeant according to its importance, the captain (or major) having command of the whole under his district commander just as groups of guns are under the several fire commanders. In case of hostilities the lieutenants, or captains at the several posts would have charge, under the post commander, of the submarine defenses of the post, the commanding officer of the torpedo company being inspector on the staff of the district commander.

ELECTRICAL DETACHMENTS

In the foregoing it has been proposed to put the care of the central power plants and the searchlights under the supervision of the torpedo company and of detachments from it at small posts, having an officer or noncommisioned officer of that company in charge at those posts. But so much of the local power plants as pertains solely to the several batteries should be in the hands of the battery commander. Experience along that line has convinced me that the idea is correct, and moreover several captains, whose opinions I respect very highly, feel as I do about this.

There is a great tendency at present towards centralization of the power plants, and although I do not believe in it, I think it is coming. These central plants will be in the hands of the artillery engineer and his assistants, but when the power is delivered at the emplacements, who is to utilize it and care for the switchboards, motors for hoists and for the guns, etc.? The telephones and telautographs and lines, who is to look after these and make minor repairs? At this post where the emplacements, eight in number and other contemplated, are scattered in a straight line along the beach, and with two electrician sergeants (the greatest number I ever had), I find it quite a problem to look after these things, and drill is sometimes delayed until some simple repairs can be made. The electrician sergeant must have many helpers, drawn from the companies, who are uncertain in qualifications and the detachment is panoramic in character. This condition of affairs is very unsatisfactory both to the artillery engineer and to the company commanders.

To remedy this condition it is proposed to turn over to the company commanders the entire care of so much of their electrical plants as is independent of all other emplacements and to provide each one with an attendant who can make minor repairs and who will have supervision over the whole. Whenever anything serious occurs the electrician sergeant will be called in and will be assisted by "company electricians" of whom there should be at least two in each company. It is believed that these men can be found and that if transfer from one company to another is allowed, there will be found enough men at every post who wish to and can learn this work. If a post does not supply them other posts may be drawn on for them. These men will form a class from which electrician sergeants may be drawn, for when they have evidenced any aptitude for the work practically, they may on their own application be sent to the school for electrician sergeants. On graduation from that school they may be held in their company until such time as there is a vacancy in the list of electrician sergeants, and even if they fail at the school they may still serve with their company as company electricians or until the company commander wishes to change for the better.

There is already in the service a precedent for this electrician, namely the grade of mechanic. This man is selected by the company commander to take charge of the armament and for making such repairs as he is competent to make, leaving more complicated ones to the ordnance machinist. The electrician corresponds to the mechanic and the electrician sergeant to the ordnance machinist. There is another similarity between the electrician and the mechanic, which, however, will not exist at first, viz., the additional pay; but if these men are appointed and do the work, so that it may be said that the necessity for the electrician exists and men are doing such work of a skilled nature, the increase of pay will come before long. It will require no law to designate these men "electricians" and to give them them the jobs, and the law giving pay will, I believe, follow.

If these electricians take the course at the school for electrician sergeants and after graduation are appointed corporals in their companies (electrician corporals, after the law passes), electrician sergeants may be taken from that class by competitive examination. I believe this will introduce a healthy competition among candidates for electrician sergeants and will give the service better men in that class because they will be drawn by competition from men who have all passed the school. At present any man who passes the school is available.

In connection, another suggestion seems pertinent. It is now required of enlisted men applying to take the course at the school for master gunners and also, I believe, at the school for electrician sergeants, that they promise to re-enlist. This promise, I fear, is honored in the breach; there is no penalty for failure to re-enlist. To retain the services of men so educated at the expense of the government, I propose that on admission to these schools they be discharged by the Secretary of War and be immediately re-enlisted for three years. This costs nothing and insures at least two years' service to the United States after graduating from these schools.

It is true that if a man wished to get out of the service he might apply to go to one of the schools and when discharged might decline to re-enlist, but such a man would well be out of the service and is cheaply gotten rid of.

The same idea might be applied to sergeants-major, commissary, quartermaster and ordnance sergeants, but neither necessity nor justice in their cases *demands* such step.

SUBTARGET GUN HOLDER

By First Lieutenant ARTHUR P. S. HYDE, Artillery Corps

THE importance of training gunners in the coast artillery service cannot be overestimated, especially at rapid fire batteries. By gunners is not meant what might be termed "gunners on paper", as shown by the result of a gunners' examination in a company, but expert practical gunners,—"men behind the sight" who are so familiar with the principles of aiming the guns to which they are assigned that they know, under all possible conditions of firing, just how to set their sights for the most favorable results.

Such results cannot be attained as the result of theoretical instruction. No matter how thoroughly a man may have been instructed in the sight, nor how thoroughly he may have learned, theoretically, that under certain circumstances he must make such a correction, while under others he must make another, if he does not have practical everyday experience under these varying conditions of service, he is not an expert practical gunner. Of course there are exceptions, but in general practical gunners can be trained only by actual firing conducted on every drill day throughout the practical season.

A number of conditions, chief of which is the attendant expense, forbids an allowance of service ammunition sufficient even to approximate to the desired result. The expense of subcaliber ammunition, though far less than that of service ammunition, is also sufficient to preclude an allowance for daily firing, while the lack of facilities for towing a target, or even of anchoring and marking a fixed one, at the majority of our coast artillery posts, prevents the subcaliber practice being held except at rare intervals, just preceding the quarterly service practice. At such times a relatively considerable amount of ammunition is fired in one or two days, the results, as far as the training of gunners is concerned, being practically nil.

The last artillery instruction order, General Orders No. 93, War Department, series 1905, prescribes that for the gunners' examination of companies assigned exclusively to rapid fire batteries, subcaliber firing with a 6-pounder gun shall replace the examination on the plotting board. The idea of making a practical demonstration of a man's ability to hit a target a requisite to his qualification as a gunner, is an excellent one, but the method prescribed has been found by practical experience to be radically wrong.

In the first place, the conditions under which the firing is conducted, are by no means those of artillery service. The firing is held on the small arms target range, at the mid range target "B," the system of marking being that used in small arms firing. A candidate is thus unable to correct his shooting by observing the splash, as would be the case in service firing, and in addition he is too far from the target to observe the result of his own shooting, by means of the telescopic sight. The target is a stationary one, while under service conditions, it would invariably be moving.

The subcaliber tube furnished for the 6-pounder gun is only the length of the fixed ammunition used in the gun, being considerably shorter than the rifle barrel for which the ammunition used is designed, and therefore not having the same ballistic value. Finally a special form of cartridge having a stronger base than the service caliber .30 cartridge is required, and no allowance of ammunition is provided, except for the examination itself, with the result that a company is absolutely without preparation for a portion of the examination which counts thirty-five per cent on the qualification of first-class gunners.

There is also a fact that has been noticeable at this post, the reason for which is not known. At the same range, using the same ammunition, and the same subcaliber tube, the elevation has varied as much as eight minutes on different days. To be more explicit, the first day's firing determined the elevation for five hundred yards to be twenty-three minutes. On successive days, this elevation was found to decrease until it reached fifteen minutes.

It was also found in firing by a member of the Board with a view to obtaining three hits on the target with the same elevation and deflection, in order to locate the center of impact, that from thirty to forty shots had to be fired before the desired result was obtained. This because it was absolutely impossible to tell where the shots were going, and corrections on the sight were mere guess-work. How, then, could a candidate be expected to find the target in the three sighting shots, which is all that is allowed him, in firing at an unknown range?

After all is said in favor of the use of the 6-pounder gun, granting that the defects to which attention has been invited above are remedied, it must be admitted that the candidate is not firing under the conditions of service at his own piece. If he is to become sufficiently proficient in firing the 6-pounder gun with the subcaliber tube, he must have a great deal of practice under the conditions, far from service, of the test. The company must, in addition to its regular work at the battery to which it is assigned, devote a large part of its time to firing this gun on the small arms range,—time and labor that are in a large measure wasted as far as practical benefits to the individual men are concerned, with reference to their proper work at their own battery.

If, on the other hand, the man is to become expert in handling the material of his own battery, he must have ample opportunity for perfecting himself in firing his own gun. Without doubt this latter consideration is the one to be desired.

The question how to obtain it is therefore pertinent. We have already seen that it cannot be obtained by means of daily subcaliber firing with the 1-pounder subcaliber tube. Hence, the gunners' examination with it, though more practical than with the 6-pounder gun, is not a fair test for the company. Nor is the allowance of ammunition, nine hundred rounds per company, sufficient to train properly the first-class candidates, even if the entire amount were authorized to be fired at a fixed target in preparation for the examination.

It is believed that a subtarget representing a silhouette of a battleship drawn to a reduced scale proportionate to a reduced range, placed at fifty yards in front of the battery, and provided with a suitable means for towing, so that the correct speed, also proportioned to the reduced range, could be given it, and to be fired at with a caliber .30 rifle attached to the gun, would be a correct solution of the problem, both of training expert gunners, and of affording a suitable test for the rating of first-class gunners.

With a view to carrying out such a system, a device has been designed for the purpose of attaching a rifle to the trunnion sight bracket of the gun.

The device is illustrated in the accompanying drawings. It consists primarily of a carriage, a cradle and a sleeve. The carriage consists of a rectangular casting, provided with two trunnions, a, to fit in the V's of the trunnion sight bracket, and a lug, b, against which the levelling screw of the sight bracket bears, for the purpose of levelling the carriage. On the rear side of the carriage is a cross level, e, answering the same purpose as the cross level of the telescopic sight. The cradle is made fast to the carriage by means of the milled-headed screw, d, passing through the hole in the carriage, e, and is capable of rotation about this screw as an axis, and of being clamped in any position by it. The cradle may be given slight motion about the vertical axis, by the tangent screws, f, passing through the vertical lugs, g.

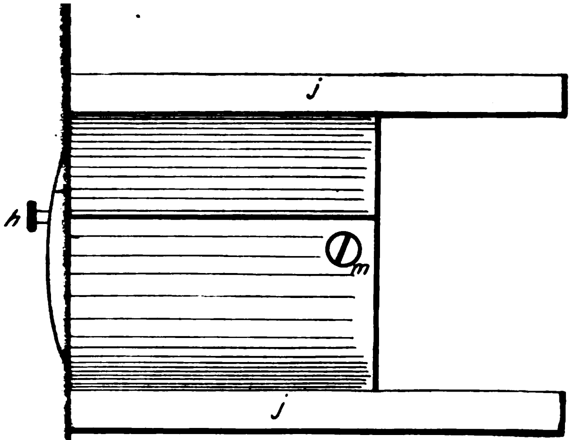
The cradle consists of two castings provided with overlapping lips, and held together by four milled-headed screws, h. A groove, i, is provided both at top and bottom of the inside of the cradle, in which the feathers, j, of the sleeve slide. A ring, k, is provided on the rear face of the cradle, near the bottom, into which the recoil spring is hooked. There are also projecting lugs, l, against which the tangent screws, f, bear.

The sleeve is also made in two castings, fastened together by means of the four countersunk screws, m. It is for the purpose of holding the rifle, and slides in the cradle. The feathers have been extended to the front, so that when the rifle is in the recoiled position, there will be no rotation about a horizontal axis.

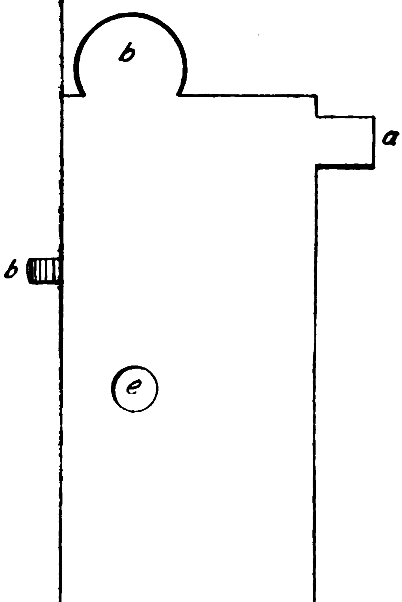
To assemble the device, the hand guard is removed from the rifle, and the rifle placed in the sleeve at the balance. The two parts of the sleeve are then screwed together by the countersunk screws, m. The sleeve containing the rifle is then placed in the cradle, the two parts of the latter being fastened together by the thumb screws, h. The cradle is then attached to the carriage by means of the thumb screw, d, and the recoil spring, n, is attached to the ring, k, and to the ring, o, attached to the front of the trigger guard of the rifle. The carriage is then placed on the trunnion sight bracket of the gun, and levelled by means of the cross level.

In utilizing a rifle for this device, no change is necessary, other than removing the hand guard, except to bore a hole through the trigger guard for the purpose of obtaining a holdfast for the recoil spring.

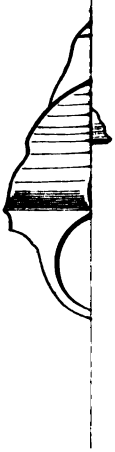
The adjustment of the device is as follows: Select a well defined point on the subtarget, and direct the gun so that the vertical cross-hair of the sight, with deflection zero, is upon it.



Side Elevation.



Plan.



Remove the bolt of the rifle, and by sighting through the barrel, move the rifle and cradle about its vertical axis until it is pointing almost on the same point of the target. Clamp the thumb screw, d, and get the rifle accurately on on the point by means of the tangent screws, f. Put in the bolt and the piece is ready for firing.

The computed maximum energy of free recoil of the service caliber .30 rifle is 10.025 foot-pounds. The recoil spring must therefore be sufficient to overcome this recoil, and return the the rifle to the firing position in the cradle.

The subtarget consists of a silhouette of a battleship of the "Rhode Island" class, as this represents the dimensions of the hypothetical target for service practice. Of course any target may be used, and it would probably result in considerable benefit to the training of the gunners, to have several different types of vessels represented, thereby being able to use different ones on different occasions.

Assuming a battleship of the dimensions of the "Rhode Island" at four thousand yards' range, and reducing this proportionally to a range of fifty yards, would make the silhouette five feet, five and a quarter inches long.

The silhouette should be made by first making a tracing, and then obtaining copies by the blue print process, the ship showing white against a blue background, which gives a fairly close approximation to service conditions as regards color, as well as being the simplest method of replacing silhouettes as they become used up.

The silhouette is pasted to a cloth-covered target frame, large enough to hold it, and the frame is suspended from a wire by means of two grooved wheels. The wire should be stretched from projecting arms of poles, at such a height that it will be on a level with the guns of the battery when in the in-battery position.

A light rope is attached to the front end of the target frame, passing over the necessary blocks to the battery or other suitable station, and from there to the rear end of the target, where it is again again attached, affording a safe means of towing the subtarget. The proportionate speed of a battleship at four thousand yards, for the reduced range of fifty yards, can readily be computed, at which speed the silhouette can be towed, affording a very close approximation to service conditions.

With a system such as this, firing can be had on every drill day of the practical season, and it is thought that the benefits derived by the personnel, will more than compensate for the small amount expended on caliber .30 ammunition.

As to the advantages of this system over the present subcaliber system, the following may be stated:

1. The expense of the subtarget gun holder is far less than that of the subcaliber tube.

2. The expense of caliber .30 ammunition is so much less than that of the 1-pounder subcaliber tube, that for the same expenditure, a very much larger and more adequate allowance could be made.

3. The cost of targets would be practically eliminated, as the frames and silhouettes can be made at any post.

4. The cost of tug hire for towing a material target for subcaliber practice would be entirely eliminated at posts which are not provided with a quartermaster steamer.

5. The training of the personnel would be vastly improved, for the reason that the practice can be had daily, instead of once, twice or three times a year, as is now the case.

6. For gunners' examination, the candidates would be examined in the method of firing in which they would have had daily practice, and it would therefore be a fair test of their ability.

7. The target can be made to simulate a greater speed than any tug or quartermaster steamer is capable of, and would therefore not only give better training to the gunners, but would more nearly approximate to service conditions.

8. Training would be given the gunners daily in correct setting for deflection, and a means provided for determining how accurate their work may be.

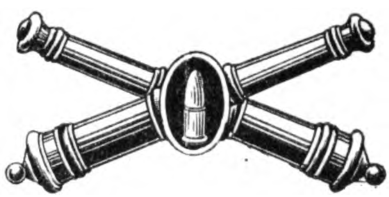
9. The target is sufficiently close for each gunner to be able to tell by means of the telescopic sight whether he is hitting the target, and thus obviate the one disadvantage of not being able to see a splash, as is the case with subcaliber and service firing.

Another disadvantage might be urged by some, to the effect that the elevation of the gun must necessarily be practically constant. This is true in general, but as almost all firing of guns is by Case II., and certainly the most accurate firing, the gunner has nothing to do with elevation. While as regards deflection, which every gunner must be able to set and correct for with accuracy, it is maintained that the subtarget system is superior to the subcaliber system.

Should practice in Case I. be desired, there is nothing to prevent the raising or lowering of the position of the subtarget, making necessary a slight change in elevation.

Should objection be raised to the substitution of this system for the subcaliber system at present in use, it is urged that great benefit can be derived in the practical training of gunners, by its use as supplement to the latter.

As stated above, the training of expert gunners is of the highest importance, especially in rapid fire batteries, and after a careful study of the question in all its phases, after a year's command of a 6-inch disappearing battery, the writer believes that the system outlined above at least has the merit of being practicable.



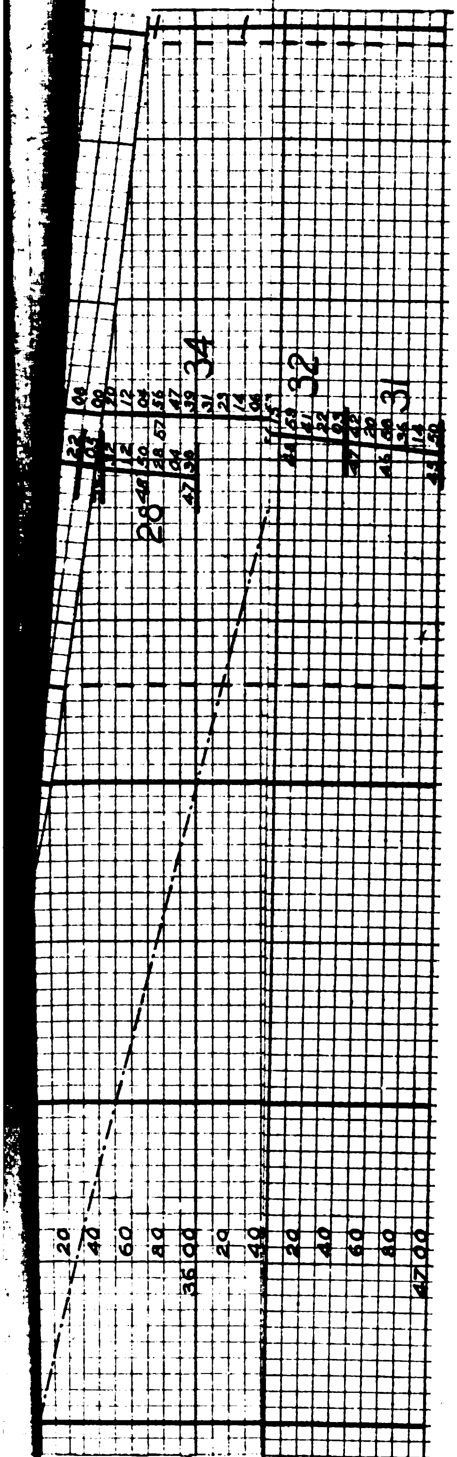
RANGE AND AZIMUTH BOARDS FOR MORTARS

By Captain S. C. VESTAL, Artillery Corps

IN the March-April number of the JOURNAL U. S. ARTILLERY for 1904, Captain Henry J. Hatch, Artillery Corps, described a time-range-board for direct fire guns. Herewith is given a description of adaptations of this board to give ranges (elevations) and azimuths for mortars. Reference is made to Captain Hatch's article for principles and for details of construction. These boards are intended for use with a D.P. Finder, with the Whistler-Hearn plotting board, or with any other device giving ranges and azimuths to a target.

Range board.—(See Fig. 1.) Time scale (abscissas), 4 inches = 1 minute. Range scale (ordinates), 1 inch = 100 yards. The distance from line A to line B represents the time interval, that is the time between the strokes of the bell. In the figure it is taken at 30 seconds or 2 inches. The distance from line B to line C represents the predicting interval. It is likewise taken at 30 seconds. As the predicting interval covers only the time required to predict, which with this board is almost inappreciable, to transmit the information to the mortars, and to lay them, this interval may be reduced with good appliances, but must be greatly increased for the old equipment. Time of flight curves are measured from line C and the elevation corresponding to the ranges is written in small figures on both sides of these curves. The medium sized figures give the time of flight, the limits of each second being indicated by the short straight lines cutting the curves. The time of flight is read from this board after the elevation is read off, for use at the azimuth board. The large block numbers indicate the zones. The time of flight curves are drawn upon a long slide, 4 inches wide, indicated by broken lines. This slide moves in a wide groove and is for the purpose of making difference chart corrections, and corrections for range errors. A difference chart scale with 1000 taken for the zero is written at the head of the slide. The pointer, which in the figure and in cross-section looks like an old style cuff button, moves in a small undercut

FIG. I.



groove in the board, indicated by one light and one heavy line, and is secured for any permanent correction by a thumb screw. A correction scale for plus and minus corrections from 0 to 400 yards is written on the board. For making hurried corrections this scale, by trial, is found to be preferable to any taken with an arbitrary number for zero. On this scale the correction obtained by trial shots is laid off. A separate slide must be used for subcaliber firing.

A knob, not shown in the figure, is secured at the head of the long slide to move it. The time of flight curves, as well as the three sets of figures connected with them, are drawn alternately in red and blue. Pin holes are punched for every ten yards upon lines A and B. A transparent ruler about 18 inches long is used with this board.

To give ranges for guns, draw in to the right of line B, measuring from line B, time of flight lines for the different calibers adding to the time of flight for each gun, the time required to transmit the information and to lay the gun. A range scale in yards should be written on the long slide to the left of the mortar lines. For a range board for direct fire guns only, the long slide should be narrow and placed close to the time of flight lines.

Use of range board.—Two men, Numbers 1 and 2, are required for the service of this board. No. 1 pins off on lines A and B the ranges read from the range finder or from the plotting board at the beginning and at the end of each time interval. He places the ruler against these pins and reads off at its intersection with the time of flight curve, the elevation, then the time of flight, and afterwards from the intersection of the ruler with line C, the range of the predicted point from the B.C. station, using for this last reading the range scale written between lines A and B. He then marks with a short line the intersection of the ruler with line D. These intersections are to secure uniformity and to enable the range officer to foretell the number of the zone in ample time to announce it for use at the pit.

No. 1 should be instructed so to place his ruler at each reading as to make the intervals between the intersections on line D very nearly uniform. Errors in the range finder, and errors due to the fact that ten yard readings only, are used on lines A and B, are shown by alternate long and short intervals on line D. By making these intersections very nearly uniform such errors are eliminated. The tendency of plotters, whatever may be the form of board used, is to assign the variations in predictions due to instrumental errors, to a change of speed of the target. Battleships and commercial vessels do not quickly change speed. A change of speed is indicated by a gradual increase or decrease in the intervals on line D. After No. 1 has marked the intersection on line D, he places the pin on line A opposite to the pin on line B, and stands ready to place the pin on line B as soon as the range is again read off.

In Fig. 1, the mixed line indicates a position of the ruler. The ranges for two readings are 3500 and 3550 yards; elevation 56°49′; time of flight 34 seconds; range of target from B.C. station 3600 yards. Several intersections are drawn on line D from which it is apparent that the range officer can select the zone in advance.

No. 2 at the head of the range board, keeps the slide set for difference chart corrections read off by No. 5 at the difference chart. In Fig. 1 the slides are set at zero.

Azimuth board.—(See Fig. 2). Time scale (abscissas), 4 inches = 1 minute. Range scale (ordinates), 1 inch = 1 degree. The lines A, B, and C are drawn in the same way that lines A, B, and C are drawn in Fig. 1. An azimuth scale is written between lines A and B. A second azimuth scale is written on a long narrow slide indicated by broken lines. This slide moves in a groove in the board and is for the purpose of making drift and difference chart corrections and corrections for azimuth errors. A difference chart scale with 10 degrees taken for the zero is written on the board near the head of the slide. A small slide with a drift scale written in terms of degrees of elevation from 45 to 60 is placed on the slide near its head. This slide moves in a narrow undercut groove in the long slide indicated by a light and heavy line. A correction scale for plus and minus corrections from 0 to 5 degrees is written on the long slide. The small slide may be moved along the scale and clamped to make corrections for errors obtained by trial shots or otherwise. Time lines for every three seconds from 27 to 60 seconds are drawn to the right of the long slide. A knob, not shown in the figure, is secured to the head of the long slide to move it. A transparent ruler about 18 inches long is used with this board.

Use of azimuth board.—Two men, Nos. 3 and 4, are required for the service of this board. No. 3 pins off on lines A and B the azimuths read from the range finder or from the plotting board at the beginning and at the end of each time interval. He places the ruler against these pins and as soon as he hears No. 1 read off the time of flight from the range board, he places the end of a pointer (not a lead pencil) against the edge of a ruler and at the proper time of flight reading and reads the azimuth from the azimuth scale on the long slide opposite the place indicated by his pointer. He then reads from the intersection of the ruler with line C, the azimuth of the predicted point from B.C. station, using for this last reading the azimuth scale written between lines A and B. He then moves his pins in the manner prescribed for No. 1.

In Fig. 2 the mixed line indicates a position of the ruler. The azimuths for two readings are 155.80 degrees and 155.20 degrees; the azimuth to be read to the mortars 151.90 degrees (opposite cross, time of flight being taken at 34 seconds); and the azimuth of the predicted point from the B.C. station 154.60 degrees (read from line C). Intersections are shown on line D. Line D on this board is not of so much importance as on the range board, for azimuth readings are usually very correct. Moreover vessels change rate in azimuth more suddenly than in range.

No. 4 at the head of the board keeps the slide set for all corrections. When he hears difference chart corrections read off by No. 5, he places the end of a soft wood pointer on the difference chart scale at the given reading and as soon as the elevation is read off by No. 1 from the range board, moves the long slide so that the given degree marked on the short slide is opposite the end of his wooden pointer. The slide is now set to correct for difference chart reading and for drift.

The short slide as shown in Fig. 2 is set for a permanent correction of −1 degree; the long slide is set for a difference chart reading of 12 degrees (or +2 degrees) and for the drift correction corresponding to an elevation of 49 degrees and 40 minutes. The algebraic sum of these corrections is −2 degrees. By comparing the two azimuth scales it will be observed that the scale on slide reads 2 degrees less than the other scale.

Use of difference charts with these boards.—One man No. 5, at the difference chart, listens for the range of the predicted point read off by No. 1, and the azimuth of the predicted point read off by No. 3. With these readings he uses the difference chart and calls out the range correction to No. 2, and the azimuth correction to No 4. For a battery with a D.P.F. near it, difference charts for the different pits, using the D.P.F. as the directing point, may be advantageously used. Much time is lost by relocating on a plotting board, and chances of making errors are introduced. Difference chart corrections for any prediction are based upon the range and azimuth of the predicted point of the next preceding prediction.

No. 6 copies the range and azimuth of the predicted point, called out by Nos. 1 and 3, respectively, takes them to the firing instrument and fires when the target crosses the predicted azimuth, provided the range error is well within the error of the mortar for the given range.

As it takes longer to lay a mortar in elevation, than in azimuth, the elevation is called first by No. 1. No. 4 uses this elevation to correct for drift. After reading the elevation, No. 1 calls out the time of flight for the use of No. 3. Hence the long slide is set for drift before No. 3 can possibly be ready to read the azimuth. Although I have never had an opportunity to try it, I believe Nos. 1 and 3 might be equipped with breast transmitters to great advantage.

The following objections may be urged against these boards.

1. An erroneous assumption is made, in that, theoretically, the boards will not give correct predictions except when the target is moving on a circle with the center at the battery or directly toward the battery or away from it. This objection is well taken. In no case, however, will the error be as great as the difference between the possible error introduced by having the least reading 25 yards, as is the case with the old plotting boards, and a least reading of 10 yards, the least reading of these boards. The objection disappears altogether when the great gain in accuracy arising from decreasing the predicting interval is considered.

2. Objection may be made to the size of the boards. They could, of course, be made much smaller, if it were not desirable to have a large scale. For many batteries with small arcs of fire, the azimuth boards could very well be made on a scale of 2 inches to the degree.

The following special advantages may be claimed for these boards.

1. Gain in time over all other predicting devices so far advocated. The elevation can be called out by No. 1 immediately after the range and azimuth is read from the range finder, and No. 3 can call out the azimuth before the telephone man at the pit is ready to receive it. Little time, therefore, is lost in relaying in case of error.

2. Accuracy due to large scale and short predicting interval.

3. The range officer can observe the course of the target as marked on line D by standing to the right of the range board without interfering with the detail. He can announce the zone as much as 2 minutes before predicting for a particular shot, if so desired. Hence he can, and should, wait until the mortars are loaded and pointed above the parapet before predicting. There is therefore no absolute necessity for breakneck speed in loading, for the length of the predicting interval does not depend upon speed in the manual of loading. Liability to accident, the one great element of danger in serving mortars, is thereby greatly decreased.

4. Four pits can be easily served simultaneously with information from one range finder, and readings could, in addition, be furnished to other batteries or range finder stations within a distance for which difference charts may be constructed with accuracy, by applying on the slide difference chart corrections.

5. Ease of operation. Each number has one single task to perform, does not have to think, and has plenty of time to do his part.

6. Almost total absence of what may be called auxiliary numbers, one only being used—the time of flight.

7. Removal of difference charts and correction devices from the pits where they are an abomination.

To secure a strong board which will not bend or warp, take two pine boards one inch thick, ten inches wide, and of proper length. Cut weakening grooves the full length of the boards. Screw the boards together so that the grooved side of one is next the smooth side of the other and so that the grooves of one board come opposite the center of the lands of the other. Cover the bottom of the lower board with a layer of boards placed diagonally across the upper boards and securely screwed to them. Mounted cross-section paper should be used in making this board.

The long slide for the range board should also be weakened by longitudinal grooves on the lower side. Four or five pieces of oak about four inches wide should be doweled at regular intervals into the grooved side to prevent it from warping.

To the best of my knowledge a long slide was first applied by Lieutenant A. L. Rhodes, Artillery Corps, to the range board for guns described by Captain Hatch.

Whatever may be the merits and defects of this form of board, I believe it is now conceded that predicting for mortars and guns must be done by devices separate from the plotting board. The plotting board should be considered as a part of a range finder and relocator. Predictions must be made as often as the instrument is read and no measurable interval should elapse from the time the instrument is read until the information is on its way to the guns or mortars. Difference charts must be abolished or taken to the plotting room and the predicting system must be capable of serving several pits and batteries simultaneously from one instrument.

ON THE IMPERFECTIONS OF THE BALLISTIC COEFFICIENT AS AT PRESENT DETERMINED

BY CAPTAIN ALSTON HAMILTON, ARTILLERY CORPS

THE object of a range table, whether for gun or mortar, is to furnish information as to what may be expected with a given set of conditions, assumed as standard.

Variations from these conditions are allowed for in most range tables. Such variations when measurable before a shot is fired should be compensated for by proper correction devices.

It is obvious, however, that the normal relations of atmospheric strata and composition, and of winds at the surface and at considerable altitudes, are frequently upset to some extent; and the powder may have deteriorated. Hence the necessity for a trial shot.

This trial shot should give the final correction, which may be called the *factor of the day;* and if the preliminary corrections have been carefully made this final correction may be made in the ballistic coefficient, or in the velocity, according as we have reason to believe that the one or the other is more likely to be abnormal.

To be able to blame the muzzle velocity we must be sure that our ballistic coefficient is nearly right; that is, as correct as we can make it. Then unless we have reason to think that atmospheric conditions are upset, we may with reasonable fairness blame the powder. *Otherwise not.*

The methods at present in vogue are not accurate and the practice obtains of determining the altitude factor and the atmospheric factor by comparatively crude methods, and absorbing portions of these factors in an adjusting factor, c, called the "coefficient of form",—how unjustly will presently appear. For c involves many cast-off functions besides that of mere form.

The purpose of this article is to show how to determine the various factors of the ballistic coefficient in such a manner as to render them *independent of each other and to determine each of them as a function of those elements* WITH WHICH IT VARIES.

This having been done, we may, by a process of exclusion, determine values of c from experiment and expect with reason to find them sensibly constant, for flat trajectories, for a given projectile; and for curved trajectories a function of the projectile, the angle of departure and the range. For direct fire, where the head is presented to air resistance the length of the projectile has little effect; and c obeys the law

$$c = \frac{2}{n}\sqrt{\frac{4n-1}{7}}$$

where n is the radius of the ogive in calibers. The projectile's head should be ogival and have no peculiarities, save that a cap does not affect c, if not too large.

In order, then, to find c or βc by experiment, we must carefully and correctly determine $\frac{\delta_1}{\delta}$, and f, and for direct fire obtain an accurate value of β also.

The factors entering the ballistic coefficient will be treated in the order of the importance of revising present methods of determining them; that is to say, in the order of the magnitude of the errors thereby introduced into the ballistic coefficient.

I. THE ALTITUDE FACTOR.

The barometric formula is

$$h = 60520\left\{1 + .002034\left(\frac{t+t'}{2}\right) - 32\right\}\log f.$$

in which t′ is the temperature at the height h.

The generally accepted rate of decrease of temperature with altitude is 1° per 300 feet rise. (See Smithsonian Meteorological Tables; Tillman on Heat; and the article of General Richard Strachey, K.C.B., on the Himalayas).

Therefore

$$t' = t - \frac{h}{300}$$

and the formula becomes

$$h = 60520\left\{1 + .002034\left(t - \frac{h}{600} - 32\right)\right\}\log f$$

$$= 56581\left\{1 + .0021756\left(t - \frac{h}{600}\right)\right\}\log f.$$

But this supposes no humidity. On being corrected for humidity the formula becomes

$$h = 62737 \log f \left\{ 1 + .002078 \left(t - \frac{h}{600} - 47.7 \right) \right\}$$

whence

$$\log f = \frac{h}{56518.5 \left\{ 1 + .0023066 \left(t - \frac{h}{600} \right) \right\}}$$

This is essentially the formula used by surveyors in barometric hypsometry except that *they measure the temperature* at the upper point, *we estimate it; they* have the *barometer* reading at the upper point, and desire to find the *height; we* have the *height* and desire the value of *f*, that is, the ratio of the readings.

Table II. is a table of values of log f for arguments h and t, in which h is the mean height* of the trajectory and t is the *temperature at the gun at the time of firing.* Hence, given barometer and thermometer readings, (as is always the case), we can take from Table II. the altitude factor *provided* we know the mean height h.

To find the mean height we need only consider the mean of the heights at which the projectile *was* while traveling in its *path,* since we are concerned with the effect of a *resistance* acting over a *path.*

The mean value taken over the path is

$$h = y_0 \left\{ 1 - \tfrac{1}{4} \left(\frac{\tan \varphi_m + \sec \varphi_m}{(\varphi_m) \cos \varphi_m} - \cot^2 \varphi_m \right) \right\}$$

in which $\varphi_m = \frac{\varphi + \omega}{2}$ and (φ_m) is Euler's function of φ_m.

The values of $\log F = \log\left(\frac{h}{y_0}\right)$ are given in Table I. for all values of φ_m from 0° to 90°.

In direct fire φ_m may be taken equal to φ without sensible error. Elsewhere not.

* The *argument* h is the mean height of the trajectory. It is not the h substituted in the barometric formula, however. The writer has ascertained that the mean ratio for a mean height h of the true value of the altitude factor to the value of the altitude factor computed with the mean height is

$$\frac{f_m}{f_h} = \frac{\lambda}{2h} \cdot \sinh \left(\frac{h}{\lambda}\right) - \sqrt{\frac{\lambda}{6h}} \cdot \varepsilon^{h/2\lambda} \cdot \int_{\sqrt{\frac{3h}{2\lambda}}}^{0} \varepsilon^{-z^2} \, dz$$

which varies with the temperature. This has been evaluated and the ratio applied as a factor to f as computed for the mean height.

Hence, to find the altitude factor, find log F, using φ_m as argument.

Then

$$\log h = \log F + \log y_0.$$

From this find h; and with h and t as arguments enter Table II. and take out log f. This applies to a *complete horizontal trajectory only.*

It is worthy of note that f varies not only on account of the variation of the temperature with the altitude which is a function of the height alone, but also with the temperature at the gun at the time of firing. This last is the sole reason for giving log f for different surface temperatures.

Colonel Ingalls' formula for the altitude factor is the best at present in use. To him belongs the credit of its introduction to us, and its development to its present state; in short he is originally responsible for the present state of efficiency of ballistic calculations in this country.

Let it be understood, then, that, in suggesting changes, the writer is not actuated by a desire to pull down, but rather further to develop the fabric which has been constructed. Accordingly, so far as is practicable the nomenclature of Colonel Ingalls has been adhered to.

The formula $$f = e^{h/\lambda}$$

as used by Colonel Ingalls, assumes a mean height of homogeneous atmosphere; that at 60° mean temperature. He assumes the mean temperature to be the surface temperature. He assumes $\frac{2}{3} y_0$ as the mean height.

It is in respect to these mean values and to the assumption that a mean value is sufficiently accurate, that his very simple and practical formula is deficient. As a matter of fact, the use of these mean values instead of the actual values for the conditions, leads to considerable error; amounting in mortar fire to as much as 10% of the height due to surface temperature alone.

Professor Alger in his text-book on Ballistics, recently published, gives a formula and a table for f.

The origin of his formula I do not know. The results, as tabulated, would for considerable values of h lead to error of immense proportions. For direct fire it is fairly satisfactory but does not consider a change in the surface temperature.*

* For h = 10000 feet Alger's table gives f = 1.312, as against the value 1.4721 for 60° in Table II. Values for 10000 from Table II. for 0° and

It will be observed that Table II. gives log f for heights varying by hundreds from —1000 feet to +11000 feet. This enables us to find C_∞ or C corrected for f, for an inclined trajectory

(*a*) where the "accurate" method is used.

(*b*) where the rigidity of the trajectory is assumed.

(*a*) Given x, y, and other data sufficient to fix the trajectory, to find C_∞ from y_0 as found from the use of the equation

$$\sin(2\varphi - \epsilon) = \sin\epsilon\,(1 + aC\cot\epsilon).$$

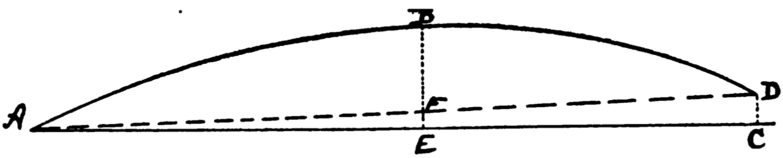


Fig. 1

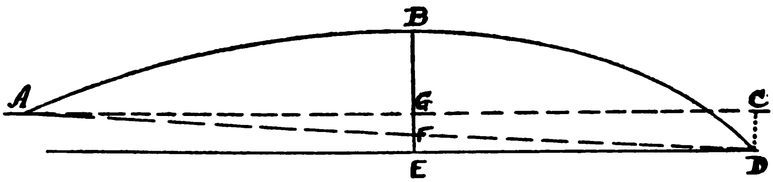


Fig. 2

If the maximum ordinate, decreased *algebraically* by $\frac{1}{2}$y, be used as y_0 in computing an *h* giving *log f* showing the ratios of the densities at F and B; and, if then, a height h = $\frac{1}{2}$ y, having regard for its sign be used and *log f* be taken out, the first f gives the ratio of the mean density of the trajectory to the density at the mean height of the extremities A and B of the trajectory. If the ratio of the latter density to that at A be taken, using h = $\frac{1}{2}$ y as an argument, the product of these two f's will give the correct f.

Hence with $y_0 - \frac{1}{2}y$ in place of y_0 and the value of log F taken from Table I., with φ as argument, compute h_1 by the formula

$$\log h_1 = \log F + \log (y_0 - \tfrac{1}{2} y)$$

from this find from Table II. log f_1, using proper t.

100° surface temperature are 1.5581 and 1.4272, respectively. A difference of 0.15 is thus visible on account of *surface* temperature *alone*. The value in Alger's table besides being too low is the *same for all surface temperatures*, which should not be the case. This accentuates the importance of the *surface* temperature; and it should be borne in mind that *not only does* $\frac{\delta_\prime}{\delta}$ *vary with the temperature*, but that its *rate of change with the height* is greatly dependent on the *surface temperature.*

Then with

$$h_2 = \tfrac{1}{2}\,y, \text{ find } \log f_2.$$

Then

$$\log f = \log f_1 + \log f_2.$$

Caution: if y is negative, h_2 must be sought between 0 and -1000; and $y_0 - \frac{1}{2}y$ exceeds y_0.

(*b*) Using the principle of the rigidity of the trajectory.

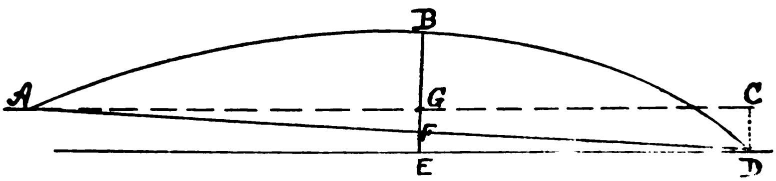


Fig. 3

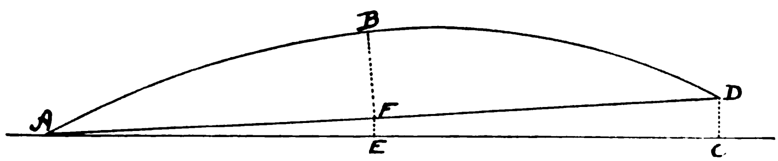


Fig. 4

Here $h_1 = FB.F = F.y_0'$

$h_2 = EF \quad = \frac{1}{2}y$ as before.

Then, find $\log f_1$ and $\log f_2$ from these, and we have

$$\log f = \log f_1 + \log f_2.$$

F is to be found with $\varphi = \varphi' + \epsilon$, as argument.

The same caution as to h_2 is due here also; that is, if y is negative, seek h_2 between 0 and -1000.

This method of finding f will involve correcting the ballistic coefficient *already found* with w, $\frac{\delta'}{\delta}$, β, and c, d, and f, *which latter f should be that at a standard temperature* used in the range tables, on account of the changing value of f. This correction will need to be made in the primary station of the battery. It can be done by a board giving the change in $\frac{\delta'}{\delta}$, with proper sign, in terms of the range and temperature. A table will answer as well. Thus, finally, at the guns, we throw the ratio $\frac{f}{f_s}$ into the ballistic coefficient, where it should go.

Of course, with mortars, this could be thrown into φ; that is, a table or board could give $\Delta\varphi$ for each range, with proper sign, with range and temperature as arguments, this φ being derived from the corrected C, and the given X. Provision could be made for f on the range-correction board.

The values of the coefficient of reduction for the 12-inch mortar having been freed of f without considering the variation of f with the temperature, still contain some part of f. This may be eliminated by reverting to the data of the actual experiments. Of course Fy_0 should also be introduced instead of $\frac{2}{3}$ y_0; and $\frac{\delta_1}{\delta}$ taken from tables based on standard conditions.

Then we would have at the head of each page of Table IV. Ingalls' Ballistic Tables, (since $\log y_0 = \kappa + \log X$ and $\log h = \log F + \log y_0$)

$$\log h = \log F + \kappa + \log X, \text{ in which}$$
$$\kappa = \log \zeta_0 - \log \xi$$

II. THE ATMOSPHERIC SURFACE-DENSITY FACTOR $\frac{\delta_1}{\delta}$.

The standard conditions on which the ballistic formulas are based are: thermometer, 15° C; barometer, 750^{mm}; and relative humidity, 50%.

Ingalls' $\frac{\delta_1}{\delta}$ table assumes $66\frac{2}{3}\%$ as the relative humidity, 30 inch barometer and 60° F. as the standard conditions. The difference in the densities is $1\frac{3}{10}\%$, which is appreciable.

The assumption of any average relative humidity is a source of error. We have a psychrometer in every meteorological station.

If it were a difficult or intricate process at the meteorological station to find the correct value of $\frac{\delta_1}{\delta}$, there might be some reason for using a mean value; but it can be simply done as will be shown.

If we assume the density of the atmosphere for 50% relative humidity; thermometer 15°C. (59° F.); and 750^{mm} (29″.53) barometer, as the unit density, and find that of the atmosphere under different conditions of temperature, pressure, and relative humidity, we may gauge the density of the medium as compared with this standard density by the value of the ratio of this density to the standard density; or, since the ballistic coefficient varies inversely as the density of the medium traversed, we tabulate the ratio of the standard to the actual density, as an inverse measure of the density of the medium and therefore a direct measure of the influence of the atmospheric conditions in favor of the ballistic coefficient.

In a table of values of $\frac{\delta_{\prime}}{\delta}$ for a standard relative humidity, the arguments are the barometer and thermometer readings. Now, the thermometer reading together with the depression of the psychrometer gives the relative humidity. Hence we may compute a table of values of $\frac{\delta_{\prime}}{\delta}$ for each psychrometer depression from 0° to 20°, at suitable intervals (preferably at intervals of 1°); or, for use in meteorological stations, a set of $\frac{\delta_{\prime}}{\delta}$ graphic charts, thus avoiding interpolation for barometer readings.

The method of use would be this:

Read the psychrometer.

With the depression select the proper chart.

With the temperature and barometer take $\frac{\delta_{\prime}}{\delta}$ from the chart, and send to the primaries.

In Table III., the values of $t - t'$ are 0°, 5°, 10°, 15°, 20°, and cover, in each case about the range of temperatures over which the given depression would occur.

The tables for values of $t - t'$ from 0° to 20° at intervals of 1° are in course of preparation and it is expected that they will appear in the next number of the JOURNAL.

Up to $t = 40°$ the psychrometer readings make little difference. From 40° up, the difference becomes more marked. For example, for $t - t' = 1°$ and $t = 100°$ we have a variation due to humidity alone of 3% in the value of $\frac{\delta_{\prime}}{\delta}$. This is, of course, not to be allowed, and the mean value fails to express even approximately the possible humidity; hence the necessity for separate $\frac{\delta_{\prime}}{\delta}$ tables for different psychrometer readings.

The advantages resulting from the use of the psychrometer depression are obvious, as the relative humidity does not need to be actually found.

It is to be noted that a table for a given value of $t - t'$ does not correspond to any particular relative humidity, as the latter varies with the temperature for a given depression.

III. THE VALUE OF β.

This, as at present available, is given as a function of φ and X; φ being in degrees and X in *metres*. The table gives values of β to *two* decimal places.

In order that the carrying of f and $\frac{\delta'}{\delta}$ to thousandths may not be made nugatory, it is essential that β be carried to three places of decimals and that *X be in yards or feet.*

The suface-ordinates of β, regarded as a function of the two independent variables, φ and X, do not follow a linear or a parabolic law, even between thousands. Nor do the partial derivatives of β with respect to X; but those with respect to φ, for a fixed X, sensibly follow the parabolic law.

While, therefore, the values of β may be found by interpolation from the values at intervals of 1000 yards' range, as given in Table IV., much better than from the present table, the accuracy is not comparable to that of values gotten from a correct table with 100-yard intervals. Such a table it is proposed to insert in the next number of the JOURNAL. In fact 100 yards is the greatest interval at which interpolation to the third place of decimals is safe.

For flat trajectories, where the wabbling or conical motion of the projectile does not obtain, the length of the projectile plays no part in its coefficient of form.

Let the *artificial* or *virtual* shape of the projectile as presented to the atmosphere which it encounters while executing this wabbling motion, be called its *flight-form.*

It is plain that the details of form of its head are now of comparatively slight importance, entering only as one of the variables; and its *flight-form* is dependent on other things also; among others, its length in calibers, the angle of departure and the range.

For flat trajectories we should find c practically constant. For trajectories of coniderable curvature we should find c by the elimination of the other factors, tabulate it for projectiles of different calibers and lengths and for shot and shell separately; and from a consideration of the results find a *coefficient of flight-form* in terms of quantities on which it depends, values, or at least approximate values, of which are available before firing.

The suggestions and methods herein given, involve for their perfect test a recalculation of the values of c or "βc" from the experimental data on which they are based.

If this be done I believe that c will be found constant for direct fire, and far more tractable for curved and indirect fire.

Until we have introduced independence of function into the various component parts of our ballistic coefficient, we may expect c to be variable; and we may frequently encounter that mysterious "something" which makes things go wrong at target practice and elsewhere, which leads to blame being cast on the powder or the atmosphere, or the gunner, or some other agent, who or which may, after all, be innocent.

(To be continued.)

TABLES I., II., III., IV.

TABLE I.

Values of log F with $\phi_m = \frac{\phi + \omega}{2}$, as argument.

ϕ_m	log F	ϕ_m	log F	ϕ_m	log F
°		°		°	
1	9.82384	31	9.81464	61	9.77619
2	9.82378	32	9.81398	62	9.77408
3	9.82372	33	9.81325	63	9.77188
4	9.82365	34	9.81251	64	9.76953
5	9.82357	35	9.81171	65	9.76716
6	9.82348	36	9.81084	66	9.76470
7	9.82338	37	9.80996	67	9.76223
8	9.82327	38	9.80909	68	9.75967
9	9.82315	39	9.80821	69	9.75686
10	9.82302	40	9.80733	70	9.75389
11	9.82288	41	9.80645	71	9.75089
12	9.82271	42	9.80550	72	9.74780
13	9.82251	43	9.80441	73	9.74453
14	9.82227	44	9.80325	74	9.74139
15	9.82199	45	9.80209	75	9.73807
16	9.82169	46	9.80085	76	9.73480
17	9.82136	47	9.79955	77	9.73159
18	9.82100	48	9.79824	78	9.72835
19	9.82061	49	9.79692	79	9.72526
20	9.82020	50	9.79560	80	9.72263
21	9.81976	51	9.79421	81	9.71933
22	9.81931	52	6.79281	82	9.71667
23	9.81884	53	9.79127	83	9.71383
24	9.81836	54	6.78958	84	9.71063
25	9.81786	55	6.78789	85	9.70757
26	9.81736	56	6.78618	86	9.70501
27	9.81685	57	9.78433	87	9.70260
28	9.81632	58	9.78247	88	9.70079
29	9.81579	59	9.78046	89	9.69966
30	9.81525	60	9.77837	90	9.69897

TABLE II. 0 to — 1000 feet.

Computed from the formula $\frac{1}{\log f} = \frac{56518.5 + 130\,t}{h} - .217$

Values of log f with h and t as arguments.

h(ft.)	t	0°	Δ_t	10°	Δ_t	20°	Δ_t	30°	Δ_t	40°	Δ_t	50°	Δ_t	60°	Δ_t	70°	Δ_t	80°	Δ_t	90°	Δ_t	100°
0																						
—100	9.9	9824	4	9828	3	9831	4	9835	4	9839	3	9842	3	9845	3	9848	3	9851	3	9854	3	9857
—200		9648	7	9655	8	9663	7	9670	7	9677	7	9684	6	9690	6	9696	6	9702	6	9708	5	9713
—300		9471	12	9483	11	9494	11	9505	11	9516	10	9526	9	9535	10	9545	8	9553	9	9562	8	9570
—400		9295	16	9311	15	9326	14	9340	14	9354	14	9368	12	9380	13	9393	11	9404	12	9416	10	9426
—500		9119	19	9138	19	9157	18	9175	18	9193	16	9209	16	9225	16	9241	14	9255	14	9269	14	9283
—600		8943	23	8966	23	8989	22	9011	21	9032	19	9051	20	9071	18	9089	18	9107	16	9123	17	9140
—700		8767	27	8794	26	8820	26	8846	24	8870	23	8893	23	8916	21	8937	21	8958	19	8977	19	8996
—800		8590	32	8622	30	8652	29	8681	28	8709	26	8735	26	8761	25	8786	23	8809	22	8831	22	8853
—900		8414	35	8449	34	8483	33	8516	31	8547	30	8577	29	8606	28	8634	26	8660	25	8685	24	8709
—1000		8238	39	8277	38	8315	36	8351	35	8386	33	8419	32	8451	21	8482	29	8511	28	8539	27	8566
Δ_h		176.2		172.3		168.5		164.9		161.4		158.1		154.9		151.8		148.9		146.1		143.4

$$\log f = \log f_0 - \Delta_h \left\{\frac{h - h_0}{100}\right\} + \Delta_t \left\{\frac{t - t_0}{10}\right\}.$$

NOTE: In the column headed t, appear the characteristic and the first digit of the mantissa—which are common to all the logarithms of f on this page. In the columns headed 0°, 10°, etc., appear the remaining four digits of log f.

Thus log f for —400 feet and 40° is 9.99354—10, f between 0 and —1000 feet being less than unity.

TABLE II. 0 to + 6000 feet

Values of log f with h and t as arguments.*

h / t°	1000	Δ_t	Δ_h	2000	Δ_t	Δ_h	3000	Δ_t	Δ_h	4000	Δ_t	Δ_h	5000	Δ_t	Δ_h	6000
0°	.01785	40	1816	.03601	82	1847	.05448	123	1879	.07327	168	1910	.09237	213	1939	.11176
10°	.01745	39	1774	.03519	79	1806	.05325	118	1834	.07159	160	1865	.09024	203	1892	.10916
20°	.01706	37	1734	.03440	76	1767	.05207	114	1792	.06999	153	1822	.08821	195	1848	.10669
30°	.01669	36	1695	.03364	73	1729	.05093	110	1753	.06846	147	1780	.08626	187	1806	.10432
40°	.01633	34	1658	.03291	70	1692	.04983	105	1716	.06699	142	1740	.08439	180	1766	.10205
50°	.01599	32	1622	.03221	66	1657	.04878	101	1679	.06557	136	1702	.08259	173	1727	.09986
60°	.01567	31	1588	.03155	63	1622	.04777	97	1644	.06421	131	1665	.08086	166	1690	.09776
70°	.01536	31	1556	.03092	60	1588	.04680	93	1610	.06290	126	1630	.07920	160	1653	.09573
80°	.01505	30	1527	.03032	57	1555	.04587	89	1577	.06164	121	1596	.07760	154	1619	.09379
90°	.01475	28	1500	.02975	54	1523	.04498	85	1545	.06043	116	1563	.07606	148	1586	.09192
100°	.01447	27	1474	.02921	52	1492	.04413	81	1514	.05927	111	1531	.07458	143	1555	.09013

* This value of log f is that pertaining to the *height of mean density*; it is corrected for mean humidity, change of temperature with altitude, and is *not* obtained by using the *mean height*. It is entered with h, the *mean height*, as argument, the relation between this and the height of mean density having been ascertained, and the mean height being readily found is used as argument. This $h = F . y_o$, in which F is a function of the elevation in degrees. The other argument, t, is the *surface temperature*.

TABLE II. 6000 to 11000 feet.

Values of log f, with h and t as arguments.

h / t°	6000	Δ_t	Δ_h	7000	Δ_t	Δ_h	8000	Δ_t	Δ_h	9000	Δ_t	Δ_h	10000	Δ_t	Δ_h	11000
0°	.11176	260	1976	.13152	305	2003	.15155	356	2036	.17191	405	2068	.19259	455	2100	.21359
10°	.10916	247	1931	.12847	293	1952	.14799	340	1987	.16786	387	2018	.18804	436	2045	.20849
20°	.10669	237	1885	.12554	281	1905	.14459	324	1940	.16399	372	1969	.18368	418	1995	.20363
30°	.10432	227	1841	.12273	270	1862	.14135	312	1892	.16027	356	1923	.17950	401	1947	.19897
40°	.10205	219	1798	.12003	259	1820	.13823	300	1848	.15671	341	1878	.17549	385	1902	.19451
50°	.09986	210	1758	.11744	249	1779	.13523	288	1807	.15330	327	1834	.17164	370	1858	.19022
60°	.09776	203	1719	.11495	240	1740	.13235	277	1768	.15003	315	1791	.16794	356	1817	.18611
70°	.09573	194	1682	.11255	231	1703	.12958	266	1730	.14688	303	1750	.16438	342	1777	.18215
80°	.09379	187	1645	.11024	222	1668	.12692	256	1693	.14385	292	1711	.16096	330	1737	.17833
90°	.09192	181	1610	.10802	214	1634	.12436	248	1657	.14093	282	1673	.15766	318	1698	.17464
100°	.09013	175	1575	.10588	206	1600	.12188	240	1623	.13811	272	1637	.15448	307	1661	.17109

TABLE III.

Table of values of $\frac{\delta_1}{\delta}$ for a psychrometer depression of 0°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1	.936	.903	.873	.846	51	1.043	1.008	.974	.943
2	.938	.905	.875	.848	52	1.045	1.010	.976	.945
3	.940	.907	.877	.850	53	1.048	1.012	.978	.947
4	.942	.909	.879	.851	54	1.051	1.015	.981	.949
5	.944	.911	.881	.853	55	1.053	1.017	.983	.951
6	.946	.913	.883	.855	56	1.056	1.019	.985	.953
7	.948	.915	.885	.857	57	1.058	1.021	.988	.955
8	.950	.917	.887	.858	58	1.060	1.024	.990	.957
9	.952	.919	.889	.860	59	1.062	1.026	.992	.959
10	.954	.921	.891	.862	60	1.065	1.028	.994	.962
11	.956	.923	.893	.864	61	1.067	1.030	.997	.965
12	.958	.925	.895	.866	62	1.070	1.033	.999	.967
13	.960	.927	.896	.868	63	1.073	1.036	1.002	.070
14	.963	.929	.898	.870	64	1.075	1.038	1.005	.972
15	.965	.931	.900	.872	65	1.078	1.041	1.007	.975
16	.967	.933	.902	.874	66	1.081	1.044	1.010	.977
17	.969	.935	.904	.875	67	1.083	1.046	1.013	.980
18	.971	.937	.906	.877	68	1.086	1.049	1.015	.982
19	.973	.939	.908	.879	69	1.089	1.052	1.017	.985
20	.975	.941	.910	.881	70	1.092	1.055	1.020	.987
21	.978	.943	.912	.883	71	1.094	1.058	1.022	.989
22	.980	.945	.914	.885	72	1.097	1.060	1.025	.992
23	.982	.947	.916	.877	73	1.100	1.063	1.027	.994
24	.984	.949	.919	.889	74	1.103	1.065	1.030	.997
25	.986	.951	.921	.890	75	1.105	1.068	1.032	.999
26	.988	.953	.923	.892	76	1.108	1.070	1.035	1.001
27	.990	.955	.925	.894	77	1.111	1.073	1.037	1.004
28	.992	.957	.927	.896	78	1.113	1.075	1.040	1.006
29	.994	.959	.929	.898	79	1.116	1.078	1.042	1.009
30	.996	.961	.931	.900	80	1.118	1.080	1.045	1.011
31	.999	.963	.933	.902	81	1.121	1.083	1.047	1.014
32	1.001	.966	.935	.904	82	1.124	1.086	1.050	1.017
33	1.003	.968	.937	.906	83	1.127	1.089	1.053	1.020
34	1.005	.070	.939	.908	84	1.130	1.092	1.056	1.022
35	1.008	.972	.941	.910	85	1.133	1.095	1.059	1.025
36	1.010	.975	.943	.912	86	1.136	1.098	1.062	1.028
37	1.012	.977	.945	.914	87	1.139	1.101	1.064	1.031
38	1.014	.979	.947	.916	88	1.142	1.104	1.067	1.033
39	1.016	.981	.949	.918	89	1.145	1.107	1.070	1.036
40	1.018	.983	.951	.920	90	1.149	1.110	1.073	1.039
41	1.021	.986	.953	.922	91	1.152	1.113	1.076	1.042
42	1.023	.988	.955	.924	92	1.156	1.117	1.079	1.045
43	1.025	.990	.957	.926	93	1.159	1.120	1.083	1.048
44	1.027	.992	.959	.928	94	1.162	1.123	1.086	1.051
45	1.030	.994	.961	.930	95	1.166	1.126	1.089	1.054
46	1.032	.996	.963	.932	96	1.169	1.129	1.092	1.057
47	1.034	.999	.966	.934	97	1.172	1.133	1.096	1.060
48	1.036	1.002	.968	.936	98	1.176	1.136	1.099	1.063
49	1.039	1.004	.970	.938	99	1.179	1.139	1.102	1.066
50	1.041	1.006	.972	.941	100	1.182	1.142	1.105	1.069

TABLE III.

Table of values of $\frac{\delta_{\prime}}{\delta}$ for a psychrometer depression of 5°

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1					51	1.039	1.004	.970	.939
2					52	1.041	1.006	.972	.941
3					53	1.044	1.008	.974	.943
4					54	1.046	1.010	.977	.946
5					55	1.048	1.013	.979	.948
6					56	1.051	1.015	.981	.950
7					57	1.053	1.017	.983	.952
8					58	1.055	1 020	.986	.954
9					59	1.058	1.022	.988	.956
10					60	1.061	1.024	.990	.958
11					61	1.063	1.027	.992	.960
12					62	1.066	1.029	.994	.963
13					63	1.068	1.031	.997	.965
14					64	1.071	1.033	1.000	.967
15					65	1.073	1.036	1.002	.969
16	.964	.930	.898	.868	66	1.075	1.038	1.004	.971
17	.966	.932	.900	.870	67	1.078	1.041	1.007	.974
18	.968	.934	.902	.872	68	1.080	1.043	1.009	.976
19	.970	.936	.904	.874	69	1.082	1.046	1.011	.978
20	.972	.938	.906	.876	70	1.085	1.048	1.013	.980
21	.974	.940	.908	.878	71	1.087	1.051	1.016	.982
22	.976	.942	.911	.880	72	1.090	1.053	1.018	.985
23	.978	.944	.913	.882	73	1.093	1.056	1.021	.087
24	.980	.946	.915	.884	74	1.095	1.058	1.023	.991
25	.982	.948	.917	.886	75	1.097	1.061	1.026	.993
26	.984	.950	.920	.888	76	1.100	1.063	1.028	.996
27	.986	.952	.922	.890	77	1.103	1.066	1.031	.998
28	.988	.954	.924	.892	78	1.105	1.068	1.033	1.000
29	.990	.956	.926	.894	79	1.108	1.071	1.036	1.002
30	.993	.958	.928	.897	80	1.111	1.073	1.038	1.004
31	.995	.960	.930	.899	81	1.113	1.076	1.041	1.007
32	.997	.962	.932	.901	82	1.116	1.078	1.044	1.009
33	.999	.965	.934	.903	83	1.119	1.081	1.046	1.012
34	1.001	.967	.936	.905	84	1.122	1.084	1.049	1.014
35	1.004	.969	.938	.907	85	1.125	1.087	1.051	1.017
36	1.006	.971	.940	.909	86	1.128	1.090	1.054	1.019
37	1.008	.974	.942	.911	87	1.131	1.092	1.056	1.022
38	1.010	.976	.944	.913	88	1.134	1.095	1.059	1.024
39	1.012	.978	.946	.915	89	1.137	1.098	1.061	1.027
40	1.015	.980	.948	.917	90	1.140	1.101	1.064	1.030
41	1.017	.982	.950	.919	91	1.143	1.104	1.066	1.032
42	1.019	.984	.952	.921	92	1.146	1.107	1.069	1.035
43	1.022	.986	.954	.923	93	1.149	1.109	1.072	1.038
44	1.024	.989	.956	.925	94	1.152	1.112	1.075	1.040
45	1.026	.991	.958	.927	95	1.155	1.115	1.078	1.043
46	1.028	.993	.960	.929	96	1.158	1.118	1.081	1.046
47	1.031	.995	.962	.931	97	1.161	1.121	1.084	1.049
48	1.033	.997	.964	.933	98	1.164	1.124	1.087	1.051
49	1.035	.999	.966	.935	99	1.167	1.127	1.090	1.054
50	1.037	1.002	.968	.937	100	1.170	1.130	1.093	1.057

TABLE III.

Table of values of $\frac{\delta'}{\delta}$ for a psychrometer depressson of 10°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
40	1.012	.977	.945	.914	70	1.080	1.043	1.008	.975
41	1.014	.979	.946	.916	71	1.082	1.045	1.010	.977
42	1.016	.981	.948	.917	72	1.085	1.048	1.012	.979
43	1.018	.984	.950	.919	73	1.087	1.050	1.015	.981
44	1.020	.986	.952	.921	74	1.090	1.052	1.017	.983
45	1.023	.988	.954	.923	75	1.092	1.055	1.020	.986
46	1.025	.990	.956	.925	76	1.095	1.057	1.022	.988
47	1.027	.992	.958	.927	77	1.097	1.060	1.025	.990
48	1.029	.994	.960	.929	78	1.100	1.062	1.027	.993
49	1.031	.996	.962	.931	79	1.102	1.065	1.030	.995
50	1.033	.998	.964	.933	80	1.105	1.067	1.032	.998
51	1.036	1.000	.966	.935	81	1.107	1.070	1.034	1.000
52	1.038	1.002	.968	.937	82	1.110	1.073	1.037	1.003
53	1.040	1.004	.971	.939	83	1.113	1.075	1.040	1.005
54	1.043	1.007	.973	.941	84	1.115	1.078	1.042	1.007
55	1.045	1.009	.975	.944	85	1.118	1.081	1.044	1.010
56	1.048	1.011	.978	.946	86	1.121	1.084	1.047	1.012
57	1.050	1.013	.980	.948	87	1.123	1.086	1.049	1.015
58	1.052	1.016	.982	.950	88	1.126	1.088	1.052	1.017
59	1.054	1.018	.984	.952	89	1.129	1.091	1.054	1.020
60	1.057	1.020	.986	.954	90	1.132	1.093	1.056	1.022
61	1.059	1.022	.988	.956	91	1.135	1.096	1.059	1.025
62	1.061	1.025	.990	.958	92	1.137	1.098	1.062	1.027
63	1.064	1.027	.993	.960	93	1.140	1.101	1.064	1.030
64	1.066	1.029	.995	.962	94	1.143	1.104	1.067	1.033
65	1.068	1.031	.998	.964	95	1.146	1.107	1.070	1.035
66	1.070	1.034	1.000	.966	96	1.149	1.109	1.072	1.037
67	1.073	1.036	1.002	.968	97	1.152	1.112	1.075	1.040
68	1.075	1.038	1.004	.970	98	1.155	1.115	1.078	1.042
69	1.077	1.040	1.006	.972	99	1.158	1.118	1.081	1.045
70	1.080	1.043	1.008	.975	100	1.161	1.121	1.084	1.048

TABLE III.

Table of values of $\frac{\delta_{\prime}}{\delta}$ for a psychrometer depression of 15°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
50	1.030	.995	.961	.930	76	1.090	1.052	1.018	.983
51	1.032	.997	.963	.932	77	1.092	1.054	1.020	.985
52	1.034	.999	.965	.934	78	1.094	1.056	1.022	.988
53	1.037	1.001	.967	.936	79	1.097	1.058	1.024	.990
54	1.039	1.003	.970	.938	80	1.099	1.061	1.026	.992
55	1.041	1.005	.972	.940	81	1.102	1.063	1.029	.994
56	1.044	1.008	.974	.942	82	1.105	1.066	1.031	.996
57	1.046	1.010	.976	.944	83	1.107	1.068	1.033	.999
58	1.048	1.012	.978	.946	84	1.110	1.071	1.036	1.001
59	1.050	1.014	.980	.948	85	1.112	1.073	1.038	1.003
60	1.053	1.016	.982	.950	86	1.115	1.076	1.040	1.006
61	1.055	1.019	.984	.952	87	1.117	1.078	1.043	1.008
62	1.057	1.021	.986	.954	88	1.120	1.081	1.045	1.010
63	1.060	1.023	.989	.956	89	1.122	1.083	1.047	1.012
64	1.062	1.026	.991	.958	90	1.125	1.086	1.049	1.015
65	1.064	1.028	.993	.960	91	1.128	1.089	1.052	1.017
66	1.066	1.030	.995	.962	92	1.130	1.091	1.054	1.020
67	1.069	1.033	.998	.964	93	1.133	1.094	1.057	1.022
68	1.071	1.035	1.000	.966	94	1.136	1.097	1.059	1.024
69	1.073	1.037	1.002	.968	95	1.138	1.999	1.062	1.027
70	1.076	1.039	1.004	.971	96	1.141	1.102	1.064	1.029
71	1.078	1.041	1.007	.973	97	1.144	1.105	1.067	1.032
72	1.080	1.044	1.009	.975	98	1.146	1.107	1.069	1.035
73	1.083	1.046	1.011	.977	99	1.149	1.110	1.072	1.037
74	1.085	1.048	1.013	.979	100	1.152	1.112	1.075	1.039
75	1.087	1.050	1.015	.981	101	1.155	1.115	1.078	1.042

Table of values of $\frac{\delta_{\prime}}{\delta}$ for a psychrometer depression of 20°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
60	1.050	1.013	.979	.947	81	1.096	1.058	1.023	.989
61	1.052	1.015	.981	.949	82	1.099	1.060	1.025	.991
62	1.054	1.017	.983	.951	83	1.101	1.063	1.027	.993
63	1.056	1.019	.985	.953	84	1.103	1.065	1.030	.995
64	1.059	1.022	.987	.955	85	1.106	1.067	1.032	.997
65	1.061	1.024	.989	.957	86	1.108	1.069	1.034	.999
66	1.063	1.026	.992	.959	87	1.111	1.072	1.036	1.002
67	1.065	1.028	.994	.961	88	1.113	1.074	1.038	1.004
68	1.068	1.030	.996	.963	89	1.116	1.076	1.040	1.006
69	1.070	1.032	.998	.965	90	1.118	1.079	1.042	1.008
70	1.072	1.035	1.000	.967	91	1.120	1.081	1.043	1.010
71	1.074	1.037	1.002	.969	92	1.122	1.084	1.045	1.012
72	1.076	1.039	1.004	.971	93	1.125	1.086	1.047	1.014
73	1.078	1.042	1.006	.973	94	1.127	1.088	1.050	1.016
74	1.081	1.044	1.008	.975	95	1.129	1.091	1.052	1.019
75	1.083	1.046	1.010	.977	96	1.132	1.093	1.054	1.021
76	1.085	1.048	1.012	.979	97	1.134	1.095	1.057	1.023
77	1.088	1.050	1.014	.981	98	1.137	1.098	1.059	1.025
78	1.090	1.052	1.017	.983	99	1.139	1.100	1.062	1.027
79	1.092	1.054	1.019	.985	100	1.142	1.102	1.065	1.029
80	1.094	1.056	1.021	.987	101	1.145	1.105	1.067	1.031

TABLE IV.

SIACCI'S β-FUNCTION, in English Units.

Evaluated and extended to three places by Captain ALSTON HAMILTON, Artillery Corps

X	yds. 1000	yds. 2000	yds. 3000	yds. 4000	yds. 5000	yds. 6000	yds. 7000	yds. 8000	yds. 9000	yds. 10000
φ										
6°	1.002	.992	.994	.999	1.001	1.000				
7	1.003	.993	.991	.994	.997	.999				
8	1.004	.994	.989	.988	.992	.997				
9	1.005	.996	.988	.982	.986	.995				
10	1.006	.997	.986	.976	.978	.991				
11	1.007	.998	.984	.971	.971	.986	1.000	1.000	1.000	
12	1.009	1.000	.985	.964	.963	.982	.996	.998	.999	
13	1,011	1.001	.987	.971	.960	.972	.991	.995	.998	
14	1.013	1.003	.990	.976	.961	.959	.982	.992	.996	
15	1.015	1.005	.994	.982	.968	.955	.970	.985	.991	
16	1.017	1.007	.997	.989	.968	.943	.959	.978	.986	
17	1.019	1.010	1.000	.994	.967	.942	.941	.968	.982	
18	1.021	1.013	1.003	.999	.980	.937	.926	.952	.970	.990
19	1.024	1.016	1.007	1.004	.986	.942	.930	.925	.959	.978
20	1.027	1.021	1.012	1.009	.991	.962	.932	.909	.928	.967
21	1.029	1.026	1.018	1.013	1.000	.972	.935	.899	.913	.953
22	1.032	1.030	1.023	1.019	1.010	.980	.937	.884	.900	.939
23	1.035	1.035	1.027	1.025	1.018	.994	.941	.874	.889	.928
24	1.038	1.040	1.031	1.028	1.024	1.004	.951	.872	.877	.913
25	1.041	1.045	1.036	1.032	1.029	1.013	.959	.877	.865	.899
26	1.045	1.049	1.041	1.037	1.034	1.019	.966	.896	.852	.887
27	1.049	1.052	1.046	1.042	1.040	1.026	.974	.909	.850	.866
28	1.054	1.055	1.051	1.048	1.045	1.034	.990	.924	.852	.845
29	1.058	1.059	1.058	1.053	1.050	1.040	1.000	.931	.858	.819
30	1.063	1.064	0.651	1.059	1.055	1.047	1.012	.951	.862	.800

THE PREPARATION OF FORT RECORD AND EMPLACEMENT BOOKS

By Captain ALFRED M. HUNTER, Artillery Corps

THE instructions which prescribe what Fort Record Books should contain are found on pages 119 and 120, Drill Regulations for Coast Artillery ; those for emplacement books are in par. I., G. O. 137, A. G. O., 1901.

These instructions indicate in general terms what such books should contain, but if most of those which have come under my observation may be taken as types of those in existence, then it is fair to say that there are no published instructions which are more habitually neglected. The whole of the instructions might be embraced in the following sentence from the instructions for Fort Record Books: "It is the duty of the commanding officer to keep up the record of details so complete that an officer taking charge will find all the information he can require, ready at hand, and in fullest detail." This is applicable also to emplacement books, which are to the battery, what the Fort Record Book is to the post. These instructions were undoubtedly published with the object of requiring officers to record information relative to posts and emplacements, so that officers taking charge would not have to waste time and labor in doing over again work that had already been done.

It is not so very many years ago that the importance of keeping these records accurately was not fully appreciated. Those were the days when an officer would collect such data in regard to work under his charge as he might deem necessary or expedient, and leave such portion of it recorded as he saw fit. In fact some officers now say that they have had to do such work over again many times, and can see no reason why they should keep records for the benefit of their successors. When these books have not been properly prepared in so far as the state of completion of the post or battery will permit, it indicates either neglect or ignorance in the part of the responsible officer.

The preparation of Fort Record Books under each of the prescribed headings, and in more extended detail than is contained in the instructions, will first be considered. All of the details may not be applicable to some places, but it is believed that they indicate what should be recorded in so far as they apply to a particular locality.

"At every artillery post a permanent record will be kept of all the details of the works, their general object, history and armament, as well as details connected with the defense scheme."

"It will contain all details of the information referred to in this manual, so far as they apply, so that if tables are lost, or figures in gun emplacements or stations are erased, they can be immediately restored."

"It will clearly indexed and kept as confidential."

"It will be arranged under the following heads:

GENERAL DESCRIPTION

"Of the works and their surroundings, (land and water), history, objects, the fire commands to which they belong, the depth, width, and direction of the channels, the height and set of the tide, the strength of the current, the position of the mine fields, and other obstructions, the barrack, camp and hospital accommodations, the water supply, the landings, the labor and transportation available, etc."

It is believed that an amplification of this last paragraph would make it include a copy of the deed or deeds of the land in the reservation, where these are recorded, a copy of the act ceding the jurisdiction over this reservation to the United States, (such acts always definitely state the portion of the jurisdiction which is retained by the State, and what State processes may be served on the reservation), the history of the reservation since it has been owned by the United States, which is to be compiled from post records, or such other authentic sources as are available. The object of the works may in general be simply stated as being to defend a certain place from attack by sea or by land, or to prevent a certain anchorage from being occupied by the naval forces of an enemy.

"The depth, width, and direction of the channels," can always be obtained from Coast Survey Charts, or from the local engineer officer.

"The height and set of the tide, and strength of the current," should include the range of the tide, extreme, mean, and least, how the tidal range varies at different seasons of the year, and at different phases of the moon, how the currents vary as the tide changes, (the current may be running in, in one portion the of channel, and running out in another portion at the same time, at certain stages of the tide), and the current strength at various stages of the tide at the different seasons. For the most important harbors this information can be obtained from tide tables published by the Treasury Department, or from that Department itself; for harbors of less importance, it may be partially obtained from the local engineer office.

"The position of the mine fields and other obstructions," should include the number of grand groups, skirmish lines, and detached groups of mines for the particular harbor, as shown by the approved plan of defense, the location of the grand junction boxes, the direction in which the groups are to extend, the number, size, and kind of mines in each group, the approximate depth of water in which each triple group is to be planted; the nature of the other obstructions to be used, where to be placed, and where the materials for them can be obtained in an emergency; whether submarines or torpedoes of the dirigible type are to constitute a part of the defense, and if so, the number and kind of each to be used, and by whom operated.

"The barrack, camp and hospital accommodations." As it is not probable that there will ever be at any of our fortifications sufficient barrack and hospital accommodations for a garrison of two or three reliefs, the location and capacity of those built should be given, as well as location of sites for proposed camps and field hospitals. It should be stated in all cases whether the proposed sites are on government or private property, and if the latter, what rental should be paid in case it becomes necessary to hire them.

Under "water supply," should be noted the source of the supply, the capacity of the reservoirs and tanks, the maximum daily amount that might be supplied in case of necessity, whether the supply is affected by a drought, whether it is ample for a war garrison, and, if not, where an additional supply can be obtained, the kind and capacity of the pumping plant.

"Landings" should include the wharves on, or contiguous to the reservation, and those convenient to proposed camp and field hospital sites, the capacity of the wharves, the number and draught of vessels that can be simultaneously loaded or unloaded at each, the depth of water, the ease with which landings can be made, their convenience to storehouses or batteries, whether they can be utilized in the planting of submarine mines.

"Labor and transportation avalable," includes the cost and kind of labor that can be hired in the vicinity, in what branches skilled, land and water transportation belonging to the government, the amount and kind of transportation which could be hired in the vicinity in time of active operations, the cost of hiring the different kinds, the facilities for storing transportation, the cost of subsisting animals hired.

FORTIFICATIONS

"All details of construction, nature and thickness of parapets, traverses, magazine cover, etc., dimensions and capacity of magazines, storerooms, etc., with plans and sections."

The information under this head should include a table showing the batteries at the post, which should show the dates of the beginning of the construction of each, the date of its completion, and when it was armed, the important repairs and alterations made since, with dates when they were made, the size of the rooms, galleries, and passage ways, the references of the interior crest, exterior crests, battery commander's stations, gun and loading platforms, magazine floors and ceilings, shot rooms and galleries, above mean low water. These and the magazine cover, thickness of parapets, materials of which constructed, etc,, are best shown by the plans and sections, which are furnished by the engineers. They are generally on too large a scale for ready reference, and copies on a reduced scale should be made in the Fort Record Book. These have the advantage of being always at hand, and save commanding officers the inconvenience of looking over the contents of a whole drawer in the office safe when a drawing is desired.

ARMAMENT

"Fixed armament.—The guns constituting each battery, their emplacement, caliber, number, mounting, height above mean low water, the capacity of their recoil cylinders, sectors of fire, actual contents and capacity of the service magazines, means of serving ammunition, the position finding station and its equipment, the communications, important azimuths for each gun and position finder for orientation, etc."

For each battery there should be a table in which should be entered the kind, caliber, model, number, place and date of manufacture, date of receipt at post, and date of mounting of each gun and carriage in the battery, together with the number of the emplacement in which mounted, the height of the trunnions above mean low water when the gun is in the firing position, and its sector of fire as given by the azimuths of its extreme right and left positions; the means of serving ammunition, whether by lift, hoist, shot crane, or hand, whether the lifts are operated by electricity or by hand, and if by electricity the number and kind of motors; whether the carriages are retracted and traversed by hand or by electricity, and if by electricity, the numbers and kind of the motors.

If the battery contains an electrical plant, the kind of boiler, the number, maximum speed, horsepower, size of cylinders, name of manufacturer of the engine; the number, type, voltage, amperes, capacity, name of the manufacturer of the dynamo; the number, size and kind of cells of the storage battery, if there is one; the manufacturer's numbers of the switchboard instruments.

The location of each battery primary and secondary station with reference to each gun of the battery, and the location of each gun of the battery with reference to each other gun, should be given in a table of azimuths and distances. In this table should also be given the azimuths and distances of the datum points from each position finder, and the azimuths and distances of points for orientation from each position finder and gun.

The dates of the construction of the battery stations, the articles of their equipment, the means of communication from the stations to the guns, from one gun to another, and with the magazines.

Important repairs and alterations to guns, carriages, emplacements, and position finding stations should be entered; minor repairs and alterations properly belong in emplacement books, but if a carriage is fitted with new counter-recoil buffers, or is supplied with power for retracting and traversing, it would seem proper to have such and similar facts noted in the Fort Record Book.

Batteries of rapid fire guns should have as much of the above information as is applicable to them entered; for these batteries also it should be noted whether they are particularly suited for the defense of the mine field.

"Movable armament.—Same as above, and in addition, the place of storage of the guns when not in position." By this is understood to mean so much information relative to movable armament as is necessary or applicable. It should include the probable places where the movable armament would be used, the ammunition on hand, the place of storage, etc.

"Mines.—Their supplies, storerooms, maps of the mine fields, and instructions for planting and operating them."

Under this head should appear all information relative to the submarine mine defense, which does not come under the heading "general description," such as the number and size of buoyant and ground mines required, the number actually on on hand, the submarine mining storehouse, its storage capacity, location, the equipment for moving mines and anchors in the storehouse, and from the storehouse to the wharf, what parts of the mine equipment are on hand, and what to be supplied, the condition of the supplies on hand; the mining casemate, its size and location, equipment, the number and power of the oil engine, the number, kind and capacity of the dynamo or rotary transformer, the storage battery, the number and size of its cells, etc.; whether all the casemate instruments are on hand, and their condition, the size of the cross sections and the length of the cable gallery, the location of its outer entrance, how this entrance is closed and marked; the location, size and suitability of the loading room, its convenience to the wharf, its equipment for handling mines; the cable tank, facilities for handling cable, the amount, kind and condition of the cable on hand, the amount required for the complete plan, the means for filling the tank; the boat service material, condition of the boat house, the number and size of the junction box boats on hand, vessels in the vicinity which could be hired for the planting of mines and the cost of hiring.

AUXILIARIES

"Communications.—Lines, conduits, purpose, terminals, markings, references to the map, etc."

Should include all communication with towns and posts in the vicinity, as well as those which are a part of the defense proper. These latter should be entered as permanent or temporary, whether overhead, or in conduits, location of manholes for inspection and repairs, kind of cable used, whether the circuits are metallic or have an earth return, plans of the conduits, whether telephones, telautograph, or speaking tubes are used, to what portion of the defense each section of the communications pertain.

"Position finders.—Stations, equipments, important azimuths and distances, etc."

Under this should appear all information relative to position finding not included under the head of the equipment of batteries; it would embrace fire and battle commander's stations and their equipments. It should also include a complete triangulation of the post, showing the triangles by which the lines joining the gun positions and stations were computed, and the computations necessary for locating points for orientation, etc. It is rarely necessary actually to measure a base line at a seacoast fortification. The azimuths and distances from each other of all lighthouses and fixed beacons in the vicinity can be obtained from the Coast Survey on application, and from these the necessary triangulation can be made for determining all other azimuths and distances required. Following the triangulation, which should be as complete as possible, should be given a table of the latitudes and departures of all the necessary points from some station, and from there the azimuths and distances should be computed and entered. For convenience in future computations the table of azimuths and distances should give the extremities of the line, its length in feet, the logarithm of the corresponding number, the distance in yards, and its azimuth to the nearest second. If this table is properly prepared, it can be extended to embrace new batteries and stations with the mininum of labor. There should also be shown the location of the bench marks used by the engineers in the construction of the batteries, and the reference of each of these above mean low water.

"Electric lights.—Kinds, number, power, arcs of illumination, emplacements, etc."

Should include the locations of the central electrical plant, and such other plants as exist at the post, other than those given as parts of batteries, the equipment and purpose of each; the engines, dynamos, etc., being entered as already given under battery plants; the number and kind of search lights, whether fixed or movable, the purpose of the lights, whether for searching or illuminating; if movable, the length of the cables; where stored; the protection of fixed lights; the system of wiring for lighting magazines, etc. The number of storage batteries, with the number, kind, and size of cells in each.

"Maps, charts, and tables.—Maps of posts, surrounding country, harbor, communications, etc.; fire and battery commander's charts, etc.; tide, range, and other tables."

A map of the post showing the reservation and its buildings can generally be obtained from either the Quartermaster's Department or the Engineers; those showing batteries, position finding stations, etc., can be obtained from the Engineers; maps of communications can be obtained from the same source; harbor charts are furnished by the Coast Survey, and can be obtained for use at posts on application; fire and battery commander's charts are furnished by the Engineers, battle charts must be prepared at posts of materials supplied by the Ordnance Department; tide tables are published by the Treasury Department; range and battery commander's tables are supplied by the Ordnance Department. A table of curvature of the earth in feet is a great convenience in a Fort Record Book, and should be computed. The logarithm of the curvature is given by the formula, 2 log D—7.6209430, in which D is the distance in feet.

The location, capacity, and contents of the peace magazine should be given under the heading of miscellaneous information.

PLANS OF DEFENSE

"Preparations when war is imminent.—Details of mobilization, additional constructions, such as traverses, shelters, intrenchments, ground mines, entanglements, etc."

With the number of troops to be mobilized at a given coast fortification in the event of the near approach of war, and the ways and means of transporting them to that place, it is probable that the commanding officer would have but little control, with the providing of shelters for and subsisting them after their arrival he would have much to do, and plans for such should be entered fully. The location of traverses, bombproofs, intrenchments for defense against landing parties, or from troops advancing by land, the places for entanglements and other obstructions, the materials of which they would be constructed, where it can be obtained, and the number of men to be detailed for their construction, should be entered.

"Defense scheme.—Complete, detailed plans for meeting the different possible forms and phases of attack."

Paragraph 27, Provisional Drill Regulations for Coast Artillery, makes the preparation of the plan of defense for each artillery district the duty of the artillery district commander. It says this plan "will be forwarded through military channels to the Chief of Artillery for approval, with such suggestions as to modifications thereof as may in his (the district commander's) opinion be required by new conditions." It happens also that each district engineer officer is required to submit to the Chief of Engineers for approval a plan of defense for each harbor in his district. Which of these plans is the authorized plan of defense may be an open question, but it is more than probable that the one in the Fort Record Book would be followed or not according as to whether is expressed the views of the then commanding officer.

By whomever written, however, the plan of defense should contain detailed plans as to the conduct of each fire command, battery, or other unit of the defense, for every form of attack to be apprehended from land or water. Such would be directions to be followed in case of attempts to countermine, to bombard the defenses from a distance, attempts to run by on the part of torpedo boats, or in force, and in case of all these forms combined; attacks from landing parties, and in case of attacks from land, where the defensive lines for the protection of the rest of the fortifications would be located; when different emplacements for the movable armament should be occupied; where the supports and reserves for these defensive lines should be placed.

JOURNAL

"In which will be recorded as they occur, all transactions permanently affecting the works, or likely to be historically or technically of use to future commanding officers."

Such information should embrace the dates of purchase of the reservation or its parts, the dates of the construction of the various works, and by whom constructed, the organizations constituting the garrison at various times, the change in the organizations, the batteries to which assigned, the dates when the batteries were armed, when the position finding stations were built, by whom, and when equipped, the dates of the orders naming the post and the batteries, and for whom named, the general results of artillery target practice, and such other events as may be properly considered to be of sufficient interest.

It is further provided that "where militia are authorized to receive instruction in the service of Coast Artillery, the district commander will, in his plan of defense for mobilization, provide for the distribution of the several organizations to the works and quarters to be alloted to their use while training." "The distribution of these organizations for the various forts, will be recorded in the Fort Record Book." These instructions do not require amplification, as it will probably be many years before militia organizations are habitually assigned to artillery districts for training.

Though not prescribed, it is believed that a Fort Record Book should contain a record of the defects of the armament reported by the artillery district commander at his inspections, and those of similar defects reported by other inspectors, with each action taken in each case. These defects should be entered separately for each supply department, as "Engineer Defects," "Signal Defects," etc. Such record would be compact, and would show a new commanding officer at once, just what was necessary to make the existing armament complete.

The Fort Record Book should be fully indexed, so that the information it contains may be easily found.

EMPLACEMENT BOOKS

The emplacement book is to the battery what the Fort Record Book is to the post. G. O. 137, A. G. O., 1901, prescribes that "The commanding officers of each battery of guns or mortars at a seacoast fortification will keep an emplacement book in which shall be entered the following information." If this means any thing it means that the emplacement book shall be kept either by the battery commander, or under his personal supervision, and he should be held to just as strict accountability for its condition as he is for the battery, or for the discipline or instruction of his company. He should not be allowed to evade the responsibility by claiming that company clerks, or lieutenants, failed to make proper entries, or made improper ones.

"Full range tables adapted to the height of guns, data required at the range finder, and other desirable information."

Full range tables mean range tables for the guns of the battery for each initial velocity prescribed, battery commander's tables for the same initial velocities, the gun commander's range scales for each initial velocity and each height of gun, and in the latter, should be entered the quadrant elevations. In addition, a circular letter from the office of the Chief of Artillery, dated August 22, 1903, requires that the quadrant elevations for each 6″, 8″, 10″ and 12″ gun for each 20 yards of range between the range of 500 yards and the maximum range permitted by the carriage for the service initial velocity, and initial velocities of 10 and 20 f. s. above and below the service velocity, be entered.

A table of curvature of the earth in feet, and a table showing the difference between the sight and quadrant elevation for all ranges, and for each height of gun, is essential.

"Data required at the range finder, and other desirable information," should be construed to mean the azimuth and distance from each battery station to the fire commander's station, to each gun of the battery, to each datum point, and point for orentation; the azimuth and distance from each gun of the battery to each other gun, and to the points for orientation; the references of the trunnions of each gun in the battery when in the firing position, of important lines of the battery, of the lines indicating heights on the datum points, of the concrete of the piers of the battery stations, and of the axis of the telescopes of the observing instruments when mounted. It should also include in tabular form the results of all computations necessary for the construction of all difference charts and plotting boards required in the battery, so that if these become unserviceable from any cause, new ones can be immediately constructed without additional computation. These tables should show the distances to be laid off in constructing the azimuth differences circles, the number of degrees to be laid off on each side of the point of no range difference, to the points of range differences of 10, 20, etc., yards. Data for the construction of battle charts should be similarly tabulated. The sectors of fire of the guns, location of bench marks near the battery, the electrical equipment of the battery, should be given as noted under Fort Record Books. A table should also show the corrections to be made in elevations due to the guns being out of level (if any are out of level) for every five degrees of azimuth throughout the sector of fire.

"The tactical number of the gun or mortar, followed by the factory or carriage number." This should include the number and model of the guns and carriages, the place and dates of their manufacture, date of receipt at post, and date of mounting.

"All letters sent or received which pertain solely to the armament or emplacement; all orders in force relating to the care and service of the same." It is believed that a synopsis of the correspondence mentioned, and the numbers, dates, and subjects of all orders published relating to the care and service of the armament or emplacement, will be sufficient. Orders which are not liable to be found on the files of companies assigned to batteries should be given in full; but general and special orders and circulars published by the War Department, or from Division or Department Headquarters, are easily referred to if the subjects of those which pertain to a particular battery, or kind of gun or carriage, are entered by the subject under the proper heading. These should always be in tabular form. The order naming the battery should be given.

"All defects noted in guns and equipment, with statement of action taken, and when and what repairs or alterations are effected." The defects which should be noted are those reported by the battery, post, or district commander or by inspectors, and should be tabulated under the heading of the proper supply department. Repairs and alterations should be similarly tabulated. The proper headings would be such as "Ordnance repairs or alterations made," "Signal defects reported," etc. They should show the date, defect reported, or repair made, by whom reported, and the action taken.

Orders subsequent to G. O. 137, A. G. O., 1901, require that the serial number of each shot fired from each gun of the battery should be given in order that a complete history of each gun and carriage may be on hand. The record of the firing of a gun prior to its arrival at a post is furnished by the Ordnance Department, records of subsequent firing would be given in the Post Record of Artillery and Artillery firing. This record should show the correct setting of the throttling valve of each carriage for each prescribed charge.

A record of the powder on hand, the date of its receipt at the post, the date it was placed in the service magazine, is required by Artillery Memorandum, No. 4, War Department, 1904.

The mimeograph giving instructions for the care and operation of Taylor-Raymond chain hoists, when installed in a battery, is also required.

A history showing the record of events pertaining to the the battery which may be of historical or technical interest is desirable, and plans and sections of the battery, showing the thickness of cover, wiring, drains, etc., and the index, are essential.

It is proper to say that the blank books furnished by the Quartermaster's Department for Fort Record and emplacement books are by no means suitable for the purpose: the pages are too small, the paper is not of good quality, no provision is made for drawings to be entered, and a pocket for reports required to be inserted is desirable in one or both covers.

In the preparation of these books several sources of error should be avoided. Information should not be entered unless it is known to be correct; it should not be entered unless it belongs in that particular book; information relative to defects of discipline or equipments of organizations are not pertinent. Things should be called by their proper names; do not call a table of quadrant elevations a range table. Do not give the sector of fire of a gun as being so many degrees, and then fail to enter the azimuths of its limiting positions. When information is known to be correct it should be entered at once; do not leave it in the books on loose scraps of paper, the backs of old letters, etc. Do not start either a Fort Record or an emplacement book by writing in the headings, and leaving the space under the headings blank. Do not enter the number of a gun unless the model, place and date of manufacture, and date of receipt at post, are also entered. Do the same in entering gun carriages. In recording the kind of engine or dynamo, give everything on the name plates. Do not give the number of cells of a storage battery unless you also give the kind and size.

If some of the details mentioned in this paper are apparently things which any officer should mention, they can be excused by saying that personal experience has been such as to convince me that the instructions for these books can not well be too minute, or too specific. As instances, within the last year I have seen four emplacement books at a single post which did not contain either a range table, a battery commander's table, or a gun commander's range scale, for the guns mounted in the batteries to which these emplacement books belonged; in one of these books the tables of quadrant elevations required by a circular letter from the Office of the Chief of Artillery, aboved mentioned, were erroneously called range tables; in in another, these elevations were entered for only 100 yards of range instead of for every 20 yards as required; in this book too, they were called range tables; they were not entered in a third, but on some loose sheets of paper in this book were some quadrant elevations which were so far wrong that to make them correct it would be necessary for a gun about 28 feet above low water to change to a height of over 600 feet at 9000 yards' range, and to a height of over 900 feet at 10000 yards; there was not a range table for subcaliber ammunition in either book. In three, there were no records of repairs and alterations made, no records of orders for the care and service of the armament or emplacements, and the records of defects reported consisted largely of those reported by the last Division Inspector, of which five defects were applicable to one battery, two to another, and the remainder were those those relating to the organizations assigned to these batteries, and having no proper place in emplacement books; in these three books the firing record was incomplete, and in one there was no data orientation. There was no data for the construction of difference charts in either, and the records of the letters sent and received were very defective.

To prepare a complete Fort Record or emplacement book requires a great deal of hard, tedious work in the first instance; to keep it up to date thereafter takes but little time, requiring only attention to keeping the entries made. There is nothing connected with a post or battery by which an officer can more completely earn the thanks of his successors than by leaving these books in proper condition; that is to say, in the condition they were intended to be left when the instructions were formulated: "So that an officer taking charge will find all the information he can require, ready at hand, and in the fullest detail."

PROFESSIONAL NOTES

THE LATEST 12-INCH BREECH-LOADING WIRE-WOUND GUNS

On pages 64 and 65 we publish drawings of a 12-in. breech-loading wire-wound gun and details of its breech gear, designed by Messrs. Vickers, Sons and Maxim, together with the drawings of the Royal Ordnance Factory's 12-in. gun, Mark VIII., and the latest Woolwich 12-in. gun, Mark IX., for comparison with those which are the subject of this paper.

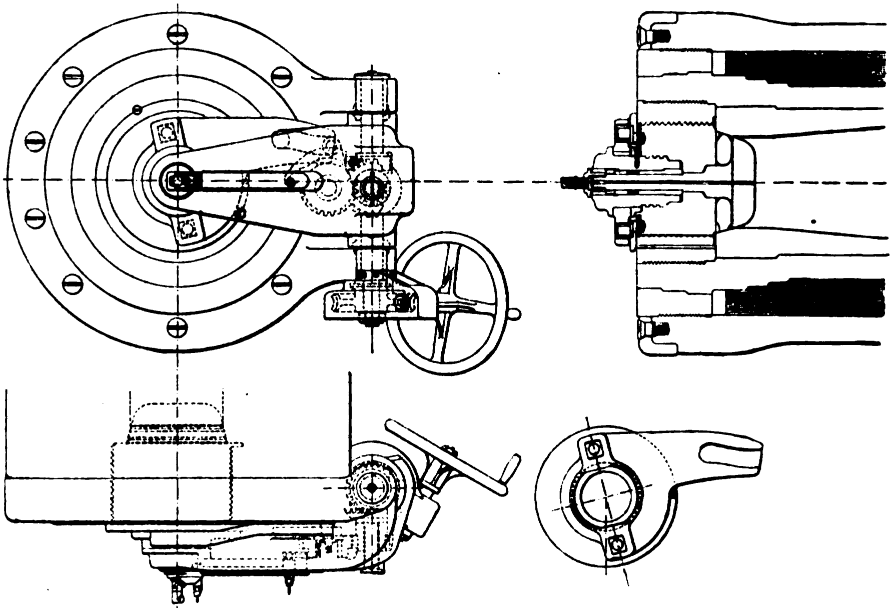
The figures recorded, as illustrating the powers of the Vickers, Sons and Maxim guns, are obviously not all given as the result of the actual firing trials, but certain of them are calculated penetrations with the high velocities specified, carefully based on the actual penetrations which have been obtained with lower velocities. The new 12-in. gun has a total length of 556.5in., or 46.375 calibers, the length of the bore being 540in., or 45 calibers. Thus it is 5 calibers longer than the latest Woolwich pattern, Mark IX., and considerable stronger towards the muzzle, as, although stretched out in the chase to a further length of 5ft., it is still 22in. in diameter behind the muzzle swell. In the drawing given the powder pressures are noted at five different positions within the bore of the gun, and range from 18 tons to the square inch, against a circumferential strength of 34.4 tons per square inch, to 7.65 tons to the square inch, against a circumferential strength of 16.1 tons to the square inch.

The powers of the latest Vickers-Maxim guns are, partially by actual experiment, partially by calculation, found to be as follows :—

Penetration of Steel Plates.

Gun.	Weight of projectile.	Muzzle velocity.	Thickness of Krupp-cemented plate penetrated by capped shot.	Thickness of mild steel plate penetrated by armor-piercing shot (uncapped).
	lb.	Foot-secs.	in.	in.
12-in.	850	2850	24.3	—
9.2-in.	380	3048	20.0	—
6-in.	100	3050	12.25	—
4-in.	31	2900	—	11.5
3-in. 76.2mm.	14	2450	—	7.9
6-pdr. 57mm.	6	2475	—	5.25
3-pdr. 47mm.	3.3	2800	—	5.1

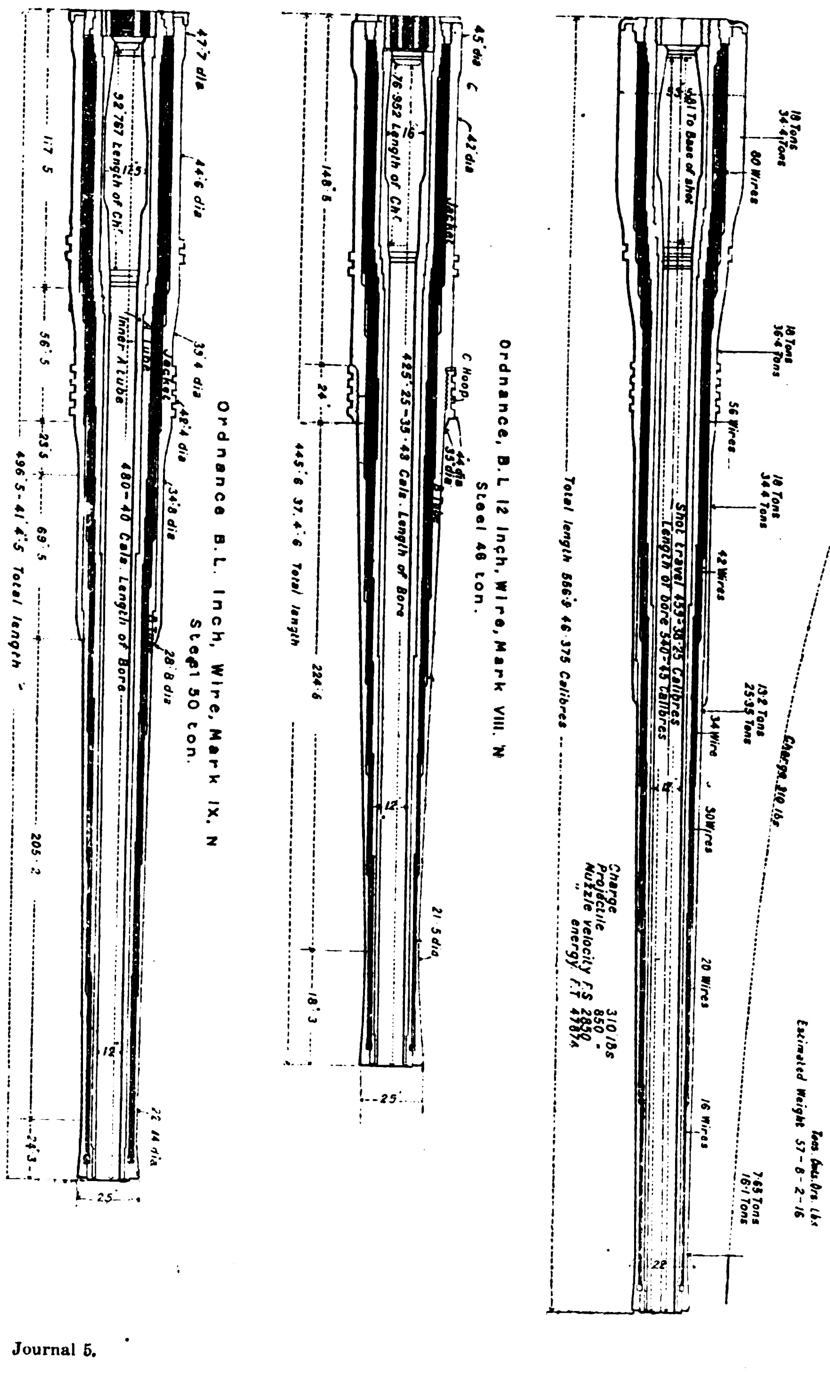
The breech mechanism for their 12-in. gun is of a new and improved type, giving considerable increase of power when closing the breech, and is operated by a hand wheel, with worm and worm-wheel gear mounted in a suitable bracket on the end frame of the gun. The worm and wheel gear is arranged so that seventeen turns are required completely to operate the breech mechanism, 12.2 turns to unlock the breech, and 4.8 turns to swing the mechanism out to "fully open" position. The breech screw is the "Vickers" type, and is mounted and retained on the stem of the carrier by interrupted screw threads.



Breech Mechanism for Vickers' 12-Inch Gun.

One of the chief features of this mechanism consists in the application of a pure "couple" for rotating the breech screw. In breech mechanisms as at present generally constructed the breech screw is rotated by a turning moment which has been found to set up considerable friction, owing to the tendency of such moment to occasion axial displacement of the breech screw. By applying a "couple" for this purpose, this difficulty is obviated, so that the whole of the available turning force applied to the breech screw is utilised in seating the obturator.

The arrangement for actuating the breech screw is as follows:—The rear face of the block is provided with studs diametrically opposite to each other. Around these studs are fitted two sliding blocks, which engage with corresponding holes in a lever plate having a long grooved arm. The lever plate is pivotally mounted on the same axis as the breech screw. It is not, however, directly pivoted on to the stem of the carrier on which the breech screw rotates, but is fitted around a sleeve, which sleeve surrounds part of the stem of the carrier to the rear of the breech screw. The hole in the lever plate is slightly elongated with the respect to the outside diameter of the sleeve, and the holes in the lever plate, into which are


Ordnance B.L. Inch, Wire, Mark IX, N
Steel 50 ton.
480-40 Cals. Length of Bore
496.5-41.4.5 Total length
Inner A Tube
Jacket
Ordnance, B.L 12 Inch, Wire, Mark VIII. N
Steel 46 ton.
425.25-35.43 Cals. Length of Bore
445.6 37.4.6 Total length
Jacket
C Hoop
Ordnance, B.L 12, Inch, Wire
18 Tons Maximum pressure
Total length 556.9 46.375 Calibres
Shot travel 459.38.25 Calibres
Length of bore 540.45 Calibres
80 Wires
56 Wires
42 Wires
34 Wire
30 Wires
20 Wires
16 Wires
Charge 310 lbs
Projectile 850 "
Muzzle velocity F.S 2850
" energy F.T 47800
Estimated Weight 57-8-2-16

fitted the sliding blocks on the studs of the breech screw, are made slightly longer than the blocks themselves; furthermore, a greater clearance than is usually allowed is made between the breech screw and the stem of the carrier on which it turns. This arrangement, together with the clearances just enumerated, ensures that any small inaccuracies in the manufacture of these parts of the mechanism are automatically adjusted, and also that the breech screw is mechanically quite independent of the lever itself, except by its engagement through the studs with their sliding blocks. As a result, when a turning moment is given to the lever, this in turn operates on the breech screw as a pure "couple."

Engaging with the groove of the long arm of the lever plate is a roller pin projecting forwardly from a short crank mounted on the carrier. The form of the groove in this arm is such that the maximum power is exerted when seating the obturator. The pivot of the short crank is provided with a roller bearing, to eliminate as far as possible the friction of the toggle joint action of the crank before the the final operation of seating the obturator. The arrangement of the crank with respect to the groove in the long arm is such that a locking point is formed when the breech is closed. The crank has spur teeth which gear with a pinion formed on a short horizontal shaft, having at its other end a bevel wheel which gears with a second bevel wheel fixed on the axis pin of the carrier. The axis pin of the carrier is operated by the worm and worm wheel gear at its lower end.

A cam plate with a specially formed groove is fitted to the crank for operating the firing gear, which latter is connected to it by means of a sliding link, which directly engages with the cam groove. When the crank revolves the firing gear is moved horizontally across the face of the carrier.

The mechanism may be provided with combined electric and percussion firing gear, or with separate electric and percussion locks. The special features of separate electric and percussion firing gear may be briefly enumerated as follows:—The same box slide is used for either electric or percussion lock. Fitted in the slide is a spring catch for the primer, so that it cannot be jerked out when slamming the breech.

The extractor, which is in two parts, is especially strong, and is of a new form, whereby the operation of the lock frame, acting by means of a fine incline on a prolonged toe of extractor, part 1, first powerfully wedges out the primer previous to its rapid ejection by the engagement of the lock with extractor, part 2.

The box slide has two sets of safety slides, one for the percussion lock and one for the electric lock. The percussion striker is fully cocked automatically on opening the breech, and has a "floating" needle so arranged that in its normal position the point of the needle is always within the face of the lock frame. The electric lock has a special arrangement, consisting of two levers, one on either side of the lock frame, which are simultaneously operated on the first movement of the lock frame on opening the breech. These levers are arranged so that a small projection round their boss trips against the lock slides on the box slide, and as the outer ends of these levers act directly on the electric needle, it is almost instantaneously drawn away from the primer on the first movement of unlocking the breech.

The spring bolts which engage the lock frame with the slide link in the carrier, and engage the slide with the operating cam on the crank, are arranged so that in the case of its being necessary, owing to miss-fire or any other reason, the lock frame may be drawn sufficiently far away to eject the primer without its being necessary to open the breech.

The obturator shown on the design has a split rear outer ring and steel inner ring in direct contact with the pad. The front disc consists of a thin copper cup and a split steel ring. —*Engineer, London.*

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HOTCHKISS 6-PDR. SEMI-AUTOMATIC GUN

The Hotchkiss Ordnance Company, Limited, has made important recent improvements in its semi-automatic guns. Through the courtesy of Mr. L. V. Benet, of that firm, we are enabled to reproduce an excellent photograph of the Hotchkiss semi-automatic 6-pounder of 57mm-caliber (2.14-in.) and 58 calibers in length of barrel.

The advantages to be obtained by the adoption of the semi-automatic system are important and definite. The rapidity of fire of guns fitted with this gear is much greater than in the case of the ordinary quick-firer. In some trials carried out on the Continent not long since with a Hotchkiss semi-automatic gun, as many as forty unaimed rounds per minute were fired. This is the maximum speed of unaimed fire for a gun of this type. The maximum rapidity of the ordinary quick-firing gun, unaimed, is about twenty-eight rounds per minute. In the case of aimed fire the semi-automatic gun will fire from twenty to thirty rounds per minute, according to the range, against fifteen to twenty with the ordinary quick-firing gun. In a recent official trial upon the Continent the rapidity of aimed fire at 1200 m. was thirty-one rounds per minute, with the large proportion of 95 per cent. of hits. The rapidity of fire above referred to can be secured with a gun crew of only four men, whereas the ordinary quick-firing gun requires five men. The third important advantage is the absolute safety of this system. By the adoption of the semi-automatic gear the breech does not open until the gun is fired, so that the accidents which sometimes arise from hang-fires, etc., are rendered at once impossible.

Gun body.—The gun body is constructed entirely of nickel-steel, comprising a tube, the bore of which is rifled with 24 grooves; the twist is uniform with an angle of 7°;

the jacket,
the sleeve,
and a locking ring.

Breech mechanism.—The breech mechanism comprises a vertical sliding block similar to that universally employed in the standard Hotchkiss quick-firing guns. The percussion and firing mechanism is of a special type which comprises but a single spiral spring. By an ingenious arrangement, this same spring not only drives forward the firing pin, but upon releasing the firing lever, automatically brings the gun to full cock. By this arrangement, the primer may be repeatedly struck without opening the breech. Safety against premature discharge is assured by the fact that the firing pin is never in a line with the axis of the bore until the breech is fully closed and locked. The firing lever is placed conveniently to the hand of the gunner.

Semi-automatic mechanism.—The semi-automatic mechanism is of the Hotchkiss standard pattern, but comprises several important improvements in detail. Two extractors are fitted to the gun and the entire mechanism, including the stop-bolt, is so arranged that every detail may be dismounted without the use of any tool. The simplicity of the working parts of the semi-automatic gear, including breech block, crank handle, and extractor, is most marked.

Mounting.—The mounting is of the Hotchkiss standard single cylinder type, the returning spring is mounted in the hydraulic cylinder, which latter is provided with grooves of variable section, computed to give a uniform resistance during recoil. It comprises:

1. A slide comprising the hydraulic cylinder, which is assembled to the gun body by means of a series of annular ribs. A longitudinal key prevents any rotation of the gun due to the reaction of the rifling.

2. A trunnioned cradle, to which the forward end of the piston is attached and which is provided with guides engaging with the cradle.

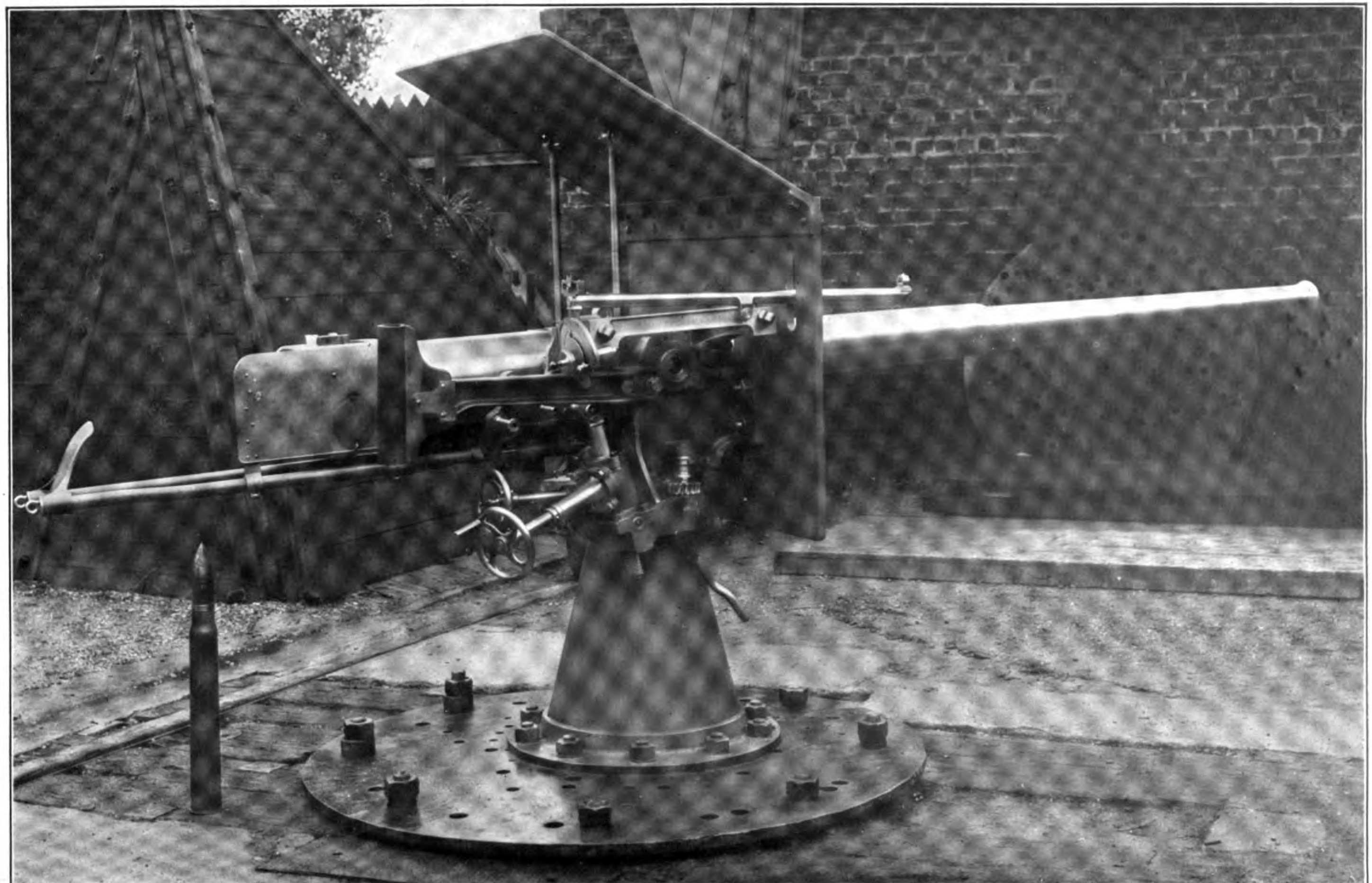
3. A fork-shaped pivot supporting the trunnions of the cradle and which is supported on a foot-step ball bearing. On the pivot is mounted the elevating and training gear, and the shoulder-piece.

4. A conical pedestal, built up of steel plate and provided with a base-plate through which pass the holding-down hooks.

Elevating gear.—The elevating gear is composed of a heavy screw attached to the cradle and supported by a trunnioned box containing a pair of mitre gears controlling a nut engaging with the screw. The whole is commanded by a hand wheel conveniently placed to the hand of the gunner. Two couples of Belleville springs are interposed between the cradle and the head of the elevating screw.

Training gear.—The training gear comprises a circular rack fitted to the pedestal and a pinion mounted on the pivot engaging with the rack. On the same spindle with this pivot is mounted a worm wheel with which engages a worm commanded by the training hand wheel. A clutch is interposed between the worm wheel and the pinion, and this is operated by means of a handle in the center of the latter. By a single motion, the clutch may be drawn out of adjustment and the gun trained directly by the shoulder-piece.

Sighting arrangement.—The sighting arrangement, which is of the bar type, has been specially studied with a view of producing a greater rapidity and accuracy of fire. It is mounted on brackets bolted to the cradle of the carriage and consequently does not participate in the movement of recoil. It comprises a bar pivoted near its forward end and supported to the rear by a toothed sector. This sector is engaged by a spiral worm which holds the sight positively in position at any angle. The worm is controlled by a small hand wheel so proportioned as to permit a very rapid lowering of the sight. The graduations are engraved on a quadrant plate and the actual setting of the sight is indicated by a pointer gear with the hand wheel. By this arrangement it has been possible so to mark the graduations that they, as well as the position of the pointer, are distinctly visible from a distance. This permits of a constant supervision of the setting of the sights of a number of guns. On the bar, two ranges of sights are provided. One of the ordinary open pattern; the second a peep sight for accurate firing. This latter is arranged to give a relatively large field of vision and except at the longest ranges is practically equivalent to the telescope. In thick weather, the peep sight has been demonstrated to be superior.



Hotchkiss Six-Pounder Semi-Automatic Gun.

DEVELOPMENT OF SMOKELESS POWDER

Mr. F. W. Jones in "Arms and Explosives" for July, in a paper on the development of smokeless powders, in which he quotes largely from Captain Ames' paper, "Ammunition for Cannon," recently published in the JOURNAL, comments on the same, saying that the experience of the United States is a useful object lesson on smokeless powders, and concludes as follows:

"The United States are still in search of a perfect powder. We cannot pretend to instruct, but the history of smokeless gunpowders points very clearly to the general characteristics of the powder of the future. Let us consider these under the various heads:

Composition.—This will be determined first by manufacture and secondly by erosion. Pure nitrocellulose powders possess one insurmountable objection when made in grains of large dimensions, because it is impossible to get rid of the solvent during manufacture. The presence of nitroglycerine and some other possible liquid ingredients lessen this difficulty. Therefore, the presence of about 25 per cent. nitroglycerine is most likely to be finally adopted. Whether this will be combined with soluble or insoluble guncotton will depend on the solvent used. The amount and nature of the moderator influence manufacture, because many substances will assist the elimination of the solvent as well as help gelatinization, and are neverthelese quite as effective as moderators of combustion. In England, we fear this has never been fully realized, because vaseline the moderator used in cordite has nothing to recommend it except perhaps its stability. Composition entirely controls the temperature of combustion and hence erosion to the extent that this depends on temperature. It cannot be said with certainty that erosion is proportionate to the temperature of combustion, but other things being equal, the coldest powder must have the advantage in this respect. There is a view prevalent that when a gunpowder contains nitroglycerine it must have hot flame. This is not so, a compound containing as much as 25 per cent. nitroglycerine can be combined with a moderator to produce a temperature of combustion even lower than that of a high nitration soluble guncotton.

Solvent.—This is determined to a great extent by the composition and nature of manufacture. The effect of solvents of equal power on the physical and chemical nature of the product has not been exhausted. It is a remarkable fact that so little has been done with gunpowders containing nitroglycerine and soluble nitrocellulose gelatinized by ether-alcohol, and therefore experience at present can tell us little or nothing as regards the effects on stability of such a solvent as acetone in comparison with ether-alcohol or a similar solvent. In this respect one has to remember that when the time factor extends over years, a very slight disposition of the solvent or its impurities to promote instability becomes evident. Consequently one may expect the solvent and its effect on stability to occupy the attention of the chemist of the future. Should ether-alcohol be found the better solvent from the point of view of stability this would determine guncotton as the best base for gunpowders of the future. Such a result is not at all improbable.

Granulation.—One might say that the United States' experience has given the death-blow to fancy granulation. The advantages obtained from perforated grains are far outweighed by the dangers. Our own cord form of granulation may be taken merely as showing that a round hole is easier to drill than any other : certainly there is no other reason for its adoption, because it is the very worst form of granulation. A flat sheet or fairly wide tape has everything to recommend it. The burning area does not decrease too much as combustion proceeds, and there are no holes to cause irregularity. In fact, in this characteristic a simple form as is often the case is practically the best."

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CONCERNING FIELD ARTILLERY

As we all know, Germany made an economic mistake when she adopted a new field gun which is known as the 1896 model. Doubtless this is a very good gun, but it is not as good a gun as the French produced a couple of years later. The existence of this gun and its French superior have set the military writers in Germany to work with a will for the last six years. As it has been at last admitted on all sides that the French gun is the better, and that a fresh rearmament of the German field artillery is now a necessity, the most debated points are whether the French were right or wrong in other innovations which they made when they introduced their new gun, the chief point being the question of the reduction of the number of guns in the battery from six to four.

The German critics have divided themselves into two schools, and have spilt much ink in their attacks on each other. The one section supports all the French innovations, while the other considers that Germany knows as much about artillery as France is likely to teach her, while, of course, now admitting the initial mistake of the Fatherland in not waiting a couple of years before introducing its last equipment. Lieutenant-General von Rohne, who is the leader of what may be called the pro-French school, was for some time opposed to its teachings; but since his conversion he has acted with all the ardor and vigor of conviction of a proselyte. It would be very laborious to follow closely all his arguments, but they come very much to the following conclusions:—That the French did strike the oil of modern artillery invention when they invented the quick-firing long-recoil field gun, and that they certainly can get more fire effect from one gun than any other Power in Europe could get from two of their old guns. Then he agrees with the French school in the belief that modern artillery is meant to be a distant bullet-sowing machine, and not a weapon designed to hit a bull's-eye and distribute bullets round that object. Not that the modern gun cannot do this as well, if not better, than any of its predecessors; but that is not the object. From this point he swallows, with the least possible quantity of salt, all the niceties of the French system of ranging and fire discipline, and with it the doctrine of the four-gun battery. Now this reduction has meant that France has been able to do with one-third less artillery for six years, her possible enemies all being armed with a vastly inferior weapon. Von Rohne, however, uses his powerful pen on every possible occasion to explain to the German nation that they should also reduce their artillery by one-third when they rearm with a quick-firing gun. His chief arguments, which are in no way supported by any war experience, are that an army corps cannot find room for more than 96 guns when deployed for battle, and also that any battery of more than four quick-firing guns is so unmanageable that all the advantage of the new guns is lost. He maintains that the fire discipline and fire tactics are really dependent on the four-gun battery being the unit.

The French seem to have good reasons for liking their four-gun batteries. When they had gained the advantage over the other armies in Europe of two to one, they could well afford to study economy to the extent of reducing the number of guns in their batteries, but they did not reduce the number of their batteries in an army corps. In fact, it seems to have been the original intention to have increased the number of batteries slowly until the number of guns in the army corps had reached the previous total. This has, however, not been done, the chief difficulties being the want of officers, men, and money for the enormous increase thereby entailed. There have been various rumors that the French were going to increase the number of guns in their batteries to six, which would not be nearly so expensive as increasing the batteries. These rumors von Rohne attributes to his Geman enemies, and not to any French source, since he knows the German school wish to carry out the change in equipment without any reduction in the number of guns in the army corps, and who would also prefer to see six-gun batteries, but it would not insist on this second point so long as the total number of guns is not reduced.

The arguments of the German school may be summed up as follows :— (1) If it were possible in the year 1896 to find room for 144 guns in a deployed army corps, there can be no reason why this cannot be done in 1906, explaining that two tiers of fire are much more easily obtained with modern guns and modern sighting. It has not been noticed anywhere that they claim any greater extension for an army corps now than formerly, though recent wars would certainly point to this as a possibility; but perhaps the German regulations have not as yet reflected the experience of the present war in this respect. (2) That when the magazine rifle was introduced it never struck anyone to suggest the reduction of the battalion to 750 men, because 500 men with magazine rifles were of more fighting value than 1,000 men with single loaders, and that their fire was harder to control. They argue that what would have been absurd for infantry is also absurd when applied to artillery. (3) They deny that the control of fire is very much, if any, better with small batteries, and consider it to be almost entirely a question of training, and with much reason they hold that the chain of artillery command will work more easily with the larger batteries. (4) They also maintain that with small batteries ranging will be more difficult, as there will be more batteries, and the fire of one will interfere with and be mistaken for that from another.

Von Rohne has urged the question of ammunition supply as a bye issue. There does not seem to be much in this, as no one can hope to keep quick-firing guns supplied if they are allowed to fire away all the time. The effect of such fire would be comparatively little. What is wanted is to silence or destroy tactical targets as they appear in the desert of the modern battlefield. Why, even with the slowest firing gun we could fire one round a minute, and at that rate two-and-a-half hours would suffice to exhaust all the ammunition immediately available with the present equipment in our service. So we see that the control of artillery fire is no new thing. The sowing of an area rapidly with shrapnel bullets is bound to be expensive in shell. It appears to be a process which is at times necessary, and the Japanese without a quick-firing gun are reported to have used it with success. But the Japanese must have also husbanded their ammunition with the greatest care, in order to make it last for a ten days' battle, even allowing for the most perfect system of supply. In fact, we may say with perfect certainty that it is modern conditions of war which cause the great expenditure of ammunition, and not the existence of the quick-firing gun, and any argument which urges this expenditure as a reason for reducing the number of guns must be very weak indeed.

So much for the French and German views on field artillery. How do they affect us in our dealings with our new gun? Probably not at all. We can certainly not afford to reduce our guns to four per battery without increasing the number of batteries, as that would leave us with only about three-fourths of a gun to 1,000 men in India; a Russian army, if it ever goes to India, will have over four guns per 1,000 men. At home we would only have about one-and-a-half gun per 1,000 men if we include the Militia and Volunteers, and no sane man can expect them to fight without artillery. The French have with their quick-firing gun over 3½ guns per 1,000 men, and the Germans at present about 5½ per 1,000. Even with our six-gun batteries we are in a miserable condition as regards artillery, be they as quick-firing as it is possible to make them, and be the arrangements for supply of ammunition perfect.

The suggestion to increase our field artillery to 225 batteries of four guns each would certainly be thrown out by the Treasury, however advantageous it might be, on the score of expense. The great advantage of having 225 four-gun batteries would be that they might eventually be increased to six guns, and then our artillery would not be so dangerously weak. It is always dangerous to try to prophesy, but it seems certain that, if Germany adopts six-gun batteries with her new equipment, France will increase the number of guns in her batteries to the same number, even though there be the greatest difficulty in finding men to fight the additional guns. Also the opinion may be ventured that, despite von Rohne and all his theories that war will prove, six-gun batteries will wipe out four-gun batteries, unless there are three of the latter against two of the former, if they are equally well fought by the commanders senior to the battery commander. It is these senior artillery commanders who have the most important duty, and their duty is made easier with the larger batteries and fewer units.—*Army and Navy Gazette.*

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THE BATTLE OF THE SEA OF JAPAN

THE APPROACH OF THE BALTIC FLEET

It may be said that from the Japanese point of view the Baltic Fleet was not regarded as a serious factor until it entered the waters of French Indo-China. Up to that time obstacles almost insuperable had seemed to bar its path to the arena of battle. For if, after passing the Strait of Malacca, the Russian Admiral had not found, as it was reasonable to expect that he would not find, any friendly ports where his ships, lying securely, might coal, provision, and equip after their long voyage from Madagascar; if it had not been possible for him to appoint a safe trysting-place where the Third Squadron, three weeks belated, could be sure of finding him; if for all these purposes the only accessible area had been the fog-ridden, tempest-tossed waters of the China Sea, then certainly his enterprise must have been doomed to failure—so plainly doomed that its very inception would have appeared almost an act of madness. Perhaps a really close scrutiny of the whole conditions should have made it clear that from the moment of quitting Madagascar—from the moment of deciding that junction with the Third Squadron, an important section of his force, should follow instead of preceding his arrival in Far Eastern waters—Rozhdestvensky possessed confident knowledge of the benevolent assistance awaiting him in French ports. Nevertheless France continued to be credited with strictly neutral intentions, and the public were for the most part content to lose themselves in conjectures as to whether the Russian Admiral would be defeated by physical difficulties before closing with the Japanese fleet, or whether he would solve the problem by seizing some Chinese or Dutch harbor and converting it into a base in defiance of the Hague and of Peking. In short, his expedition lagged so much in its early stages, showed so little competence to overcome its preliminary embarrassments, forfeited its opportunities so palpably, and seemed so impotent for final purposes without some desperate violation of neutrality, that it became ultimately an object of apathetic conjecture rather than a serious menace.

THE REASONS OF JAPANESE CONFIDENCE

A complete and sudden change of view took place, however, when it became evident that the Indo-Chinese ports were to be placed at Rozhdestvensky's disposal. Immediately his hitherto semi-mythical force became a practical reality and the Japanese saw he was to be led to their very door by the hand of a Power which they had implicitly trusted to stand neutral. It is a fact worth noting that, much as this development shocked Japan's sense of fairness, it did not at all shake her confidence. She protested in tolerably loud tones of indignation—so loud that some mistook them for signs of trepidation. But the pulse of the nation—the Stock Exchange—remained undisturbed throughout. There were no fluctuations. The people implicitly trusted their sailors to beat the Russians, whatever facilities the latter might derive from breaches of neutrality. This confidence becomes remarkable when the issues at stake are considered. Not the mere command of the sea was in question; collateral consequences of the gravest nature were involved. If Rozhdestvensky could crush, or even cripple, his adversary, half a million Japanese soldiers in Manchuria would immediately find their main line of communications severed. The possible magnitude of such a disaster had scarcely any limits. It must have completely reversed the situation. Japan could have had no alternative but to abandon the war and to accept whatever terms might extricate her armies from their compromised position. It will always remain, indeed, a profoundly perplexing problem why Russia did not make this essay sooner. There was a time in 1904 when her squadron in Port Arthur mustered six powerful battleships, one first-class armored cruiser, and four fine protected cruisers, to say nothing of minor craft. On the 10th of August these vessels made an abortive attempt to emerge from the beleaguered port and reach Vladivostok—an attempt which ended in the destruction of one of the protected cruisers, the disarming and internment of a battleship with two other protected cruisers, and the return of the rest to Port Arthur in a condition so crippled that they henceforth ceased to be a fleet *in esse* for the immediate purposes of the war. History will probably describe that sortie as the most stupendous blunder in the whole campaign. There was no apparent reason for it, certainly no pressing necessity. The ships might have remained at least three months longer in port. During those three months Togo's squadrons must have maintained their enervating vigil outside, and during those three months, had expedition at all commensurate with the crisis been employed, the Baltic Fleet, or at any rate a large part of it, might have reached the China Sea.

In that event the naval situation would have been almost desperate for the Japanese. Rozhdestvensky with at least six battleships and five armored cruisers coming from the west could have assailed Togo on one flank, while Vitoft, emerging from Port Arthur with six battleships and one armored cruiser, could have assailed him on the other, and against these twelve battleships and six armored cruisers Togo could not have mustered more than four battleships and eight armored cruisers. Nor was this all. The sinking of the Rurik in the Sea of Japan may be regarded as an incident of the Port Arthur squadron's sortie on the 10th of August. Had the Port Arthur ships remained in harbor, pending the arrival of the Baltic Fleet, the Vladivostok cruisers would necessarily have reserved themselves for the same occasion. In that event Togo, threatened simultaneously from the north, from the east, and from the west, must have detached at least three of his armored cruisers to watch the Vladivostok squadron, and would therefore have found himself with four battleships and five armored cruisers caught between the Baltic and the Port Arthur fleets mustering twelve battleships and six armored cruisers. The man behind the gun could scarcely have redressed such an enormouse discrepancy of fighting material, especially as the Japanese vessels, deprived of leisure to go into dock, must have been even in worse plight than their enemies. Russia, however, missed this unique opportunity. Never did a Power more conspicuously squander its forces in isolated efforts. Even Vladivostok and Port Arthur could not contrive to co-operate effectively. The Port Arthur fleet steamed out to its fate on the 10th of August. The Vladivostok cruisers approached the Tsu Shima Straits on the 14th of the same month. Had the former succeeded in its purpose of breaking through to Vladivostok, the belated sortie of the latter would have been superfluous. Had the Port Arthur squadron been driven back, then the subsequent intervention of the northern cruisers must have merely exposed them to unrequited destruction. Vladivostok certainly succeeded in diverting a section of Togo's force from the main field, but even with his strength thus divided the Japanese Admiral was able to drive the Port Arthur ships back to their death-trap and to shatter the Vladivostok ships so badly that they became thenceforth a negligible quantity. As an example of Russian naval strategy the events of that month added to the belligerent assets of the Japanese navy a large stock of self-confidence. The Baltic Fleet alone remained to be disposed of, whereas a little forethought and management might have combined Vladivostok, Port Arthur, and the Baltic for a joint effort which could scarcely have failed to crush the Japanese navy. Tokio understood all this when it put its hand to the war-plough. Hence the desperate and sanguinary efforts made to capture Port Arthur at an early stage, for who could have foreseen that an intelligent Power would thus neglect its opportunities, or what prudent strategist might have looked for such ineptitude in his enemy?

The really grave peril thus averted, Japan watched, at first with a partially academic interest, the laborious progress of Rozhdestvensky's fleet eastward, and awoke suddenly to a vivid but not startled perception of his potentialities when France was seen to be preparing him for the lists. He lingered nearly five weeks in French territorial waters, loading his vessels with coal and provisions, resting their crews after the long voyage, awaiting the advent of the squadron under Nebogatoff, which joined him in an Indo-Chinese bay, and using French telegraphs to collect any information or effect any arrangements essential to his enterprise. His movements were watched, but since French local officials, while placing the Saigon wires at his disposal, vetoed their use by other foreigners, Japanese agents were at much disadvantage. It became duly known, however, that on May 16 Rozhdestvensky steamed away from Honkohe Bay, his last resting place in French waters, and that his flag was followed by every unit of the fleet originally placed under his command, all in good fighting trim. That in itself was no small feat. To have brought without mishap of any kind from the Baltic to the China Sea this heterogeneous collection of vessels, excluded from every haven *en route* except French ports, showed Rozhdestvensky to be at least a great organizer and a great sailor. The Japanese applauded him unreservedly.

TOGO'S CALCULATIONS

It need scarcely be said that for months public curiosity had busied itself with conjectures as to the route the Russian Admiral would choose. One thing was certain, Vladivostok must be his bourne, since there remained to Russia no other naval base in the Far East. Now, to reach Vladivostok from the China Sea three avenues offered—the Soya Strait, between the southern shore of Sakhalin and the northern of Yezo; the Tsugaru Strait, between the southern shore of Yezo and the northern of Japan proper; and the Tsu Shima Strait, between the southern shore of Korea and the south-western of Japan proper. It was Togo's imperative business to determine which of these routes the Russians would select. He could not guard the three simultaneously; they were too remote from each other. He could not even organize such a system of intelligence as would justify him in concentrating his force in a central position and there awaiting a summons to the threatened point. He saw himself absolutely compelled to make a forecast and to abide by it for good or for evil. His forecast was the Tsu Shima Strait, and he reasoned thus:—Soya involves such a lengthy voyage that to choose it would complicate the coal question for Rozhdestvensky, and, moreover, its approaches present easy opportunities for mechanical obstacles. Tsugaru is a long and intricate passage, especially in the season of fogs, and its narrows are strewn with mines—nominally, at all events. Tsu Shima therefore becomes practically inevitable.

This reasoning deserves to be specially noted, for many critics have assigned Rozhdestvensky's choice of route as a main cause of the disaster that ultimately overtook him. Yet Togo himself would have made the same choice, and saw such valid reasons for making it that from first to last he waited with assurance for the Russians at Tsu Shima. If he doubted at all, it was only lest they should maintain the continuity of their record by doing exactly what common sense did not dictate.

Apart from these considerations, however, the Japanese Admiral had one great cause for uneasiness. If the Russians knew that he was awaiting them at Tsu Shima, the knowledge might outweigh all other arguments and drive them to head for Tsugaru or Soya. Not that they were suspected of reluctance to fight; they had never given any one a right to question their bravery. But to have reached Vladivostok without suffering the smallest hurt, to have gained at once a safe refuge and access to docks as well as to supplies of coal, to have condemned the Japanese fleet to undertake another interminable vigil, to have created a standing menace to Japan's oversea communications, and to have acquired the privilege of choosing their own time for fighting—all these things would have constituted a notable achievement second only to victory in battle. Therefore Togo had to take care lest by proclaiming his presence he should drive the enemy beyond effective reach. At first sight it seems impossible that a great fleet of warships during a period of several months should effectually hide its whereabouts. Yet Togo did it. From March to May he made his chief naval base at Chinhai Bay, a port in Southern Korea, and, though thousands of his countrymen must have known that he was there, they kept the secret inviolate from first to last. The Russians, it is true, were so circumstanced that they could not employ scouts or make reconnaissances. They had to rely on spies solely. Yet, when it is remembered of what vast value any certain information would have been, how many accredited agents Russia had in Chinese ports, how many adventurers were willing to work for her money, and how many friends she had among the foreign communities in Japan, and even in the foreign Legations in Tokio, it is indeed wonderful that Togo's ships were able to lie so long *perdu*.

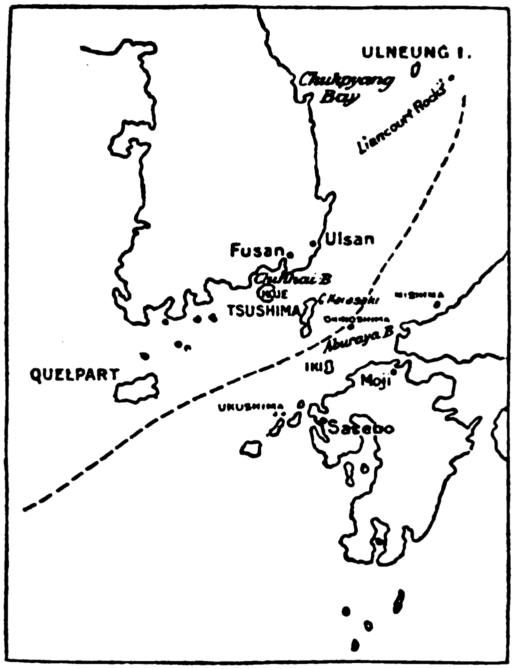
THE LAST STAGE OF THE ARMADA'S VOYAGE

Thus on May 16 Rozhdestvensky moved out of Honkohe Bay, having done everything within the range of skilful leadership to prepare his fleet for the pending ordeal, and having established a title to ultimate success by the resourceful adroitness and calculating courage which had hitherto distinguished his conduct. His way was to be by Tsu Shima. The strategical reasons making for that choice were reinforced by his personal equation, since a risk of encountering the enemy attracted rather than deterred him. But even this decision left two routes available. One was to steam up the China Sea through the Formosan Channel and steer direct for Tsu Shima; the other, to leave the China Sea, pass out into the Pacific, and thence shape a course for Tsu Shima eastward of Formosa. In point of distance neither road had any preponderating advantage. But in other respects they differed. For by advancing up the Formosan Channel Rozhdestvensky would not only make it quite clear that Tsu Shima was his goal, but would also expose himself to attacks by torpedo craft emerging from the harbors of Formosa; whereas by passing out into the Pacific he would avoid the latter danger and would also have the advantage of the double objective, since from the Pacific he could steer either for Tsu Shima or for Tsugaru. On May 19 he made the straits between the Philippines and Formosa, and, after a brief delay for coaling purposes, his fleet steamed out into the Pacific.

In Russia and in Europe generally rumor had been busy about Togo's program. Now he was confidently alleged to be lying in wait for the enemy in the Straits of Sunda. Again, the passages into the Pacific between Luzon and Formosa were indicated as the certain scene of a torpedo *guet-apens*. Anon he was declared to have his base at Kelung in northern Formosa, whence he could strike at the Russians whether they approached by the Pacific or by the China Sea. But, if Togo, analyzing the professional aspects of the situation, divined the Russian Admiral's intentions correctly, Rozhdestvensky, on his side, credited Togo with wisdom sufficient not to relinquish easily the advantages of fighting in home waters. This is shown by the fact that the Russian Admiral made no attempt to sift his squadrons until he neared the coasts of Japan. He kept with him all his heterogeneous mob of ships, his victualling vessels, his colliers, his converted cruisers, and his special-service steamers, impedimenta with which he would never have saddled himself had he looked for an imminent encounter with the enemy. Not until he re-entered the China Sea from the Pacific, thus commencing the last stage of his journey to Tsu Shima, did he dismiss these non-combatant followers. With a few exceptions they were directed to enter the Yang-tsze and there await the issue of the impending struggle. Their appearance off Wu-sung on May 25 created a profound sensation and evoked many bewildered conjectures. But for Japanese naval officers the incident had nothing perplexing. They read it as a plain intimation that Rozhdestvensky intended to put his fate to the test at Tsu Shima, since, had it been his purpose to make for Tsugaru or Soya, he must have retained the services of these auxiliary ships during several days longer. It is apparent, indeed, that the Russian Admiral here made his first cardinal mistake; he should have kept his non-combatant vessels out of sight as long as possible. Their absence from the arena would have been a mysterious element, whereas their apparition, especially as a segregated squadron in the Yang-tsze River, furnished an unerring clue to expert observers. This want of judgment becomes the more singular in the context of an adroit attempt which Rozhdestvensky certainly did make to mislead the enemy. A Norwegian steamer, consigned to a Japanese firm and bound for Japan, was visited by Russian cruisers near the Bashi Strait, and after brief detention was released with information that the Baltic Fleet might be expected at Tsu Shima in a few days. Rozhdestvensky knew that this intelligence would precede him to Japan, and he argued that, since the Japanese could not possibly credit him with sincerity in such a matter, they must interpret the news in an opposite sense. Further, to color the deception, he slowed down, so that the Japanese, who knew the exact distance he had to travel from the point of the Norwegian steamer's release to Tsu Shima, and knew also the average speed at which he had hitherto travelled, might construe his non-appearance in due time as a proof that he had steered elsewhere. In point of fact this incident did cause some anxiety.

THE BALTIC FLEET IN SIGHT

When May 25 came and went, and when the 26th came and went, without any appearance of Rozhdestvensky's fighting ships, the Japanese waiting at Tsu Shima must have begun to suspect anxiously that he had gone elsewhere. But at 5 a.m. on the 27th one of their guardships, many of which were posted at various points in the seas southward of Tsu Shima, reported by wireless telegraphy—"Enemy's squadron sighted in No. 203 section. He seems to be steering for the East Channel." To understand this message it is necessary to observe that, for facile conveyance of information, the whole area of sea between the island of Quelpart and Vladivostok had been parcelled out by the Japanese into squares like those on a chess board. Each square had its number, and, when "203" reached Togo's staff at dawn on the 27th, maps lying before them showed the exact point where Rozhdestvensky's ships had been sighted. Incidentally it may be mentioned that for the Japanese public at large "203" possessed a significance of its own. The capture of Two-Hundred-and-Three Metre Hill had sealed the fate of Port Arthur, and that the first phase of the great naval battle should be a report from 203 section seemed a singular and suggestive coincidence. As for the "East Channel" mentioned in the same message, the explanation is that the sea between southern Korea and western Japan is divided mid-way, by the island of Tsu Shima, into two passages, of which that on the Japanese side is called the "Eastern Channel," that on the Korean side "the Western." This message meant then, that certain Russian ships were drawing up from the direction of Quelpart towards the eastern avenue of the Tsu Shima Straits.



Map to illustrate the battle.

But what ships? The morning was foggy and the exact nature of the approaching vessels could not be clearly ascertained; they might be Rozhdestvensky's main fighting force, or they might be only his minor craft, offered as sacrifices to engage the attention of the Japanese in the south while the battleships and their strong consorts forced the northern avenues. Not until nearly noon was this all-important question answered definitely. Admiral Togo then knew that the full fighting force of the two Baltic Squadrons was entering the East Channel of Tsu Shima, and that the danger of a mere diversion need no longer be apprehended. It is worth noting that when he telegraphed the fact to Tokio a feeling of profound thankfulness at once prevaded official circles. That the two fleets should meet fairly and squarely seemed a matter of congratulation to men so confident of the result as were the Japanese.

THE CONTENDING FORCES

Neither of the squadrons now approaching each other to fight one of the most momentous naval battles in the world's history possessed such a preponderance of strength as to render the issue at all certain. The details were as follows :—

THE RUSSIAN FLEET OF THE FIRST LINE.

1. Borodino—battleship; 13,516 tons displacement; 18 knots speed; completed in 1904; armor, complete Krupp steel belt 9 inches amidships tapering to 4 inches at ends; main armament, four 12-inch guns in pairs in turrets, twelve 6-inch in pairs in secondary turrets.

2. Imperator Alexander III.—battleship; sister of Borodino; completed in 1904.

3. Orel—battleship; sister of Borodino; completed in 1904.

4. Kniaz Souvaroff—battleship; sister of Borodino; completed in 1904.

5. Oslyabya—battleship; 12,674 tons displacement; 19 knots speed; completed in 1901; armor, Harvey steel belt 9 inches amidships tapering to 6 inches 30 feet from bow and stern; main armament, four 10-inch guns, ten 6-inch in casemates, one 6-inch in unarmored bow battery.

6. Sissoi Veliky—battleship; 8,880 tons displacement; 16 knots speed; completed in 1894; armor, partial compound 11.8-inch to 15.7-inch belt, 247 feet long and 7 feet deep; main armament, four 12-inch in pairs in turrets and six 6-inch in upper redoubt.

7. Navarin—battleship; 9,476 tons displacement; 16 knots speed; completed in 1895; armor, partial belt 14-inch to 16-inch for 212 feet; main armament, four 12-inch in turrets and eight 6-inch in superstructure.

8. Imperator Nikolai I.—battleship; 9,700 tons displacement; 15.9 knots speed; completed in 1892; armor, complete composite belt 6-inch to 14-inch and 8 feet wide; main armament, two 12-inch, four 9-inch, and eight 6-inch.

9. Admiral Oushakoff—seagoing coast defense ironclad; 4,648 tons displacement; 16 knots speed; completed in 1895; armor, Harvey steel belt 10-inch to 7.8-inch and 176 feet long; main armament, four 9-inch and four 6-inch.

10, Admiral Seniavin—sister to Admiral Oushakoff.

11. Admiral Apraxine—seagoing coast defense ironclad; 4,126 tons displacement; 15 knots speed; completed in 1898; armor, Harvey steel belt 10-inch to 7.8-inch and 176 feet long; main armament, three 10-inch and four 6-inch.

12. Admiral Nahkimoff—armored cruiser; 8,524 tons displacement; 16.7 knots speed; completed in 1888 and reconstructed in 1900; armor, complete compound belt, 10-inch to 6-inch; main armament, eight 8-inch and 6-inch.

13. Dmitri Donskoi—armored cruiser; 6,200 tons displacement; 15 knots speed; completed in 1885; reconstructed in 1896; armor, complete 7-inch belt; main armament, six 6-inch.

14. Vladimir Monomakh—armored cruiser; 5,593 tons; 15 knots speed; completed in 1885 and re-armed in 1898; armor, complete complete compound belt, 10.inch to 6-inch; main armament, five 8-inch and twelve 6-inch.

THE JAPANESE FLEET OF THE FIRST LINE.

1. Mikasa—battleship, displacement, 15,200 tons, 18 knots speed, completed 1900, armor, Krupp steel 9-inch to 4-inch, main armament, four 12-inch guns, and fourteen 6-inch.

2. Asahi—battleship, displacement, 15,200 tons, 18 knots speed, completed 1899, armor, Harveyed nickel steel belt 9-inch to 4-inch, main armament, four 12-inch guns, and 14 6-inch.

3. Shikishima—sister ship of the Asahi, completed 1898.

4. Fuji—battleship, displacement, 12,300 tons, 18 knots speed, completed 1896, armor, partial Harveyed belt 14-inch to 18-inch, main armament, four 12-inch and ten 6-inch.

5. Asama—armored cruiser, displacement, 9,750 tons, 23 knots speed, completed 1898, armor, Harvey nickel steel complete belt 7-inch to 3½-inch, main armament, four 8-inch and fourteen 6-inch.

6. Tokiwa—sister ship of Asama.

7. Idzumo—armored cruiser, displacement, 9,800 tons, 22 knots speed, completed 1899, armor, complete Krupp steel belt 7-inch to 3½-inch, main armament, four 8-inch and 14 6-inch.

8. Iwate—sister ship of Idzumo.

9. Yakumo—armored cruiser, displacement, 9,850 tons, 20 knots speed, completed in 1899, armor, complete belt 7-inch to 3½-inch of Harvey nickel and Krupp steel, main armament, four 8-inch and twelve 6-inch.

10. Adzuma—armored cruiser, displacement, 9,456 tons, 21 knots speed, completed 1899, armor, complete Harvey nickel steel belt 7-inch to 3½-inch, main armament, four 8-inch and twelve 6-inch.

11. Kasuga—armored cruiser, displacement, 7,700 tons, 20 knots speed, completed 1904,

armor, complete belt Krupp steel 6-inch, main armament, one 10-inch, two 8-inch and 14 6-inch.

12. Nisshin—armored cruiser, displacement, 7,700 tons, 20 knots speed, completed 1904, armor, same as Kasuga, main armament, four 8-inch and fourteen 6-inch.

The ships in these tables constituted the real fighting forces of the two navies. There were also on each side a number of protected cruisers—six Russian and sixteen Japanese—but such vessels serve mainly as the eyes and ears of a fleet, and cannot contribute anything material to the result of a battle in which armored ships are engaged. It thus appears that the Russians had fourteen fighting ships against twelve Japanese. If the armaments of the two forces be examined, the following are the results:

ARMAMENTS OF THE OPPOSING NAVIES.

	12-in.	10-in.	9-in.	8-in.	6-in.	Totals.
Japanese	16	1	0	30	160	207
Russian	26	7	12	13	121	179

The numerical superiority was on the Japanese side, but in the heaviest classes of ordnance—9-in., 10-in., and 12-in.—the Russians had an enormous advantage, their cannon numbering 45 against the Japanese 17. Had it been possible for Rozhdestvensky to choose his own distance and maintain it, he certainly would have fought at long range throughout, thus benefiting to the full by his heavy metal. Such, in fact, was the program anticipated by many of his countrymen in Russia. But in order that a squadron may choose its own range, it must be able to maneuver at a higher speed than the enemy, which is precisely what Rozhdestvensky could not do. Considered with regard to speed his fleet fell into three divisions. First, five new and powerful battleships capable of developing and sustaining a speed of 16 to 17 knots. Secondly, a group of six protected cruisers—the Aurora, the Oleg, the Izumrud, the Jemchug, the Svietlana, and the Almaz—capable of steaming 17½ to 18 knots at least. And thirdly, a squadron of three battleships, three coast-defense ironclads, and three armored cruisers, which, if they regulated their speed by that of their slowest unit (the Nikolai I.) could not develop more than 13 knots, if as much. With such an unequal mob of vessels the Russian Admiral's best plan—supposing his sole objective to be the arrival of a *maximum* number of ships at Vladivostok—would probably have been to make a division, taking the five first-class new and fast battleships through the Tsu Shima Strait, sending the slow squadron of second-class battleships, coast-defense ironclads, and armoured cruisers *via* Tsugaru, and letting the six swift cruisers steer for the Soya passage. But, inasmuch as he endeavored to combine two objects—to crush the Japanese and to reach Vladivostok—the idea of scattering his forces seems to have been intolerable. He kept the whole mob together, thus compelling himself to limit his speed to that of the slowest unit, with the result that throughout the battle he maneuvered uniformly at a rate of 12 knots. On the other hand, Togo's fighting vessels—four battleships and eight armored cruisers—could easily move in company at a speed of 16 or 17 knots, and, in point of fact, they maintained a rate of from 14 to 16 knots throughout the fight. The difference between 12 knots and 14 or 15 does not appear much at first sight, but its practical significance becomes apparent at once, if one fleet be supposed at rest and the other moving at from two to three knots. The latter can evidently place itself as it pleases and choose whatever range suits it with regard to the former.

TOGO'S PLAN OF OPERATIONS

Admiral Togo's original plan of operations embraced the whole interval between Quelpart Island and Vladivostok and covered a space of four days. He had mapped out a battle of seven phases, but with regard to the first and second of them no information has been allowed to reach the public except that the weather rendered them impossible. The third phase was a direct engagement between the two fleets in the southern part of the Japan Sea; the fourth was a torpedo attack during the night following the engagement; and the fifth was the assembly of his surviving ships on the morning after the torpedo attack along a line stretching from the Ulneung Islands to the Liancourt Rocks, and thence eastward towards the Japanese coast, so as to intercept any Russian vessels attempting to escape northward. As for the sixth and seventh phases, they have not been described, and were not carried out, as the course of events rendered them superfluous.

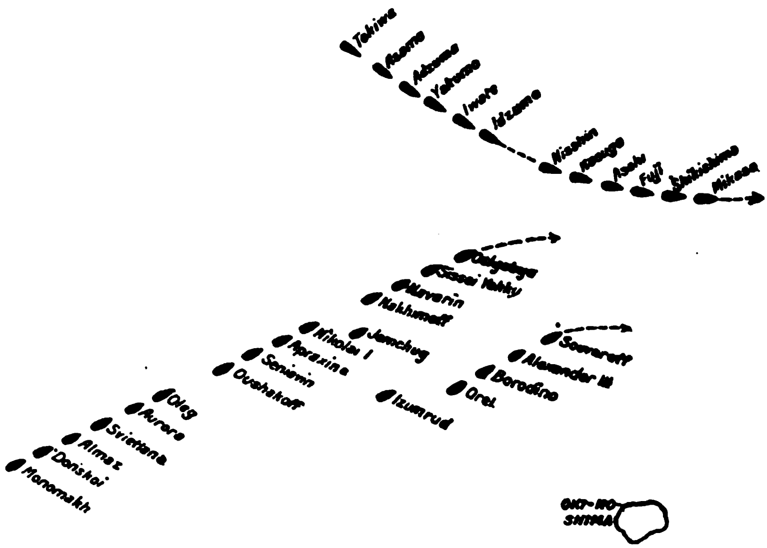
Togo's base being Chinhai Bay on the Korean coast, where the island of Koje effectually sheltered him from observation by vessels passing up or down the Sea of Japan, and his purpose being to assemble his squadron on the eve of the fight in the neighborhood of Oki Island at a distance of nearly 150 miles from Chinhai, it became essential that he should obtain the timeliest information of the enemy's movements. With that object, scouting vessels—cruisers and special-service steamers—were posted at intervals along the routes of approach to Tsu Shima, their instructions being to cling to the enemy if once they sighted him, and to report his doings continuously. So faithfully and so adroitly was this important duty discharged that the wireless telegrams of the scouting ships kept Togo unceasingly informed, and, although a fog rolled over the surface of the sea, the Japanese Admiral knew, from between 10 and 11 a. m., exactly whither the Russians were heading, at what rate they were steaming, and how their vessels were disposed. As for Rozhdestvensky, what he saw as he sailed up the East Channel of Tsu Shima was the frequent apparition of Japanese vessels on his starboard bow, but what their fitful presence portended he had no means of clearly ascertaining. His fleet was not preceded by vedettes, and, judging only by such glimpses as the fog allowed him to obtain of his enemy's maneuvers, he formed the not unnatural conclusion that whatever attack was to be apprehended would come from the north-east. He knew that he was under observation. Since 5 o'clock in the morning the disturbance of his telegraphic indicators had told him that the Japanese were conversing about him. But there was no discernible indication that their main force was in the neighborhood. On the contrary, everything went to indicate the truth of information received by Rozhdestvensky while still in Indo-Chinese waters—namely, that the Japanese had divided their strength, posting the bulk of it on the northern avenues of Tsugaru and Soya, and leaving only a secondary section to watch Tsu Shima. The ships he sighted through the fog were all of inferior quality. Among them was the obsolete battleship Chinyen, a vessel 21 years old, captured from the Chinese in 1895 and no longer capable of steaming more than 12½ knots. The Chinyen had cost the Japanese some anxious moments in the days when their own fleet did not possess so much as one armored cruiser, but she was no longer fit to take her place in the first fighting line, and to have included her in it would have been on Togo's part a mistake analogous to that made by Rozhdestvensky when he marshalled in his ranks side by side with the Borodino and her mates such vessels as the Nikolai I., the Dmitri Donskoi, and the Vladimir Monomakh. One very useful function the old battleship could discharge, however; she might show herself to the Russians among the protected cruisers hanging on their starboard bows, and she might send a few shells in their direction from her 12-in. Krupp guns, thus confirming Rozhdestvensky's impression, that he had only second-class material to deal with. Acting upon that impression, he made his dispositions. They were to form the whole of his fleet into two parallel columns line ahead. The right, or eastern column, consisted of his four strongest battleships, the Kniaz Souvaroff, the Alexander III., the Orel, and the Borodino. The left or western column consisted of four sections. The foremost among these sections comprised the Oslyabya, the Sissoi Veliky, the Navarin, and the Nakhimoff—that is to say, one first-class battleship two second-class battleships, and an armored cruiser. The second section comprised the Nikolai I., followed by the three coast-defense iron-clads. The third section, considerably in the rear, had at its head the protected cruisers Oleg and Aurora, followed by the Svietlana and the Almaz; and the fourth section was led by the armored cruisers Dmitri Donskoi and Vladimir Monomakh, having in their rear six special-service steamers and one converted cruiser. Rozhdestvensky thus observed in part the recognized principle of reinforcing the extremities of a line-ahead formation. The fast cruisers Izumrud and Jemchug held the place of scouts between the two columns.

Meanwhile Togo's fleet, with the exception of a few vedettes, had assembled on the north of Oki Island. The Japanese Admiral now knew all about his enemy's formation and saw that the Russians expected to be attacked from the east. He therefore determined to deliver his assault from the west. His main fighting force had been divided into two squadrons. Of these, the first comprised the four battleships Asahi, Fuji, Mikasa, and Shikishima, with the the two armored cruisers Nisshin and Kasuga, which, owing to the distribution of their armor, were suited for maneuvering in company with battleships; the second consisted of six armored cruisers. These two sections were to engage the enemy's leading columns, while all the protected cruisers were to steer south and direct their attack against the ships of their own kind forming the rear sections of Rozhdestvensky's armada. Thus the battle resolved itself into two distinct actions, one in the north of the field, the other in the south, and these may be considered independently.

THE MAIN BATTLE

Before dividing his fleet for the purpose of a dual battle, Togo signalled:—"The fate of the empire depends on this effort. Let every man do his utmost." He then led his main fighting force south-westward until a convenient position had been reached on the enemy's port side, when, changing his course to the north-east and with his two squadrons in a single column line-ahead, he steered to cross the enemy's bows at an angle of 45°, pouring a concentrated fire on the leading ships, first of the Oslyabya section, and then of the Souvaroff section.

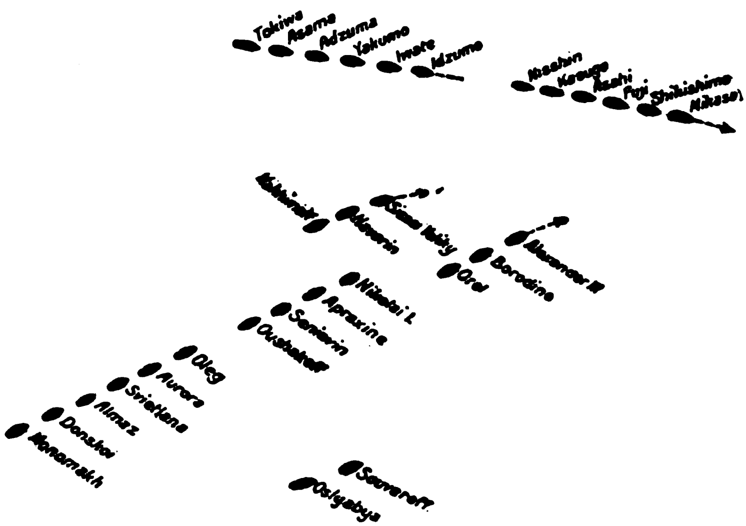
Togo moved at 15 knots, the Russians at 12. A strong wind was blowing from the south-west and the sea ran high, so that gunnery presented many difficulties. The Russians, when they saw Togo bearing down on them from the west, sheered off a little as though to keep a parallel course



and prevent the Japanese from crossing their bows. But that maneuver could not have succeeded without a material increase of speed, and, had the Souvaroff column of battleships put on forced draught, they would immediately have drawn away from the Oslyabya column, which included the comparatively slow Sissoi Veliky, Navarin and Nakhimoff. Fire was opened by the Russians at eight minutes past 2 in the afternoon, at a range of from 9,000 to 10,000 meters. They sought to utilize to the full their heavier metal. But the Japanese did not reply until the distance separating the fleets had shortened to 6,000 metres. These tactics were new from Togo's point of view. Hitherto he himself had always chosen long-range actions, his imperative duty being to avert as far as possible every diminution of his country's strictly limited naval forces. But, being now in the presence of the last considerable fleet Russia could assemble in Far Eastern waters, the moment had come for him to make destruction his main object.

From the very outset it became apparent that the Russian gunners were completely outclassed. Careful observations indicated that in the opening stage of the fight the Japanese scored three hits for every one made by the enemy, and very soon the ratio reached four to one. It was noted that the Japanese bluejackets remained perfectly cool throughout. Scarcely any recourse was had to the buckets of drinking water placed within their reach. Absolute confidence of victory pervaded all ranks, the fighting had become a mere pastime to these veterans, and their enthusiasm was still further roused by the splendid skill of their Admiral in carrying his squadrons over scores of miles towards an invisible enemy so as to meet him at exactly the right spot on this waste of waters. Only sailors could fully appreciate that feat.

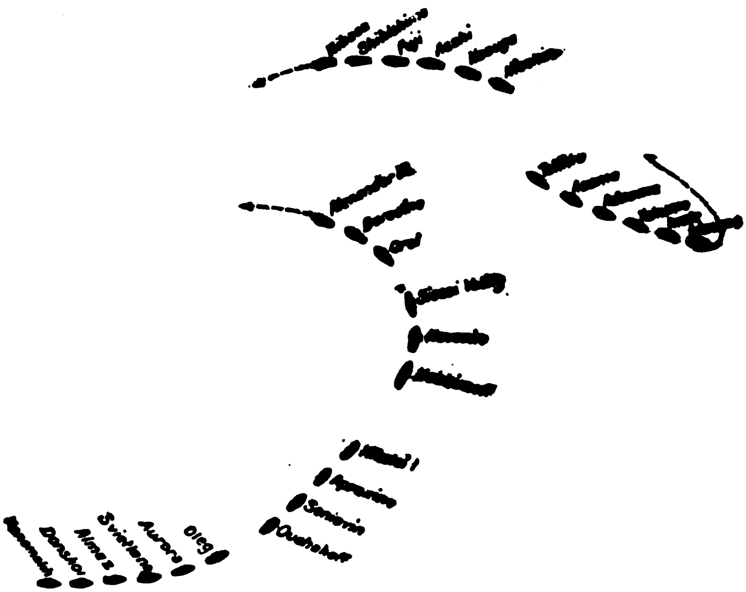
As Togo's squadrons drew up and crossed the Russians' bows the superiority of the Japanese tactics became as palpable as that of their gunnery; for, whereas they poured a concentrated fire on the Oslyabya and the Souvaroff, which led the enemy's columns, the ships in the rear of the latter were unable to train their guns on the Japanese. Under these circumstances the Oslyabya and the Souvaroff were so heavily hit that they burst into flames and had to leave the fighting line. The Russians here made a change of formation. The Oslyabya section (now headed by the Sissoi Veliky) steered a little westward, so as to unblanket the guns of the Nikolai section, and the whole gave increase easting to their course, with the object of drawing parallel to the Japanese.



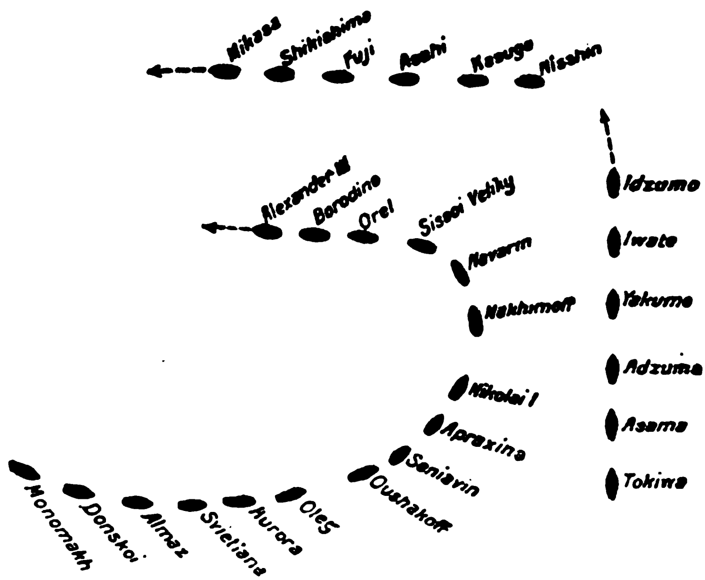
This maneuver proved futile, owing to the superior speed of Togo's force, and finally the Russians, suffering always more and more severely, not only changed direction from the east to the west, but also altered their formation from double column to single column line ahead, the eastern section of battleships placing itself in front of the Sissoi Veliky section, and the whole steering in a direction exactly opposite to that of Togo's force.

In this maneuver the Alexander III. was badly injured and she too, bursting into flames, left the fighting line, so that the Russian force was reduced by three of its strongest units. Togo now put about and, increasing his speed, steered so as to repeat in the west the tactics hitherto pursued in the east—namely, to carry his ships across the enemy's (starboard) bows. This brought his armored cruiser squadron temporarily into line at right angles with his own, so that the two fell into an L-shaped formation, the battleships pouring their fire on the Russians from the north, the armored cruisers from the east.

On the Japanese also some injury had been inflicted. The armored cruiser Adzuma had her steering gear crippled and was leaking so badly that she had to withdraw for a time to repair, and three of the Kasuga's 6-in. guns had been put out of action. But the battle was practically won. Forty minutes had sufficed to shatter three of the best battleships and to hurt several of the others so severely that they became occupied with thoughts of escape rather than of victory. Admiral Folkersahm had been killed in the Oslyabya's conning-tower, and Admiral Rozhdestvensky,



severely wounded, had been transferred to a destroyer, the command-in-chief devolving on Admiral Nebogatoff in the Nikolai.



The Russians now, steering west in single column and seeking to avoid having their bows again crossed by the Japanese, were pushed southward, just as they had previously been pushed eastward, but in little more than an hour (at 3 p. m.) the superior speed of Togo's squadrons carried them once more across the enemy's front. Thereupon the Russians again changed their course to the north, and Togo's battleship squadron, reversing their course so as to bring the Nisshin in front, repeated the old maneuver. This, indeed, was the unvaried feature of the fight: the Japanese again and again crossing the bows of the Russians and the Russians perpetually sheering off to avoid these tactics. A scheme of attack pursued with unremitting tenacity; incomparably more skilful gunnery and superior speed—these were the factors which told in favor of the Japanese. At a few minutes past 3 in the afternoon the Oslyabya sank; the first battleship sent to the bottom by gun-fire alone. Half an hour later the Souvaroff, then presenting the appearance of a wreck, one of her masts and two of her funnels shot away and her hull enveloped in smoke and flame, invited the attention of some Japanese destroyers. In spite of a hot defensive fire from the battleship's consorts, she was hit by a torpedo at 4:45 p. m., and, though not immediately sunk, remained thenceforth in a wholly crippled condition.

At a little before 5 o'clock the Russians, having been for nearly three hours under a deadly fire, which, although marked by great deliberation in its latter stages, had left not one of their principal fighting units without severe injury, made a desperate attempt to escape, by first steering due south, as though intending to flee back to the China Sea, and then turning on their tracks and steaming north-east. Smoke and fog hid them from Togo at the critical stage of this maneuver, and he had headed south for some 30 minutes, believing them to be still ahead, before he realized the truth. Divining then what had happened, and seeing no further serious resistance was to be apprehended, he turned northward himself in pursuit of the Russian main force and sent his armored cruiser squadron southward to join the battle in that part of the field. After a brief interval of steaming at full speed, Togo found the remnant of the Russian main force fleeing in a cluster to the north-east. They numbered six—the Orel, the Alexander III., the Borodino, the Sissoi Veliky, the Navarin, and the Nakhimoff. It subsequently transpired that the Nikolai I. and the other three units of her section (the coast-defense ironclads) had gone south and were assisting the protected cruisers. Once again Admiral Togo, now with only four battleships and two armored cruisers, repeated his tactics of steaming past the enemy and crossing his bows, by which means the Russians' course was deflected first to the west and then to the north-west. This phase of the battle lasted from 6 p. m. to dusk (7:28 p. m.). Five minutes previously the Borodino, which had led the enemy's column, sank. She had been on fire for 43 minutes, and the flames seem to have reached her magazine. The torpedo took no part in her destruction, but neither can she be strictly regarded as a victim of the gun. Another first-class battleship, however, certainly succumbed to artillery. The Alexander III. dropped out of the fighting line and, struggling to the vicinity of the Nakhimoff, turned turtle and went to the bottom at 7:07 p. m.

THE BATTLE OF THE PROTECTED CRUISERS

Meanwhile a battle of protected cruisers had been proceeding vigorously in the south of the field. It has been seen that when Togo shaped a course to bear down on the port flank of the Russian main squadrons, he ordered his protected cruisers to steer south and engage the vessels of their class in the rear of the enemy's line. It is unfortunately impossible to analyse the organization of the protected cruisers in this action. They are known to have been divided into four squadons, but the units composing each squadron have been kept secret. Only two of these squadrons entered the battle from the outset. They were the squadron commanded by Rear-Admiral Dewa—probably the Kasagi, the Chitose, the Yakumo, and the Tokiwa, all vessels of 21 knots or over and carrying 8-in. and 6-in. guns; and the squadron commanded by Rear-Admiral Uriu—probably the Naniwa, the Niitaka, and the Otowa, somewhat smaller vessels than the former, having slightly less speed and carrying nothing heavier than 6-in. guns. Ranged against these on the enemy's side were the armored cruisers Dmitri Donskoi and Vladimir Monomakh, and the six protected cruisers Aurora, Oleg, Izumrud, Jemchug, Svietlana, and Almaz. Dewa and Uriu pursued the same tactics as those followed by Togo, but in an inverted direction—that is to say, instead of bearing down on the enemy's front and crossing her bows, they bore down on his rear and crossed astern, emerging on his starboard. This action they repeated. In the language of the official report "taking advantage of their superior speed, they changed front at their own convenience, sometimes engaging the enemy on the port side, sometimes on the starboard." In point of fact three of the Russian cruisers were faster than any ships in the Japanese navy, but their speed was useless where they had to maneuver with vessels like the Dmitri Donskoi and the Vladimir Monomakh, which could not steam more than 14 knots. No signally destructive results were achieved by this attack. The enemy's formation was broken, and two of his special-service steamers were sunk, but, though his cruisers all suffered more or less, none actually succumbed.

After two hours' fighting the remaining two Japanese cruiser squadrons reached the scene and joined forces with the Dewa and Uriu squadrons. But this reinforcement was more than counterbalanced by the arrival of the Nikolai I. and her comrades, the three coast-defense ironclads. A sharp engagement ensued, and in its course the flagships of Dewa and Uriu had to leaving the fighting line to effect repairs. Within an hour, however, the Japanese armored cruiser squadron, coming down from the north quickly changed the complexion of affairs, the Russians breaking up and fleeing northward, hotly pursued by three of the Japanese protected cruiser squadrons, together with a torpedo squadron. The results of the pursuit were the sinking of another special-service steamer and the final torpedoing of the Souvaroff, which was found lying unmanageable. The battleship fought to the bitter end. Only one gun astern remained serviceable, but her crew worked it to the last.

At nightfall all the Japanese fighting ships, in obedience to Admiral Togo's order, steered northward for the rendezvous at the Ulneung Islands, whence before daylight a cordon was drawn eastward to intercept any Russian vessels heading for Vladivostok.

THE TORPEDO ATTACK

The second phase of the battle, as prearranged, now took place. It consisted of a torpedo attack on an absolutely unprecedented scale. Six squadrons of destroyers and as many of torpedo-boats took part in it. Togo's plan had been to hold the enemy's vessels in the southern part of the Japan Sea, shatter their secondary armament, and then to launch against them a cloud of torpedo craft, which they would be more or less incompetent to resist. Throughout the greater part of the day the prospect of success in this phase seemed very small, for a heavy wind and high seas threatened to forbid all maneuvers by these frail little vessels. Towards evening, however, the wind abated, and, though the waves remained riotous, no question of abandoning the program was allowed to intrude itself. Officers and bluejackets alike felt that the torpedo was now to have its final trial. Since its comparatively trivial achievement at Port Arthur on the opening night of the war it had accomplished virtually nothing, though handled with all the adroitness and resolution indubitably possessed by Japanese sailors. The climatic conditions, indeed, were unfavorable on this crowning occasion, but, if the torpedo can never be deadly except in a millpond sea, it must take rank as an inefficient weapon. For the attack of the enemy's main force five squadrons of destroyers were assigned. One approached from the north, two from the north-east, one from the east, and one from the south-east. For the attack of detached vessels of his main force and of his cruisers, four squadrons of torpedo-boats drew up from the south. Lastly, for the attack of ships which might have steered independent courses, one squadron of destroyers and two of torpedo-boats went out. This terrible onset began at 8:15 p. m. and continued until within an hour of midnight. In several cases the torpedo craft steamed in to such close quarters that the ships could not depress their guns sufficiently to bear on them, and finally the Russians scattered in all directions to avoid their desperate assailants. The results of the attack were that two battleships—the Sissoi Veliky and the Navarin—and two armored cruisers—the Nakhimoff and the Vladimir Monomakh—received their *coups de grace*, while three of the torpedo-boats were sunk, and the casualties through all the assaulting squadrons were 22 killed and 65 wounded.

Such a record must do much to rehabilitate the reputation of the torpedo, though, in view of the number of craft employed and the probably demoralized condition of the Russians, even more signal achievements might perhaps have been expected. It is, nevertheless, the opinon of Japanese experts that, had the sea been calm, scarcely any of the Russian ships would have escaped, and that the indirect effects of the onset must be included in the account—namely, the dispersion of the enemy's ships and their consequent annihilation piecemeal on the following day. Stating the results of the battle's three phases, these experts give 30 per cent. to the 27th, 20 per cent. to the torpedo attack, and 40 per cent. to the pursuit on the 28th, 10 per cent. representing the vessels that escaped.

Certainly the disruptive effects of the torpedo attack became very visible on the 28th. The Russian fleet, or such part of it as remained above water, had ceased to be an organized entity, and was broken up into eleven isolated fragments. Three of the protected cruisers—the Oleg, the Aurora, and the Jemchug—had abandoned not only the field of action, but also the purpose of their eastward voyage, for, fleeing south, they had repassed the Tsu Shima Straits and headed for Manila. One other vessel of the same class—the Almaz— had steered for Vladivostok, followed thither by one of the nine destroyers attached to Rozhdestvensky's fleet. Two other destroyers had fled for Shanghai, one sinking *en route* thither, and the only group of vessels that retained any semblance of cohesion consisted of two battleships—the Orel and the Nikolai I.—two coast defense ironclads—the Apraxine and the Seniavin—and one protected cruiser—the Izumrud. In the turns and twists of the battle during the 27th and in the bewilderment caused by the torpedo onslaught during the night these ships had lost their bearings, and Rear-Admiral Nebogatoff, who was in command, decided to steer westward until some point on the Korean coast became identifiable. At dawn he sighted the Ulneung Islands, and thereafter shaped a course for Vladivostok. But again in this part of the field, nearly 200 miles from the place where the fight had opened, the drama of the previous day was repeated. While Togo and Nebogatoff were still 60 miles apart a wireless message indicated to the former that the Russians were drawing up, and at half-past 10 in the forenoon Nebogatoff and his officers and men, who must have been rejoicing at a rapidly-opening prospect of escape, found themselves surrounded by 27 Japanese warships, exclusive of torpedo craft. The fast cruiser Izumrud made a rush for safety and broke through the cordon, only to become a wreck subsequently in Vladimir Bay. The other four ships surrendered.

NEBOGATOFF'S SURRENDER

This incident of the battle naturally excited much comment. Admiral Nebogatoff's explanation was that, resistance being futile, he felt constrained to save the lives of the officers and men under his command, numbering more than 2,000. But his critics affirm that, even had he opened the Kingston valves and sent his ships to the bottom, only a very small fraction of his men would have perished with them. Such seems to have been the view taken by the Tsar also, for his Majesty refused to sanction the release of Nebogatoff and his officers on parole, though the Japanese were willing to release them. To conceive a Japanese Admiral surrendering in similar circumstances is scarcely possible, yet it is interesting to know what a prominent Japanese naval officer has said on the subject:

> Folks looking with every-day eyes condemn this surrender as cowardly and disloyal. But the changes that a soldier's sentiments undergo on such occasions are not a simple matter like movements of chessmen at a desk. Admiral Nebogatoff is an officer of reputation and common sense. He suffered from no lack of resolution to blow up his four ships and thus prevent them from falling into the enemy's hands. But the feat would have been hard to accomplish. Sympathizing with the pain the Russian Admiral must have felt, I think that those who condemn him for surrendering really underrate the skill shown by Togo and the efforts made by all under his command to render this surrender inevitable. Consider the reasons of the capitulation. Not only had the Russian vessels been deprived of a large part of their fighting power during the battle of the previous day, but thereafter they had been subjected to a terrible torpedo onslaught throughout the night. They were so weary as to be almost incapable of movement. They did not know what had become of their comrades. At this hour of anguish and danger Togo's flagship suddenly appeared at the head of a fleet of 27 warships, strong and fresh. What was to be expected but surrender in such conditions? The Russian officers are just as brave as ours. No one should fall into the error of imagining that any ordinary considerations would induce them to surrender.

THE RUSSIAN AND JAPANESE LOSSES

Apart from this striking incident the fighting on the 28th presented few features of interest. The scattered fragments of the defeated force were pursued here and there and destroyed with scientific thoroughness that resembled fatality. Nothing lightened the gloom of Russia's disaster except the grand courage of her officers and men. In several cases isolated vessels, confronted by greatly superior force, fought until the sea closed over them. The captain and navigating officer of the Nakhimoff refused to allow themselves to be saved. They went down with their ship and were subsequently found clasped in one another's arms. The Japanese, on their side, spared no effort to save life and treated their prisoners with the greatest kindness. As illustrating the ratio of casualties to escapes when a ship is sunk by gun-fire in daylight, the case of the coast-defense ironclad Oushakoff is noticeable. She was sent to the bottom at about 6 o'clock on the evening of the 28th, after half an hour's long-range bombardment by the armored cruisers Iwate and Idzumo, and out of her complement of 422 men, only 80 perished; the rest were picked up by the two Japanese ships. Another fact receives prominence from this incident—the terribly demoralizing effects of of such an ordeal. The men rescued from the sea were immediately undressed, re-clad in dry clothes, and given a small quantity of brandy. But many of them behaved like madmen. Some ran wildly hither and thither; some struggled to ascend the companion ladders; some caught hold of the nearest objects and clung to them. The poor fellows were evidently re-acting in imagination incidents of the terrible experiences they had just undergone. In judging the acts of a naval commanding officer it should not be forgotten that the human material at his disposal is liable to such demoralization. How many of Nebogatoff's men fell into a similar condition when, after a battle ordeal of 18 hours, they found themselves menaced with instant destruction just as the light of safety seemed to have dawned?

The Japanese lost in this battle three torpedo-boats and had 116 killed and 538 wounded. The fate of the Russian fleet is shown in the following table.

I. Battleships eight, whereof six were sunk (the Kniaz Souvaroff, the Alexander III., the Borodino, the Oslyabya, the Sissoi Veliky, and the Navarin) and two were captured (the Orel and the Nikolai I.).

II. Cruisers nine, whereof four were sunk (the Admiral Nakhimoff, the Dmitri Donskoi, the Vladimir Monomakh, and the Svietlana), three fled to Manila and were interned (the Aurora, the Oleg, and the Jemchug), one escaped to Vladivostok (the Almaz), and one became a wreck in Vladimir Bay (the Izumrud).

III. Coast-defense ships three, whereof one was sunk (the Admiral Oushakoff) and two were captured (the Admiral Apraxine and the Admiral Seniavin).

Destroyers nine, whereof four were sunk (the Buini, the Buistri, the Gromky, and one other), one was captured (the Byedovi), one went down on account of her injuries when attempting to reach Shanghai (the Blestyaschtchi), one fled to Shanghai and was disarmed (the Bodri), one escaped to Vladivostok (the Bravi), and the fate of one is unknown.

IV. Auxiliary cruiser one, which was sunk (the Ural).

V. Special-service steamers six, whereof four were sunk (the Kamchatka, the Iltis, the Anastney, and the Russi), and two fled to Shanghai, where they were interned (the Korea and the Sveri).

VI. Hospital ships two, which were both seized, one (the Kastroma) being subsequently released, and the other, (the Orel) made prize of war.

RECAPITULATION.

38 Ships.

20 Sunk.
6 Captured.
2 Went to the bottom or were shattered while escaping.
6 Disarmed and interned after flight to neutral ports.
1 Fate unknown.
1 Released after capture.
2 Escaped.

The casualties on the Russian side were 7,282 prisoners, including Admirals Rozhdestvensky and Nebogatoff, and some 4,000 killed.

THE CAUSES OF JAPAN'S VICTORY

What were the causes of this signal victory, and what the new lessons, if any, it teaches? As to the causes, some have alleged that the Japanese used submarines. There were no submarines. Others have asserted the presence of floating mines, those instruments which had demonstrated their deadly efficacy at Port Arthur. There were no floating mines. Success followed the exercise of qualities which have always been regarded as worthy to secure it—good gunnery and good tactics. The Japanese shot so much more accurately than the enemy that their gun-power was trebled and even quadrupled by comparison. On paper they had sixteen 12-inch guns against the Russians' 26. In actual practice the ratio was as 48, or even 64, to 26. This greatly superior gunnery was supplemented by tactics which furnished opportunities for its *maximum* efficacy. The Japanese vessels were again and again in positions that enabled them to concentrate their fire on special units of the enemy's fleet. But it was to the greater speed of their ships that they owed the opportunity of pursuing such tactics. It is easy to see what great advantages attended Togo's tactics, but it is also easy to see that such tactics would not have been possible had he not been able to outsteam the Russians, who committed the error of mixing their units so that the speed of the whole had to be reduced to the speed of the slowest. There is nothing new in all this. It is merely a vivid illustration of an old story.

SOME OF THE LESSONS OF THE BATTLE

Does the battle convey any novel information to naval architects? Nothing radical, is the Japanese reply. At first there was a disposition to cry out that the superiority of projectile to armor had been demonstrated conspicuously and unexpectedly. But this conclusion does not bear close scrutiny. Out of six battleships sent to the bottom, only two succumbed to gun fire, and there is no reason to believe that the principal armor of these vessels was pierced. The captured Orel, though her lightly-armored portions were shattered, remained quite sound as to her chief armor. What appears to have happened in the cases of the Oslyabya and Alexander III. was that, being very deep in the water—laden down with coal, provisions, and ammunition—the injuries they received above the belt were invaded by high waves, which, pouring in above their protected decks, destroyed their stability. Thus the value of armor is in no way challenged, though the manner of its distribution may require reconsideration.

One lesson very plainly taught seems to be the comparative inaccuracy of light guns, especially when fired from such an unsteady platform as a second-class cruiser in rough seas. It is noticeable that the cruiser action, carried on throughout nearly a whole afternoon, produced no fatal results whatever, though the tactics were the same as those pursued by the armored squadron, and the man behind the gun was not inferior. For fighting purposes the value of the battleship and the armored cruiser is more than ever vindicated.

As this article is compiled from Japanese sources, it may aptly conclude with the views of a prominent naval officer translated in the columns of the *Japan Mail*:

> The teaching of the last great naval battle does not represent any very new lesson. Many points, always recognized as of vital importance, remain unaltered. Thus the man behind the gun is as cardinal as ever; so is the necessity of homogeneity of units; so is the value of high speed; so is the inadvisability of having weak vessels like special-service steamers attached to a squadron; so is the disadvantage of going into action with heavily-laden ships and without an adjacent base. All these things must be recognized as not less important than ever. Again, there has been no reversal of the theory that the power of the gun is still inferior to the resis-

tance of armor; in point of fact the armor of the Russian ships resisted excellently. Further, it has been demonstrated that heavy guns are essential factors in a naval fight. As to the idea that torpedo craft are not capable of signal service, the lesson of the war is that the utility of these vessels depends mainly on the men handling them. Naval experts have been tolerably unanimous as to all these things and their verdict now will be that no reasons for a radical change of opinion have been furnished. Nevertheless there are some noteworthy points. The first is that in the armament of a battleship there should be not only 12-inch guns, but also 10-inch and 8-inch, with an auxiliary equipment of 6-inch pieces. Speed, too, must be at least 18 knots, and there should be bunker capacity to suffice for a long voyage. Every battleship should also have armor capable fully of resisting an armament such as she herself carries, and this means that her displacement must be over 16,000 tons. Further, if the probability of improved explosives be taken into account, the armor demanded to resist them may involve building ships with a displacement of something like 20,000 tons. Many of these arguments apply to armored cruisers also. When their special duties are taken into account as well as their certain place in the line of battle, they, too, will tend to become larger, probably reaching a displacement of 15,000 tons. As to the armament of such cruisers, the line now taken in England is to mount two 9-inch guns, but probably two 8-inch with strong shields are fully as effective. There can be no doubt, however, of the inferiority of four 6-inch pieces to two 8-inch. The cruiser of the future will probably have four 10-inch guns mounted in turrets fore and aft, with 8-inch pieces for auxiliary armament; the alternative being that the whole should be 8-inch weapons. There is room for further experiment in this direction, but on the whole the indications are in favor of a mixed armament of 10-inch and 8-inch pieces. What is beyond all question is that these cruisers must be capable of developing a speed of at least 23 knots. To come now to the question of protected cruisers, there has been much learned. Wireless telegraphy was expected to dispense with some of the functions of cruisers, but wireless telegraphy is shown to have its limitations. Protected cruisers remain a necessity. The torpedo destroyer, with its great speed, suggests itself as a good scout, but its structural weakness and inability to face high seas are plain disqualifications. The cruiser must to a large extent serve as the eyes and ears of the fighting squadron and as a commerce destroyer. Here the great speed now given to merchant steamers has to be taken into account. There have been many instances of failures on the part of cruisers to capture merchant steamers, and the lesson is that, for scouting as well as commerce-destroying, there should be attached to every fleet a number of cruisers, from 3,000 to 4,000 tons displacement, with a speed of 25 knots at least, something of their protection being sacrificed if necessary. The Russian cruisers Jemchug and Izumrud are approximately suitable types, and what is now wanted is an improved form of these vessels. They should also be able to steam to great distances without recoaling. Concerning torpedo-destroyers, the only direction in which improvement seems specially desirable is that of sea-going capacity. Some minor changes of internal arrangement suggest themselves, but the power of making voyages is the main point. As to submarines, they remain in the experimental stage. Finally, with regard to the general question of the forms of ships, there does not appear to be any reason for change.

—*Tokio Correspondent of the London Times.*

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GERMAN TURBINE CRUISER LUEBECK

The Luebeck was the first German warship, excepting the torpedo boat built at Schichau's Elbing yard, to be fitted with turbine machinery. She is a small third-class cruiser, of 3200 tons displacement, and has three sisters, the Hamburg, Bremen, and Berlin, all of which are propelled by two sets of ordinary reciprocating four-cylinder triple-expansion engines. The armament consists of ten 4-in. guns—two behind shields at the bow and stern, and three more on either broadside—ten 1.4-in., and four machine guns. Two torpedo tubes for 18-in. torpedoes are carried, both of which are submerged. Her deck armor is 2-in. thick, with ¾-in. armor at the ends and 3¼-in. on the conning tower. Her principal dimensions are:—Length, 361 ft.; beam, 40 ft.; and draught 17¼ ft., so that she is 33 ft. longer than the preceding Arcona class, and carries a crew of 259 men. A longitudinal bulkhead divides the engine-room for the turbine machinery, and there are two smaller compartments for the auxiliary power. Each side of the ship has two shafts, driven by a high and low-pressure turbine, all four of which can be reversed for astern steaming. Steam is generated by Schulz-Thornycroft boilers, and the indicated horse-power is 11,000. At this power the Hamburg made 23.3 knots, which the Luebeck is reported to have exceeded. If this is the case, the result tallies with competitive trials held between the Topaze and Amethyst in the British fleet, when the latter vessel reached 23.5 knots, or 1.2 knots faster than her sister. In both instances the turbine-engined vessel had a lower coal consumption than the reciprocating, which means an increased radius of action on the same supply of fuel. The Dreadnought, to be built at Portsmouth, is, it is said, to have turbines of 23,000 horse-power, and it is probable that in the new German battleships turbines will be fitted.

The Luebeck was laid down on April 1, 1902, at the Vulcan Yard, Stettin. —*Engineer London.*

BOOK REVIEWS

Curso Elementar sobre Substancias Explosivas. By Capitan Jose M. de Oliviera Simoes. Vol. 1. Materias primas e polvoras. 427p. il. O. Lisboa. Typographia do Arsenal do Exercito. 1904.

This book, treating of explosive materials and gunpowders, forms the first of three volumes on explosives and their manufacture. The second volume will be on explosives "proper", while the third will deal with pyrotechnics, ammunition, and the application of explosives.

The present volume is a very complete work. In the first part are given brief descriptions of all the various substances used in the manufacture of explosives, with their properties and preparation. The treatment of the subject-matter in this part is fuller but similar to the corresponding part of our Artillery Note No. 16. The second part is devoted to a detailed account of the manufacture of gunpowder and other powders of the explosive mixture class. It gives the composition of a large number of different kinds of powders, and includes also a large amount of matter special to Portuguese powders. According to the division of the subject, as adopted by the author, smokeless powders are apparently reserved for the second volume.

The third and fourth parts treat of powder works and of the storage and transportation of explosives. A discussion of the phenomena of explosion, including combustion, detonation, dissociation, etc., and the force and power of explosives, with a chapter on the experimental measurement of their mechanical effects, forms the fifth part; after which the volume concludes with five chapters devoted to the properties, analysis and proof of powders.

There are 163 illustrations in the text, mainly of a diagrammatic character.

Though covering the usual ground of works of a similar nature in English, the subject-matter is well arranged and up-to-date, and judging the series by this first volume the work is a thorough and comprehensive treatise on its subject.

The Gunner's Examiner. Prepared by Harold E. Cloke, Captain, Artillery Corps, U. S. A. Ed. 1. 6+128p. il. O. New York. John Wiley & Sons. 1905. Cloth, $1.50.

Captain Cloke is to be congratulated on having prepared such a good book as this is for the benefit of the enlisted men of the Artillery Corps desirous of becoming gunners and for officers, also, as a guide in instructing their men. Its publication is a step in the right direction and tends towards greater efficiency in the Corps, presenting as it does, in compact and convenient form, with excellent illustrations, a mass of information and instruction which should be in the hands of every enlisted man in the coast artillery.

The book is based on the requirements of the gunners' instruction and examination as laid down in G. O. 141, 1904. This examination has been modified in some respects by G. O. 93 of 1905, due to the introduction of new methods and appliances and the constantly occurring changes in details of the art of gunnery. But the main principles remain the same, and with the present work as a basis, revision from year to year can readily make it conform to the requirements of general orders on the subject. The author says it is intended that this is to be done.

The arrangement of the subject-matter treated is good. After quoting the provisions of G. O. 141 relating to gunners and their instruction and examination, the author by a simple system of questions and answers, covers in detail the whole course of instruction as prescribed in the syllabus. Technical language has been avoided wherever practicable, so that the enlisted man has at his disposal in clear and simple language the information necessary to fit him for the efficient performance of his duties. In fact, the great value of the book lies in the fact that all the theoretical knowledge needed by a gunner is contained in one volume of a very convenient size.

The type is clear and so spaced as to make it very easy to read. The illustrations, of which there are 67, are in most cases perfect. Some, we believe, could be improved and no doubt will be in another edition.

The book should receive an eager welcome at the hands of the artillery soldier, and undoubtedly will be much sought after and referred to by all interested in this class of work.

Notes and Suggestions on the New Infantry Drill Regulations. By Captain M. B. Stewart, 8th U. S. Infantry, Senior Instructor Infantry Tactics, U. S. Military Academy, and Captain R. C. Davis, 17th U. S. Infantry, Assistant Instructor Infantry Tactics, U. S. Military Academy. 112 p. il. S. Kansas City, Mo. Franklin Hudson Publishing Co. 1905. Leather, 75 cents.

These notes and suggestions form a convenient and attractive little book designed as a book of reference to assist in the study of the infantry drill regulations. It differs from the general class of so-called interpretations in that no attempt has been made to "interpret" any portion of the drill regulations, except by applying the governing rules and principles to the particular case. Hence there are no arbitrary rulings but rather explanations of every paragraph about which there may be any doubt, combined with many practical suggestions as to methods of obtaining the best results, evidently based on the authors' experience at the Military Academy where the infantry drill is so thoroughly and perfectly known and executed.

The book covers the infantry drill regulations thoroughly, each paragraph being numbered to correspond with those of the regulations in order to facilitate reference. It concludes with a short chapter suggesting ideas for practical field work with limited forces, time, and field of operations, which, if properly carried out, will be found of value in training men in the elementary principles of attack and defense under conditions approximating actual service.

The book is well printed and neatly bound in limp leather. It will prove of value to all interested in infantry work and thoroughness in drill.

Jahrbuch fuer das Eisenhuettenwesen. (Ergaenzung zu "Stahl und Eisen"). Ein Bericht ueber die Fortschritte auf allen Gebieten des Eisenhuettenwesens im Jahre 1902. Im Auftrage des Vereins deutscher Eisenhuettenleute bearbeitet von Otto Vogel. 3rd Year. 16+465 p. il. O. Duesseldorf. Kommissionsverlag von A. Bagel. 1905. 10 Mk.

This book is the third volume of this excellent index of the world's metallurgical literature and that of all departments of the iron and steel industries, which appeared in the technical press during the year 1902. The work has been delayed in issue, as the editor explains, but it is none the less valuable as a book of reference to the metallurgist and other specialists engaged in the manufacture of iron and steel.

It not only maintains the standard set by the preceding volume as regards accuracy and thoroughness of the work and systematic arrangement of the subject-matter for ready reference, but has been improved in several respects and contains many more entries. From 1800 in the first volume and 2000 in the second, the number of single references has now risen to 2600 in this. In addition there are abstracts of the more important papers. These entries and abstracts are made from 134 technical journals and annuals, of which 46 are published in Germany and 88 in other countries. This in itself is sufficient to indicate the scope of the work and its value as a means of enabling one to keep in touch with what may be of value to him in this mass of literary matter dealing with technical subjects along this special line.

In this connection, we recall Mr. Hadfield's remarks in his Presidential Address to the Iron and Steel Institute, in which he paid a high tribute to the technical press. He frankly confessed that to it he largely owed such progress as he had been able to make in acquiring information, and then dwelt on the necessity of accessibility of such information. The important factor is how to make the information obtained from this source most readily available. To fulfil this object in the metallurgical field is the aim of this book, and the cordial reception given former volumes shows that it has met with success in its efforts.

From the Yalu to Port Arthur. An Epitome of the First Period of the Russo-Japanese War. By Oliver Ellsworth Wood, Lieutenant-Colonel, United States Artillery. (Late Military Attaché, Tokyo.) 15+252 p. maps. O. Kansas City, Mo. Franklin Hudson Publishing Co. 1905. Cloth, $1.50.

For the future historian of this war and for military students, Colonel Wood has performed valuable service in compiling this book. From his position as military attaché at Tokyo for nearly four years, he had unusual opportunities for observing military conditions in Japan and her preparedness to meet her huge antagonist in the field, and, during the war, for obtaining at first hand reliable information from various sources.

In this brief history of the first period of the war, up to and including the siege of Port Arthur, he has compiled the official reports which were daily received from the Imperial Japanese Headquarters covering the operations and movements of the Japanese armies and presents them accompanied by interesting critical comments by himself, and by other important information he was able to secure. No reference is made to naval operations except where land and sea forces co-operated, for, as the author says, the naval history of the war should be written by a naval man.

The accounts of the various battles are instructive, and the book contains a vast amount of statistics on the forces engaged, composition of the various Russian and Japanese armies, casualties, etc. In reading it, it is rather disconcerting to meet the names of many places, made familiar by previous reports and books on the war, under new forms of spelling. Some of these are not recognized at first. But the author truly says this confusion will doubtless continue until the record of the Russo-Japanese war is written in a universal language. At any rate, this book has the merit of being well supplied with a number of excellent maps, illustrating the operations, on which the spelling of the names of places shown corresponds to to that in the text.

The chapters on the siege of Port Arthur are particularly interesting. They contain many graphic descriptions of the desperate fighting that took place there, concluding with an account of a week spent by the author at Port Arthur after the surrender.

From the standpoint of military history, the book is a valuable contribution to the literature of the subject.

Wellington's Campaigns: Peninsula-Waterloo, 1808-15. Also Moore's Campaign of Corunna (for Military Students). By Major-General C. W. Robinson, C. B. Part II. 1811-12-13, Barrosa to Vittoria and Invasion of France. 200p. maps and plans. O. London: Hugh Rees, Ltd., 124 Pall Mall, S.W. 3s 6d. net.

The general characteristics of this work as shown by Part I. have already been given in the May-June number of the JOURNAL. This Part II., which it is a pleasure to welcome, covers the years 1811, 1812 and 1813, and carries the narrative along, up to the invasion of France, in the same admirable manner as the previous operations in Part I. were treated.

The principal military events of the campaigns in Portugal and Spain during those years are described and all the essential items of military information are carefully considered. The work being designed especially for military students as a study of the strategy and tactics of these campaigns, the political history and minor military details are eliminated except in sufficient amount to make a properly connected narrative. In this manner a clear and definite idea is had of the development, effects of, and principles underlying the *military* operations, as a foundation for future study. A valuable feature of the book is the instructive, critical comments given by the author at the end of each phase, in which the strategical and tactical questions arising from the operations described are concisely discussed.

It is a handsome book, printed in large, clear type on soft paper. There are three maps covering the general theatres of operations, and nine smaller plans of battles, etc. Altogether, it is an instructive work presenting in interesting form the valuable lessons to be gleaned from Wellington's wonderful series of Peninsular campaigns.

1815 — Waterloo. By Henry Houssaye, of the French Academy. Translated by S. R. Willis. 268p. O. Kansas City, Mo. Franklin Hudson Publishing Co. 1905.

This study from the pen of a prominent French historian and critic covers fully all the events connected with this decisive campaign. It begins with the reorganization, equipment and concentration of the army following Napoleon's return, showing the conditions of the times and the difficulties he had to contend with; discusses in detail the preliminary battles of Ligny and Quatre-Bras, and gives a minute account of the main battle, Waterloo. A final chapter, which is thoroughly good, reviews the campaign as a whole.

The book forms an interesting study, and is written in a fair-minded spirit, the author's criticism, as well as praise, being distributed in an impartial manner. He brings out clearly the lost opportunities of leaders, errors and failures due to indecision, delay, or disobedience on the part of subordinates, and errors of execution committed by others. The style is attractive and the narrative moves briskly. The translator has done his part well, though occasionally the French construction is noticeable.

The subject is one that has been much discussed and as one of the world's great battles has been made familiar in all its details. But this new work by an historical and critical writer of acknowledged ability possesses interest both for the military student and general reader on account of the information it contains, based on original documents, the broad-minded manner in which it is treated, and its literary qualities.

Nautical Technical Dictionary for the Navy. English, French, German and Italian. Vol. II., Part I. A–K. 14+1355 p. O. Published by the Editor, "Mitteilungen aus dem Gebiete des Seewesens." Pola. 1905.

This is the first part of the second volume of this valuable work, the first volume of which appeared in 1883 followed by a supplementary volume in 1900 which brought the work up to a high state of perfection from the most modern standpoint of maritime knowledge. These volumes were in German, Italian, French, English, and now we have the English-French arrangement.

In the composition of this work, published with the approval of the Navy section of the Austrian War Department, the authors have in view the construction of a dictionary in four languages which should contain a complete collection of expressions relating to maritime and military affairs and their auxiliary sciences. It contains the various expressions belonging to artillery, astronomy, shipbuilding, balloons, hydrography, machinery, marine materials, mechanics, technology, maritime law and commerce, seamanship, mines and torpedoes, naval tactics, etc., also those relating to bridge construction, fortification, railway matters, chemistry, explosives, hydraulics, agriculture, mathematics, physics, etc.

It should be useful to officers of the navy and mercantile marine, to ship builders and engine constructors, to hydrographers and artillerists, to electricians, and engineers, also to technologists, experts, and to all interested in maritime subjects and the sea. They will find in it technical expressions, in four languages, relating to the subjects in regard to which they may desire information.

The dictionary is arranged in two ways, namely, alphabetically, English and French words in sequence; and systematically according to the similarity of their technical application. The object of this latter arrangement is to facilitate the finding of special words. In character the work is essentially technical, but the time spent in its preparation, the high qualifications of its collaborators, its official character and the immense field it covers, all contribute to make it a valuable contribution to the literature of naval and military science, and also a useful general technological dictionary.

JOURNAL

OF THE

UNITED STATES ARTILLERY

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

VOL. 24 NO. 2 SEPTEMBER—OCTOBER, 1905 WHOLE NO. 75

THE BALLISTIC COEFFICIENT

ITS ELEMENTS AND THEIR PROPER DETERMINATION AND USE

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THIS explanation of the exact nature of the ballistic coefficient may appear somewhat prolix and academic; but there are many of the readers of this JOURNAL who will welcome a complete description, inasmuch as there is no explanation of similar nature in any modern text-book or article that has come under the writer's notice. This includes Colonel Ingalls' valuable work on the subject, which for lack of space did not enter into details; nor would it have been consistent with the highly condensed character of his appendix.

Certain new features are introduced by the writer, but in all cases explanation of their nature and *raison d'etre* is given in detail and their validity established. The result is that the solution of a problem in finding "c" from firings is vastly simplified and made more accurate; and the exclusion of the principle of the rigidity of the trajectory as a *sine qua non* in finding log f_a is a desirable feature.

The wind problem is handled by means of a factor somewhat analogous to the altitude factor in that certain elements of the trajectory need to be known or calculated before this correction is applied.

The idea involved in the wind-factor method is that of Maitland's formula, except that here a table of factors is used; and the mean velocity in the trajectory is used instead of the mean horizontal velocity as in Maitland's. The introduction of the wind effect into the ballistic coefficient makes the handling of the problem independent of the method used—that is, it is not confined to flat trajectories.

For fire with seacoast mortars, on account of uncertainty as to the upper wind, correction for wind is of doubtful utility; but, for field mortars and mortar subcaliber tubes, the table of wind-factors will probably be useful.

The use of a factor obviates the complexity of the solution of wind problems; and, as no interpolations between tabular velocities are needed, the tediousness and liability to error from interpolation are avoided.

On one occasion the writer compared twenty-three papers of student officers whose work as a whole was unusually good, and found *no two results the same!*

A projectile in its flight through the atmosphere suffers retardation due to air-resistance. This resistance is of the nature of friction and its resultant direction at any point of the trajectory is directly opposite to that of the motion of the projectile. In overcoming this resistance the projectile performs work, the amount of which in a given interval is measured by the loss of kinetic energy of the projectile. This work is also measured by the product of the mean resistance (encountered by the projectile in this interval) and its path in feet.

Let ρ = mean resistance in pounds.

w = weight of projectile in pounds.

d = diameter or caliber of projectile in inches.

r = the retardation of this projectile due to ρ.

v_1 = the velocity of the projectile at the beginning of the interval.

v_2 = the velocity of the projectile at the end of the interval.

g = the acceleration due to gravity = 32.16 f.s. per sec.

m = the mass of the projectile $= \dfrac{w}{2g}$.

a = the length of path considered.

Then

$$\text{work done} = \frac{mv_1^2}{2} - \frac{mv_2^2}{2} = \rho a$$

whence

$$\rho a = \frac{w}{g}\left(\frac{v_1+v_2}{2}\right)(v_1-v_2) \qquad (1)$$

or

$$\rho = \frac{w}{ga}\left(\frac{v_1+v_2}{2}\right)(v_1-v_2)$$

The resistance is numerically given by the product of the mass by the retardation; that is

$$\rho = \frac{w}{g} \cdot r$$

If, now, with a view to establishing the relation between the velocity and acceleration a great number of shots are fired, the resistances and retardations computed and tabulated in some form, we may begin to predict what will happen when a certain projectile is fired with a certain velocity in atmosphere of a certain density; for we would then know the law of decrease of velocity, at least practically.

This has been done in a most systematic manner; and an explanation of the general character of the method involved is not only interesting but essential to a knowledge of the elements of ballistics.

Shots are fired through screens at carefully measured intervals and as a shot passes through a screen an electric circuit is broken. Elapsed time between the screens of a pair is thus registered or computed from registered data, and the distance divided by the elapsed time gives the mean velocity which is taken as the velocity at a point midway between the two screens. A second pair of screens gives a second velocity, of the projectile at a second point. We thus have v_1, v_2, and a of formula (1).

The screens of a pair are placed at such a distance apart as to make the assumption that the mean velocity is the velocity at the middle point, practically correct; and, at the same time, far enough apart to make the percentage error in the determination of the elapsed time sufficiently small.

Thus was determined a mass of data regarding different projectiles and under different atmospheric and other conditions.

These results were standardized and made accessible for application to *any* conditions by proper modifications.

In order to show how this mass of data could be so standardized, the following discussion would appear necessary:

A projectile of a certain form assumed as standard and moving with a velocity v in an atmosphere of density δ_s, assumed as standard, does work in moving one foot along its path, which work is numerically equal to the mean resistance, since the path is unity. The volume of air encountered in moving one foot is proportional to the area of cross-section of the projectile and therefore to $\frac{\pi d^2}{4}$ or to d^2, the square of its caliber. Hence the retardation is also proportional to d^2. The resistance is seen to be dependent on the velocity of the projectile and on the caliber, but not on the weight. The retardation, from the equation

$$r = \frac{g}{w}\rho$$

is seen to vary inversely as the weight. Hence the retardation varies directly as the square of the caliber and inversely as the weight; and it is different for different velocities.

Let us assume that we have found the retardation pertaining to a projectile, as above, in air *not* of standard density. It is desired to find what it *would have been* for air of standard density. The weight of air in a given volume is proportional to its density; hence the resistance varies directly as the density of the air; and so, therefore, does the retardation. Denoting the corresponding retardation in standard atmosphere by r_s, and standard air density by δ_s, we have

$$r_s : r :: \delta_s : \delta$$

or

$$r_s = \frac{\delta_s}{\delta} \cdot r$$

In this way we might find a set of values for the retardation for different velocities for a given projectile of standard form, of weight, w, and caliber, d.

If then r_1 is the retardation suffered at any particular velocity by a projectile of one pound weight, one inch caliber, of standard shape, and moving in the standard atmosphere, we would have for the retardation for that velocity of *any* projectile of standard form moving in an atmosphere of density δ,

$$\delta_s \cdot \frac{1}{1} \cdot r = \delta \cdot \frac{d^2}{w} \cdot r_1 \qquad \text{or } r_1 = \frac{\delta_s}{\delta} \cdot \frac{w}{d^2} \cdot r$$

Denoting $\frac{\delta_1}{\delta} \cdot \frac{w}{d^2}$ by C we have

$$r_1 = Cr$$

Hence by multiplying the actual retardation of an experimental firing by C we standardize it; and if we tabulate the values of r_1, we may obtain the corresponding values of r when the data for C are known.

It is interesting to note the character of C as thus far described.

Let a projectile of standard form, caliber 1 inch, weight 1 pound, and moving in an atmosphere of standard density, δ_1, be termed the *unit projectile*; then the retardation for any projectile, for a given velocity is inversely proportional to C, since it is given by the ratio of r_1 to C.

C therefore represents the inertia of the projectile under the conditions; or its power to retain its velocity.

Since, other things being equal, retardations vary inversely as the masses on the application of a given force, it follows that we may conceive of C as the fictitious weight of a projectile of 1 inch caliber, and of standard form, which would traverse the standard atmosphere with the same facility as the actual projectile (of standard form) traverses the actual atmosphere.

C is called the ballistic coefficient of the projectile under the conditions. But the shape of the projectile may not be standard. Suppose that its head is differently shaped and that the projectile encounters greater or less resistance than that due to one otherwise the same but of standard form. The effect is the same as if the area of cross-section were suitably increased or diminished.

If we introduce a factor c such that the value cd^2 would be equal to the square of the caliber of a projectile (of standard form but otherwise the same as the given projectile) which would encounter the same resistance, we have for the *given* projectile

$$C = \frac{\delta_1}{\delta} \cdot \frac{w}{cd^2}$$

This c is called the coefficient of form and is habitually determined by experiment.

Recent experiments have given data and conclusions from which the following formula has been derived

$$c = \frac{2k}{n}\sqrt{\frac{4n-1}{7}}$$

in which n is the radius of the ogive in calibers and k a constant which is ordinarily unity but which allows for peculiarities of conformation not attributable to the radius of the ogive; k is determined by experiment.

This value of c holds true only for flat trajectories; for trajectories of considerable curvature c would be otherwise determined, since the projectile may not present its head direcly to resistance; in which case the *coefficient of flight-form** depends less on the conformation of the head than on the length in calibers, the range, and the angle of departure. In the descending branch of the trajectory, especially with great angles of departure, the gyroscopic attributes of the projectile would *tend* to keep the projectile parallel to its general inclination at the moment of firing; but the center of gravity is placed forward of the center of figure purposely to counteract this tendency. What is the resultant of these conflicting efforts of nature and of human ingenuity is as yet not exactly determined; but the problem appears susceptible of analytical treatment.* Experiment must at present be relied upon to determine a mean value of this coefficient of *flight-form* and by process of exclusion to determine it as a function of the different variables mentioned.

THE ALTITUDE FACTOR, f_a.

Thus far we have supposed the projectile to be moving in an atmosphere of uniform density. But we know that, as the projectile rises above the level of the gun, the density of the air diminishes, obeying the barometric law.

If δ_a be the density of an atmosphere, which, being uniform throughout, would give the same range as the actual atmosphere,

*Recent experiments seem to indicate that the gyroscopic attributes of the projectile, so long as the energy of rotation is not too much diminished, *tend* to keep the projectile parallel to its original position. When the kinetic energy of rotation drops below a certain critical amount gravity asserts itself overpoweringly, and the projectile falls point foremost. The kinetic energy of rotation is, for a given gun, directly dependent upon the initial velocity. In the descending branch gravity asserts itself as an accelerator, thus increasing the linear but not the rotational velocity, which has fallen off. It would thus follow that for certain trajectories in which the time of flight is above a certain amount the projectile would fall point foremost; for others it would fall more or less on its side.

The drift must give us a clue to the gyroscopic properties of a projectile in flight.

Experiment seems to demonstrate that a zero drift obtains at 90°, 66°, and 0°. Beyond 90° it is equal and opposite in inverse order. Hence the graph is a central curve. It seems to be classifiable as a Fourier composite periodic curve.

The periodicity of the drift seems to strengthen the credibility of the assumption of the preponderance of the gyroscopic effect up to a certain point.

other conditions being the same, δ_h would be the mean density of the air encountered by the projectile in its flight and should be substituted for δ in the ballistic coefficient; we would then have instead of $\frac{\delta_1}{\delta}$ the ratio $\frac{\delta_1}{\delta_h}$.

But $\frac{\delta_1}{\delta}$ is already determined and δ_h is, as yet, unknown; hence we proceed as follows

$$\frac{\delta_1}{\delta_h} = \frac{\delta_1}{\delta} \cdot \frac{\delta}{\delta_h},$$

and if we denote $\frac{\delta}{\delta_h}$ by f_a we have

$$\frac{\delta_1}{\delta_h} = \frac{\delta_1}{\delta} \cdot f_a$$

To determine f_a, we must know the height to which the projectile ascends; but that, in turn, is dependent on C; that is, on f.

The process used is that of successive approximation.

Thus, with $C_0 = \frac{\delta_1}{\delta} \cdot \frac{w}{cd^2}$, find y_0; from y_0 and φ find $h = F \cdot y_0$. With h and t (the air temperature at the gun) find log f_a from Table II. Correct C with this f_a getting

$C_1 = f_{a_1} \cdot \frac{\delta_1}{\delta} \cdot \frac{w}{cd^2}$; thence y_0 and log f_a again.

Then $C_2 = f_a \cdot C_0$ etc.

The values of f soon cease to change sensibly. Two or at most three trials will give f_a.

The use of log f_a in the general case (inclined trajectory) is given in the introduction to this article (see JOURNAL U. S. ARTILLERY, July-August, 1905).

In these determinations of f_a by trial the following must be kept in mind:

1. If V, φ, and data for C be given, it is clear that by using the surface-C we use one, in general, too small, since it lacks the altitude factor which is, in general, greater than unity; therefore the X calculated with this C and the given V and φ will fall short of the true X; hence the calculated trajectory would lie altogether within the true trajectory and, therefore, the calculated y_0 be too small. The corrective factor f_a is, therefore, too small; and C will, when corrected by this f_a, be still too small, but greater than before; and so on *ad libitum*.

Hence the altitude factor approaches its true value as a maximum, the successive values rapidly approximating to the true value.

2. If, on the other hand V, X and data for C be given, our first determination of f will be too great, for the following reasons :

Since X is fixed, with a given V, C being too small, a greater elevation is necessary for this C than for the true one. The calculated trajectory lies therefore altogether outside the true one, hence y_0 is too great and the calculated f_a too great. We now, on introducing this f_a into C, obtain too large a ballistic coefficient, whence in the second calculation too small a φ is found and the value of f_a is less than the true. The next f_a will be greater than the true one; the next, less; and so on.

Thus by alternately larger and smaller approximations the true C is rapidly approached.

There is one other set of observations for determining f_a : but this time f_a is found for the purpose of separating it from C. It is as follows :

Given V, φ, and X, as is common in direct fire, or V, φ, T ; V, X, T ; or φ, X, T, or, indeed, any three elements of the trajectory sufficient to determine it. Then C is completely determined, since it *must* have such a value as is consistent with the three given elements.

In this case, then, C is correct; and y_0 as determined from it is correct, and no *approximations* occur. This C should be referred to as $\frac{X}{Z}$.

This situation occurs in handling data from firing, in order to determine the coefficient of form or that of flight-form, as the case may be.

THE WIND FACTOR, f_w.

Let us suppose a wind blowing W_x feet per second along the range; +, if a head wind; —, if a rear wind.

Then the component of this wind along the the path of the projectile at any point is $W_x \cos\theta$; and its mean value over the trajectory, $W_x \cos\theta_m$; in which $\cos\theta_m$ is $\frac{\tan\varphi_m}{(\varphi_m)}$, in which,

$$\varphi_m = \frac{\varphi + \omega}{2}$$

Now, the mean value of the velocity of the projectile in its path, is given by the ratio of the path to the time of flight; it is

$$v_m = \frac{S}{T}$$

in which S is given by

$$S = \frac{X}{\cos \theta_m}$$

since $\triangle X$ at any point is equal to $\triangle S \cos \theta$. Taken over the arc, then,

$$S = \frac{X}{\cos \theta_m}$$

and

$$v_m = \frac{S}{T} = \frac{X}{T \cos \theta_m} = \frac{X}{T} \cdot \frac{(\varphi_m)}{\tan \varphi_m}.$$

Now the number of air particles encountered in its flight by the projectile has a percentage increase of

$$\frac{W_x \cos \theta_m}{v_m} = W_x \cdot \frac{\tan \varphi_m}{(\varphi_m)} \div \frac{X}{T} \cdot \frac{(\varphi_m)}{\tan (\varphi_m)}$$

$$= \frac{W_x T}{X} \cdot \frac{\tan^2 \varphi_m}{\{(\varphi_m)\}^2}$$

Now if W_x be the head- or rear-wind component, $W \cos \alpha = W_x$, if W is the wind speed and α its inclination to plane of fire. If, moreover, we take W in miles per hour and replace X by its equivalent 3R, in which R is the range in yards, our formula becomes:

$$\delta_w = \delta \left\{ 1 + \frac{44}{90} \left\{ \frac{W T}{X} \right\} \frac{\tan^2 \varphi_m}{\{(\varphi_m)\}^2} \right\}$$

$$= \delta \left\{ 1 + .489 \frac{W T}{X} \cdot \frac{\tan^2 \varphi_m}{\{(\varphi_m)\}^2} \right\}$$

Thus, due to wind the density indicated by the barometer and thermometer is increased by $48.9 \cdot \frac{W T}{X} \cdot \frac{\tan^2 \varphi_m}{\{(\varphi_m)\}^2}$ per cent. of itself. Therefore

$$\frac{\delta_1}{\delta_w} = \frac{\delta_1}{\delta} \div \left\{ 1 + .489 \frac{W T}{X} \cdot \frac{\tan^2 \varphi_m}{\{(\varphi_m)\}^2} \right\}.$$

Of course if W_x is a rear wind we have a negative percentage increase.

Table V. gives values of f_w; i.e. of

$$1 \div \left\{ 1 + .489 \frac{W T}{X} \cdot \frac{\tan^2 \varphi_m}{\{(\varphi_m)\}^2} \right\}$$

for values of $\frac{W_x T}{X} = \frac{W T \cos \alpha}{X}$ varying by hundredths from —10 to +10 and for values of φ_m from 0° to 70°, by intervals of 10°.

THE FACTOR, $\beta' = \frac{1}{\beta}$.

The difficulty in solving the equations of the trajectory is enhanced by the complexity of the law of retardation. The latter has been determined practically by experiment, and it has been found to follow different parabolic laws for different velocity-ranges with sufficient accuracy.

The laws are all of the form

$$C r = A v^n.$$

The values of A and n for each particular velocity-range are given in Colonel Ingalls' Artillery Circulars, M and N.

Using this value of r, the ballistic problem is discussed. In general, however, the equations rigidly deducible therefrom are very complex and difficult to handle, and, in general, the laborious method of quadratures would need to be used.

To avoid this for direct fire, and to present a simple and flexible method, Colonel Siacci, the great Italian authority, assumed that $\cos^{n-1}\theta = \cos^{n-2}\varphi$, which assumption is practically correct for flat trajectories. For sensibly curved trajectories, however, this requires a compensating factor in the ballistic coefficient. This factor will differ somewhat according as X, T, θ, or other quantity is being considered.

Siacci, in effect, compared the results of the use of his equations to those computed rigidly by the tedious process of quadratures and taking a weighted mean value of the factor required in the ballistic coefficient in any one of his computed trajectories to make his equations for direct fire give the same result, tabulated his results.

Briefly, in effect, he found the artificial value to be ascribed to C, which, used with his equations, would give sensibly the same results as those obtained by the rigid method using the actual C.

The ratio of the actual C to the C to be used with his equations was plotted as β.

Thus C for use with Siacci's method becomes

$$C = f_a \,.\, f_w \,.\, \frac{\delta_1}{\delta} \,.\, \frac{w}{\beta c d^2}$$

or making $\frac{1}{\beta} = \beta'$ we have

$$C = f_a \,.\, f_w \,.\, \frac{\delta_1}{\delta} \,.\, \frac{\beta' w}{cd^2}$$

Table IV. is a table of values of β' or $\frac{1}{\beta'}$ with φ and X as arguments. X is in yards.

Intervals: for φ, 1°
for X, 100 yards.

ILLUSTRATIVE EXAMPLES

Example 1. **6-inch gun.** V = 3003, barometer 29.786, thermometer 46.81, cast-iron solid shot capped, w = 106 pounds, quadrant elevation 12°, jump 0′. Height of gun above water at the time 19.88 feet. Observed time of flight 24″.7. Measured range 10742 yards.

Find the coefficient of flight-form.

Solution:

$$x = 32226 \text{ feet}$$

$$k = [3.33326-10](10742)^2 = \text{curvature in feet}$$

$$\begin{aligned}
2 \log 10742 &= 8.06217 \\
\text{const} \log &= 3.33326-10 \\
\hline
\log 24.856 &= 1.49544 \\
&\ 19.88 \\
\hline
\log y = \log -44.736 &= 1.65056_n \\
\text{a.c.} \log x &= 5.49179-10 \\
\hline
\log \tan \varepsilon &= 7.14245_n-10 \\
\varepsilon &= -0°04'46.''2 \\
\phi &= 12° \\
\hline
\phi - \varepsilon &= 12°04'46.''2
\end{aligned}$$

$$\frac{aC}{x} = \frac{a}{z} = C' = \frac{2 \cos \phi \sin (\phi - \varepsilon)}{x \cos \varepsilon}$$

$$\begin{aligned}
\log 2 &= 0.30103 \\
\text{a.c.} \log \cos \varepsilon &= 0.00000 \\
\log \cos \phi &= 9.99040-10 \\
\log \sin (\phi - \varepsilon) &= 9.32070-10 \\
\text{a.c.} \log x &= 5.49179-10 \\
\hline
\log C' &= 5.10392-10 \\
C' &= .000012703 \\
V = 3003 \quad \therefore \quad z &= 12757.2 \\
\hline
\log z &= 4.10576 \qquad \therefore \quad \log B' = 33860 \\
\log x &= 4.50821 \\
\hline
\log \frac{x}{z} &= 0.40245
\end{aligned}$$

$$\log \sin 2\varphi = 9.60931-10$$
$$\text{a.c. } \log \frac{x}{z} = 9.59755-10$$
$$\log A = 9.20686$$
$$\therefore \quad A = .16101 = a_0'$$
$$a_0'' = 4973$$
$$\log a_0'' = 3.69662$$
$$\log \frac{x}{z} = 0.40245$$
$$\log \tan \varphi = 9.32747$$
$$\log y_0 = 3.42654$$
$$y_0 = 2670.2$$
$$-\tfrac{1}{2} y \quad 22.4$$
$$y_0 - \tfrac{1}{2} y = 2692.6$$
$$\log (y_0 - \tfrac{1}{2} y) = 3.43017$$
$$\log F = 9.82029$$
$$\log h = 4.25046$$
$$h_1 = 1780.12$$
$$h_2 = -22.8$$
$$t = 46^\circ.81$$

$$\therefore \quad \log f_{a_1} = .01633 + .78012 \times 1658 - .681 \times 34 - .78012 \times .681 \times 36$$
$$.02884$$
$$\log f_{a_2} = 9.99964$$
$$\log f_a = .02848$$

$$\log W = 1.00000$$
$$\log \cos \alpha = 9.98060$$
$$\log T = 1.39270$$
$$\text{a.c. } \log R = 5.96891$$
$$\log \frac{W\,T \cos\alpha}{R} = .02199$$
$$\log B' = .38860$$
$$\log \tan \varphi = 9.32747$$
$$\log \tan \omega = 9.66607$$
$$\omega = 27^\circ 37'$$
$$\varphi = 12^\circ$$
$$\varphi + \omega = 39^\circ 37'$$
$$\varphi_m = 19^\circ.8$$
$$\therefore \quad f_w = .9902$$
$$\log f_w = 9.99572$$
$$\frac{\delta_1}{\delta} = .993 + 2 \times .81 - 33 \times .786 = .9687$$
$$\frac{1}{\beta} = .995$$

$$\log \frac{\delta_{\prime}}{\delta} = 9.98619$$
$$\log w = 2.02531$$
$$\log z = 4.10576$$
$$\log \frac{1}{\beta} = 9.99782$$
$$\text{a.c. } \log d^2 = 8.44370$$
$$\text{a.c. } \log x = 5.49179$$
$$\log f_u = 0.02344$$
$$\log f_w = 9.99572$$
$$\log c = 0.06973$$
$$c = 1.11742$$

NOTE.—Here the principle of the rigidity of the trajectory is not introduced. The method is rigid in every respect and the wind-factor materially shortens and simplifies the process, while enhancing its accuracy. This method of finding the altitude factor does not require the principle of the rigidity of the trajectory, whereas all previous methods *have* required it. $\frac{1}{\beta}$ is here introduced in such computations for the first time.

Example 2.—The 12-inch B.L.R., V = 2300 f.s. is fired at an angle 3°58′ with the horizontal, which, in still air would give a range of 6000 yards and time of flight of 9.12 secs. How much over will the projectile strike if a wind from the rear is blowing at the rate of 18 miles per hour?

$$\text{Here } TW \cos \alpha = -18 \times 9.12 = -164.15$$
$$\therefore \frac{TW \cos \alpha}{x} = \frac{-164.16}{6000} = -.02736$$
$$\frac{\varphi \cdot \omega}{2} = 5°, \text{ approx.}$$
$$f_u \quad 1.011 \cdot .736 \times 5 - \tfrac{1}{2} \times 1$$
$$= 1.014$$
$$\log \sin 2\varphi = 9.14994$$
$$\text{a.c. } \log x = 5.74473$$
$$\log C' = 4.88467$$
$$z = 2623$$
$$\log z = 3.41880$$
$$\log x = 4.25527$$
$$\log C = 0.83647$$
$$\log f_w = .00604$$
$$\log C_w = .84251$$
$$\log \sin 2\varphi = 9.13994$$
$$\log A_w = 8.29743$$
$$A_w = .019835$$
$$z_w = 2593.2$$
$$\log z_w = 3.41384$$
$$\log C_w = .84251$$
$$\log x_u = 4.25635$$

$$x_w = 18044.8$$
$$x = 18000$$
$$\Delta x = 44.8 \text{ feet}$$
$$= 15 \text{ yards}$$

It is noticeable with regard to this wind-corrective f_w, that it applies to any trajectory whether flat or curved, and to any method: Siacci's, that of quadratures, or any other, in that it enters the ballistic coefficient.

For convenience a table of values of colog d^2 and of colog d is given as table VI. Space is left for the insertion of those corresponding to such new calibers as may be adopted.

In the application of this method to the construction of range tables from firings, the coefficients of form or of flight-form may be deduced as in Example 1. The value of log f used in conjunction with this for the particular range in the range table should be taken for a temperature of 59°, i.e. under normal surface conditions. A temperature variation of the ballistic coefficient (say for 10° temperature) should be inserted in a column thus allowing C to be corrected for temperature. This variation for C should be included in data for a range-board and may readily be added.

As to the 6-inch gun it would seem that c is of the nature of a flight-form coefficient differing for a given projectile with the range and angle of departure. It is in my opinion a mistake to adopt a mean value of it for the entire range table.

The application of this method may well be illustrated by the solution of a problem in high angle fire. I will take Example 1 of the article by Captain Harris in JOURNAL U. S. ARTILLERY, January-February, 1905.

Example 3.—Given $V = 1000$ f.s.; $\phi = 59°$; $X = 7780$ yards; $d = 12''$; thermometer 65°; barometer 31''; $w = 1000$ pounds.

As found in his solution

$$\log C_c = 0.82548 \quad \text{and} \quad \frac{V}{\sqrt{C_c}} = 386.6$$

$$\therefore \omega = 62°20'$$
$$\phi = 59°$$

$$\frac{\phi + \omega}{2} = \frac{121°20'}{2} = \phi_m = 60°.7$$

$$\log F = 9.77697$$
$$\log .45 = \log \frac{\zeta_0}{\zeta} = 9.65321$$
$$\log X = 4.36810$$

$$\log h = 3.79828$$
$$h = 6285$$
$$\log f_a = .08392 \qquad t = 65°$$
$$\log .964 = \log \frac{\delta'}{\delta} = 9.98408-10$$
$$\log w = 3.00000$$
$$\text{a.c. } \log d^2 = 7.84164$$
$$\text{a.c. } \log C_c = 9.17452$$

$$\log c = .08416$$
$$c = 1.2138$$

In the example quoted, c was found to be 1.3045; a difference of 9%. It will be noticed that log F = 9.77697—10, corresponding to F = .59837 instead of .66667 as used by Ingalls. The value of log f_a is, of course, different.

"c" as tabulated in high angle fire is really a factor to account for the difference between calculation and fact. The fact that c is smaller tends to show that, by the new method, fact and theory are more nearly in accord. The value of c being thus clear and free of all except accidental errors (such as might occur in taking the data) is now fit for consideration and tabulation with a view to getting its value as a function of those elements with which it varies. Normal equations might thus fitly be taken with this in view.

PRINCIPLES THAT SHOULD GOVERN THE ALLOTMENT TO, AND EMPLOYMENT IN, COAST FORTRESSES OF LIGHT Q.F. GUNS, AND METHODS OF FIRE CONTROL AND DIRECTION BEST SUITED TO OBTAIN EFFECTIVE FIRE.

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"DUNCAN" GOLD MEDAL PRIZE ESSAY, 1905.

Reprinted from *Journal of the Royal Artillery*, August, 1905.

HAVING first of all defined the expression "Light Q. F. Guns," the subject will then be split up into three sub-headings, and then each sub-heading dealt with in its natural sequence.

"Garrison Artillery Training," Vol. II., tells us what in our service are light Q.F. guns, and for the purpose of this essay the 12-pdr., 12 cwt., Q.F. may be read instead of that expression.

Whether or not the 12-pdr, is the right caliber of gun to use for the purpose is not considered within the scope of this essay, but it may be noted that the Americans use a 15-pdr., the French rely mainly on the 3-pdr., the Germans a 20-pdr., and other nations like ourselves mostly on the 12-pdr., although in some of our latest cruisers the 3-pdr. is being largely installed; this seems however to be more in the nature of an experiment, as an improved and heavier 12-pdr. is being turned out for the navy.

SUB-DIVISION OF HEADING

The subject may then be considered in the following order :—

(a) How should 12-pdrs. Q.F. be employed in a Coast Fortress?

(b) What principles should govern the numbers allotted to a Coast Fortress?

(c) The methods of fire control and direction best suited to obtain effective fire.

The seward side only of the fortress is taken into account.

(a) will first be considered.

The principal object of the gun is to prevent torpedo boats, and in a lesser degree submarines, entering the harbor, destroying mines and booms, or in fact coming near enough to do damage. This will be generally agreed on.

The only question open to argument is whether they should be employed for other purposes, *i.e.* to take part in an action against larger vessels, and if so, whether this should affect the number allotted.

The damage that 12-pdrs. can do to an armored ship is infinitesimal, whereas, once they have fired, their position is given away, and if the enemy have any intention of attacking with torpedo boats at night, they will at once turn their attention to the 12-pdrs., as these are the principal means of keeping the boats out.

In some places it is almost impossible to conceal their position, such as at the end of breakwaters, but even here with a few dummy guns sprinkled about, it would be much more difficult to put the guns out of action if their exact position was not exposed by firing, and it would be better policy not to use them except against torpedo craft. "Garrison Artillery Training," Vol. II., says they might be used against unarmored parts of bigger ships, but in modern ships, the unarmored parts are becoming scarce, and of course against the armored parts, catapults would be as good.

It is not meant to lay down a hard and fast rule, but to point out that generally it would be making an improper use of the 12-pdrs. to employ them except against small craft. There are exceptions. For instance, in a small place defended by two or three 6″ or 4.7″ and some 12-pdrs., it would obviously be absurd for the 12-pdrs. not to take part in an action against a third-class cruiser; although even here the armored deck would keep out all projectiles from the engine room.

Generally too, 12-pdrs. are not sited advantageously for engaging big ships; they are more often on low sites, where they are much more vulnerable.

The question then arises whether in addition to the 12-pdrs. mounted as anti-torpedo-boat guns additional ones should be mounted in more advantageous sites, for the purpose of engaging larger vessels. The enemy, whether battleship or cruiser, has large numbers of this type of gun, and it is believed that their tactics would be to run into close range and overwhelm the forts with the fire from medium and Q.F. guns. Why, it may be asked, should not the land batteries have 12-pdrs. to meet this fire, and try and keep it down?

At first sight it appears reasonable to say that this would be done, but on looking into it further, a different conclusion will be arrived at.

Presume no such thing as a torpedo boat, destroyer or submarine, then there would be no light Q.F. guns on a battleship except perhaps in the tops or some spare corner. They are mounted in ships to deal with torpedo craft, and not for the purpose of engaging other battleships or attacking coast fortifications. They are used against the latter because they are there.

On land then why should we mount them except against torpedo craft. It is not a question of weight or cost. Presuming so much money available, no one would choose 12-pdrs. instead of 6", or if it comes to that, 6" instead of 9.2". It is not easy to say what is the average cost of emplacements, magazines, &c., so much depending on local conditions, but speaking roughly, a complete battery for two 12-pdrs. would cost about £5,000, the guns, mountings, and ammunition another £3,500, totalling £8,500.

For two 6" guns the cost would again be roughly £10,000 for emplacements, &c., and £16,000 for guns, &c., totalling £26,000.

Two 6" guns would therefore equal six 12-pdrs. in cost, and if there were £26,000 to spend in armament, against anything but torpedo boats, no one would choose the six 12-pdrs. in preference to the two 6". The latter would do infinitely more damage. The tendency is setting in for battleships to be armed with an anti-torpedo-boat gun and a large caliber gun, thus showing that it is the big shell that does the damage and not the greater number of smaller ones. As a proof of this tendency there is the armament of the "Lord Nelson" class doing away with medium guns under 9.2", and the battleship proposed by the Italian designer Cuniberti mounting only 12" and 12-pdrs.

It is interesting also to note the opinion of the Chief of Artillery of the United States, Coast Artillery, which is that the 12" only—apart from defense against torpedo boats—should be mounted for coast defense. The present war has so far entirely borne out the above ideas.

All this shows that for so much money the 6" is preferable to a greater number of 12-pdrs. At a short range, say 1,800 yards, every shot from the fort will be a hit somewhere, but the 12-pdrs. will be harmless against the whole of the secondary armament and its gun crews, and do practically no damage to material.

There is no doubt also that the 12-pdrs. with their thin shields would be the first to be put out of action, whereas the 6" shield would probably keep out all the light Q.F. projectiles, and unless hit at the normal, those from the secondary armament. Moreover, of course the 6" would be effective at a much greater range.

CONCLUSIONS

To sum up then, the conclusions arrived at under subheading (a) are as follows:—

(1) 12-pdrs. should be mounted with a view to dealing with torpedo craft only.

(2) As a rule they should not expose their positions by taking part in any general action, but should only open fire on the craft they are intended for.

(3) Additional 12-pdrs. to deal with larger vessels should not be mounted.

We now come to the second sub-heading, (b), viz. what principles should govern the number of 12-pdrs. allotted to a coast fortress.

What is wanted is a basis, on which some sort of calculation can be made, for it is impossible to avoid calculations here.

No man can say a gun will stop one boat or two boats or indeed have any opinion worth listening to unless he knows from actual fighting experience or has calculated on some basis.

It is no good dumping down 12-pdrs. haphazard on any suitable positions there may be, just because, say, there are suitable positions, or saying, "Make out a defense scheme against torpedo boat attack, but the cost is not to exceed so much," or imagining because so many guns and lights are sufficient for such and such a place, therefore the same number are sufficient for another place, even though the latter may be of no greater importance. What we want to know is, firstly what a 12-pdr. is capable of in a way of stopping boats, and then for any particular harbor, the number of boats likely to attack and their nature; with this data it is possible to calculate how many guns and lights are sufficient, taking into consideration the available sites, nature of harbor entrance, &c.

Most defense schemes state the number and class of ships by which a coast fortress is liable to be attacked, but as regards torpedo boats it is generally deemed sufficient to say that the harbor is liable to torpedo boat attack, to counteract which there are such and such guns, but the class of torpedo boat attack should also be mentioned. There is as much difference between an attack by three divisions of 1st class boats or destroyers, and one by two or three 3rd class boats, as between an attack by a fleet of battleships and one by a 3rd class cruiser, and it should be clearly stated in the defense scheme the number and class of boats the Q.F. defense is intended to meet.

Before any calculation can be made, the first thing is to settle what a 12-pdr. can do in the way of hitting a torpedo boat, and then to decide how many hits would stop it.

As night is the usual time torpedo boats will attack, then the gun's powers by night must be worked out.

What is there to go on? Clearly the result of practice by day would give us no data of any use even with high speed targets. We are narrowed down then to practice by night. I believe Shoeburyness is the only place where practice by night at high speed targets is regularly carried out, and as these targets are really high speed, are lit up by search lights, and when the detachments are good enough, run in four at a time, a fairly good idea of what the gun is capable of in the way of hitting can be obtained.

The night practice on September 24th, 1903, at Freshwater Redoubt, also affords us valuable data, which I propose to compare with the calculations derived from Shoeburyness practice.

The Shoeburyness report for 1904 states that 1.87 hits per gun per minute were obtained by the 12-pdr. against the high speed targets at night.

We will now examine the conditions under which these hits were obtained, and compare them with war conditions, beginning with the size of the target.

The size of the latter was 18 feet by 4 feet with no beam, and they came in at about an angle of 70° to the end-on position.

The size of the service target would be, length 120 feet to 220 feet, freeboard 4 feet to 5 feet 9 inches, and beam from 10 feet to 20 feet, the larger measurements being those of an ordinary type of destroyer. Taking a typical French torpedo boat we get a target of 150 feet by 14 feet by 4½ feet. But this supposes the boat at right angles to the line of fire, whereas the probable course would be at an angle of about 20° to the end-on position, in which case the boat would represent a target about 70 feet long, with 40 feet beam. Now against the small Shoeburyness target quite half the misses were for line. The rate of fire was 6.36 rounds a minute; if half the misses were misses for line, then out of 6.36 shots—

1.87 were hits.

∴ 4.49 were misses.

Of these 2.24 were misses for line.

∴ 4.12 shots were in for line.

Of these 1.87 hit.

∴ If all shots were in for line, the hits would be—

$$\frac{1.87 \times 6.36}{4.12} = 2.89.$$

But besides extra length we have extra beam and freeboard, and extra hits will result as follows:—

With a target 4 feet high and no beam, the permissible error at 900 yards (an average torpedo boat range), from a height of 40 feet is 133 yards.

With a target 4½ feet high and 40 feet beam, under same conditions it is 163 yards.

2.89 hits out of 6.36 shots is a percentage of 45; it therefore resolves itself into the following sum:—

If you get 45% hits on a horizontal target of 133 yards, what percentage will you get on one of 163 yards.

Working by the probability table, the answer is about 54%, which is equal to 3.43 hits.

Therefore if a torpedo boat had been substituted for the 18 feet by 4 feet target, the 12-pdr. would have got 3.43 hits per gun per minute on it. Now as to the remaining conditions:—

(1) The speed of the targets was at least 20 knots.

(2) The range was a good average torpedo boat range and altered quickly.

(3) The height was about 40 feet.

The above conditions hold good for war.

(4) The layers were not trained layers. There were some of the latter amongst the detachments, but every man in the detachment took his turn in firing.

Trained layers would of course considerably increase the number of hits, especially with a Q.F. gun traversed from the shoulder, and moreover always working with the same loading numbers, should make a difference.

(5) The time of series was half a minute.

In most cases the time of firing will be over a minute rather than under it, as will be shown later. This will give the layers more time to settle down, and so increase the hits per gun per minute.

(6) The detachments were not being shot at, nor were they troubled with searchlights playing on them. The result of these must be a matter for conjecture. They would certainly decrease the hits per gun per minute, although not as much as would appear at first sight. The shooting from the boats would be so inaccurate that the effects of their fire would be purely moral and if this can be impressed on layers and detachments, the shooting should not suffer much. A searchlight in the gun layer's face would be awkward, but it would want considerable skill to keep it in the right position and all the guns would not be affected.

The factor of surprise and the men being awakened from sleep has not been taken into account, as in no case should the gun layer be allowed to sleep.

Conditions (4) and (5) then would increase the number of hits and condition (6) decrease them, and in the writer's opinion (4) and (5) would counterbalance (6) and the hits per gun per minute may be taken as 3.43 as already worked out.

We arrive then at the very important conclusion that at night time in war, a 12-pdr. will make rather more than three hits per gun per minute on an average war target.

It is now necessary to ascertain how long a time there will be to shoot at the boat, or in other words the length of time the boat is in the illuminated area. This depends on two things, viz. the speed of the boat and the width of the illuminated area. But before going on, it will be as well to state that the question of lights must be considered as well. It is quite impossible to discuss the question of the number of guns without reference to the illuminated area.

"Garrison Artillery Training" says that "Electric lights are usually arranged so as to illuminate as brightly as possible the whole water area for a distance of at least 1,000 yards from the narrowest part of the entrance." This may be the case in a few important fortresses, but in the great majority of places a width of more than 600 yards is rarely found, and as is well known, there are places without lights, and others with only one or two.

The following table shows the number of seconds a boat would be in the illuminated area for different speeds and widths of area:—

The left-hand vertical column is the speed of the boats in knots and the top horizontal line the width of the illuminated area. The remaining figures are the number of seconds the boats are in the illuminated areas at their different speeds.

KNOTS.	400	600	800	1000 YARDS.
15	48	72	96	120
20	36	54	72	90
24	30	45	60	75
25	29	43	58	72
30	24	36	48	60

It will thus be seen that the time may vary from 24 seconds in the case of a 30-knot boat and a 400 yard illuminated area, to 2 minutes with a 15-knot boat and 1,000 yard illuminated area.

For purposes of illustration, we will take a boat going 24 knots.[1]

This, according to the table, will be under fire in a first-class fortress 1′15″, and on the assumption of 3.43 hits per gun per minute, will be liable to just over four hits during the run in.

In a second-class place with, say, an illuminated area of 600 yards, they will be under fire 45 seconds, and be liable to just over 2½ hits.

In the case of destroyers, their greater speed would be a good deal more than neutralized by the larger target they represent, not only in length and breadth, but especially in freeboard.

We can now compare this with the results obtained by detachments from service companies with their trained layers at night firing at Freshwater Redoubt on 24th September, 1903.[2]

High speed targets were used. The average range was 1,300. Eliminating two companies, which gave results far

[1] Barring destroyers, there are only about a dozen French boats that could do more than this. I have arrived at this by taking Brassey's list and knocking off two knots, as the speed given there is the maximum trial speed.

[2] Obtained from the report of Chief Instructor.

below the others, owing to being stopped by the umpire for dangerous mistakes or the target being too indistinct, the remaining eight companies, forming sixteen detachments, gave an average of five hits per gun during the run in. The time however was 1′ 25″. We are assuming a time of 1′ 15″ and in that time the hits would have been 4.4.

In this case also the detachments were not being shot at or worried by searchlights being turned on them. To counterbalance this, however, the targets were very indistinct, and the electric lights only temporarily put up for the occasion and their intensity varied owing to rather uncertain engine power.

In addition to this the difference between laying on such a small object as a high speed target and a torpedo boat must be taken into account.

These conditions would quite counterbalance the absence of hostile guns and lights, and we may assume that under ordinary conditions in war time the guns would have got 4.4 hits during the run in.

This shooting entirely bears out the calculations already made as to the night shooting at Shoeburyness for the year, although showing slightly better results, and the conclusion is that *at night a 12-pdr. will in war time put in quite four hits on a target the size of a torpedo boat during the run in.*

The next step is to find out how many hits are necessary to *stop* a boat. It is by no means necessary to sink it.

Can anything be learnt from the present war on this point? Up to the present time, only accounts of war and other correspondents, who were not actually present, and brief official reports are available, and it is not possible to get hold of any detailed accounts of the torpedo boat operations. Undoubtedly later on we shall get most valuable data, *i.e.* if the Japanese allow other nations to get the value of their experiences, quite a doubtful question, as the "Andromeda" incident shows, and their ability to keep things dark, is certainly well exemplified by the loss of the "Yashima".

However the following points seem clear:—

(1) The Japanese boats did not once attempt actually to get into harbor to torpedo ships inside, although the harbor contained many large ships close together, and the crippling of these ships was the great object of the Japanese. It may have been because they did not wish to lose any boats, but although this was obviously true as regards battleships, it could hardly be so as regards torpedo boats, which Japan can build herself

in large numbers and in comparatively short time. Evidently the Japanese regarded the getting into a bottle-necked harbor like Port Arthur, well protected with light Q.F. guns, as impossible.

(2) The number of boats actually lost seems extraordinarily small. This seems to show that it is by no means necessary to sink a boat, but that a boat when hit badly will sheer off if possible or get towed away by a consort and will not, as some people think, come at a reduced speed or even endeavor to drift to close quarters to fire a torpedo.

(3) The Japanese boats do not appear to have attacked at close ranges, or, any way, the ranges that would be necessary to run through the illuminated area of a well defended fortress. This is borne out by the first attack on the Russian fleet, when the Japanese boats not only surprised the latter, but had the whole of the fleet as a target and only put in four hits; also by the small number of boats lost, even allowing for bad Russian firing. The exception seems to be the attack on the "Sebastopol," and here we know several boats were hit, in some cases seriously, although no boats were actually sunk. The conclusion arrived at may turn out to be wrong, but if so, the reason for only four hits in the first attack will be interesting.

On the whole nothing very definite as to what will, or will not, disable a torpedo boat or destroyer can be learned at present from the war.

For reliable data to go on, one must turn to the Ordnance Committee report of 1894, dealing with the trials of 6-pdrs. and 12-pdrs. against torpedo boats.

There is no reason to suppose that the conclusion the Committee came to is not just as sound now as it was then. The guns are the same, and the boats are much the same. The conclusions were "that the 12-pdr. Q.F. gun was sufficiently powerful to disable a torpedo boat, and that guns of less caliber could not be relied upon for that purpose," and again, "a shell from a 6-pdr. Q.F. striking a torpedo boat would not necessarily disable her, but that a 12-pdr. Q.F. would almost always do so." This refers to a shell striking the engine room or boilers. This latter space is about a third of the length of an ordinary boat to about one half in a destroyer. In addition to hits here, a shell outside the engine room and boilers might also disable the boat, such as one on the water line, the steering gear, a magazine, or a loaded torpedo tube. Taking this into account we may safely say that *two hits from a 12-pdr. will disable a* *torpedo boat,* and to this it is safe to add *or destroyer.* A destroyer is certainly larger, but on that account she is easier to hit, and in addition has comparatively a much larger vulnerable target which can hardly be missed. Her sides are no stronger, and a shell in the engine room will play just as much havoc as in that of a torpedo boat.

Moreover a destroyer is less handy, has a greater draught and so more liable to run amuck in a night rush, and it is quite safe to say that any measures taken to defeat torpedo boats will also stop destroyers.

It is interesting to note in connection with the above that amongst the rules of Jane's Naval War Game are found the following:—

One hit from a 6-pdr. will sink a torpedo boat.

Three hits from a 12-pdr. will sink a destroyer.

Even if the word "sink" is really meant, and taking into consideration the larger number of compartments a destroyer has, there cannot surely be all this difference. Whereas if for "sink" you read "disable" then clearly the rule is a bad one, as the engine room and boilers of a destroyer are just as fragile and just as easily put out of action as those of a torpedo boat.

"Garrison Artillery Training" is very pessimistic on the subject, and says that two guns will generally be sufficient for one boat. At this rate we are indeed undergunned.

It does not of course necessarily follow that because a gun will put in four hits in the run in and that two hits will disable a boat, a gun will disable two boats that enter the illuminated area simultaneously. The responsible person, be he gun group commander, gun captain, or gun layer (it is proposed to discuss this later) must take an appreciable time in deciding when the boat fired at has had enough. The boat will not show at once she is knocked out, she will not necessarily sink or blow up, and consequently the tendency will be to fire at her for a longer time than necessary, and it is here the man with the cool head and common sense will be wanted. However we had some margin over our four hits during the run in, and we will let the four hits hold good and assume therefore that *a 12-pdr. will knock out two boats during the run in with a good illuminated area. If the harbor has a poor illuminated area, of say 600 yards, then one gun unless lucky cannot be assumed to account for more than one boat.*

We have thus arrived at a definite relative value between guns and boats.

The next step is to consider now many boats we are likely to have to deal with.

If a harbor is worth getting into and sacrificing boats for, it would be good policy for the enemy to use as many boats as can be useful at one time without impeding one another; this number would depend on the approaches and form of entrance to the harbor, formation of adjoining coast line, channels, shoals, &c., and the number of boats, and method of attack all depend on the above. In the case of a harbor with two entrances, if both are left open, then each entrance must be legislated for as if it was the only entrance, and the whole of the attack was pressed on it alone.

It may be assumed that three divisions, or say 18 boats, may be told off to attack a harbor, of which twelve may actually be engaged at one time trying to run in, the remainder forming a reserve to assist damaged boats in retreating, and perhaps being used to make feints, fire on the batteries, and use their searchlights. We must then legislate to defend 12 boats entering the illuminated area at the same time or thereabouts in order to force an entrance.

Assuming then that all the guns are mounted so as to bear over the whole of the illuminated area, then by the previous conclusions, six guns should disable these boats. This makes no allowance for guns or lights being out of action through accident or damage by the enemy's fire and it would be advisable to allow two more guns both on this account and to be on the safe side and allow for bad shooting or a layer losing his head.

This calculation however is based on the supposition that each gun can bear over the whole illuminated area, and that this latter extends to 1,000 yards.

The former supposition can hardly ever be the case, and therefore the conclusion arrived at must only be regarded as a standard to work from, and more guns will nearly always be wanted. To find how many more guns are wanted, each gun's value can be found according to the proportion of the illuminated area it bears over; for instance to take the simplest case, presume a gun bears only on half the area, and another gun bears only on the other half, then the value of each gun is only ½, and another gun is required to bear on each half of the area. It will be found that on drawing to scale imaginary harbors, very rarely will more than 12 guns be required. If the entrances are wide and ranges therefore long then fresh calculations based on the hits per gun per minute at those ranges must be made and more guns will be found necessary.

Again, if guns are very conspicuous and exposed to bombardment, and so more liable to be put out of action beforehand, more guns will be required.

Now comes the question of a reduced illuminated area, which is much more difficult.

Imagine a second rate harbor where it is desired to keep out a certain number of boats, and that X guns with Y lights are considered sufficient, but it is found that this entails too great expense and that only half the guns and lights asked for are sanctioned. They won't keep out half the original number of torpedo boats contemplated.

For if there are only $\frac{Y}{2}$ lights, then to keep out the same number of torpedo boats you want 2X guns, but instead of this you only have $\frac{Y}{2}$ guns and the value of the defense is quartered, although the guns and lights were only halved.

It will thus be seen that if guns and lights are skimped, the value of the torpedo boat defense rapidly falls away and soon approaches zero.

The main thing is to have an illuminated area of at least 600 yards. The cost of a light is very roughly about £1,500, taking into consideration everything in connection with it, viz. engine with all necessary fittings, dynamo, cable, emplacement, and telephones, and so, therefore, a much cheaper affair than a 12-pdr.

Without lights guns are useless at night.

Twelve guns without any electric lights are valueless on a dark night, whereas one gun with a good illuminated area will disable two boats. It is therefore bad policy and false economy to reduce the lights; money is saved by reducing the lights, but on the other hand, the money spent on the guns is wasted.

The smaller the importance of the harbor, the more difficult does it become to decide what is sufficient for its defense, but a harbor with any value at all and liable to attack by torpedo boat should firstly have an illuminated area at least 600 yards wide. Then with this width, four guns will keep out four boats and with luck might account for a division of six, *i.e.* if mounted with all round arcs of fire.

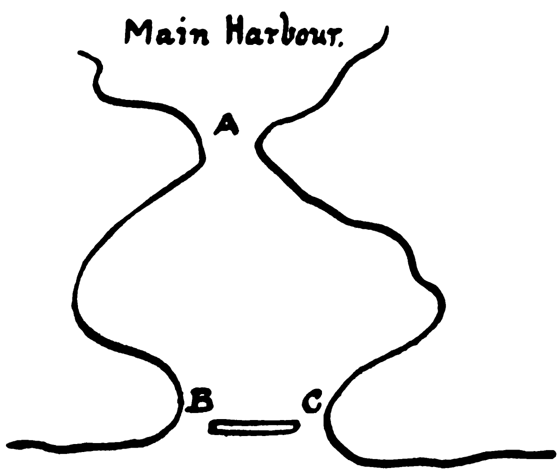
It is doubtful whether an illuminated area narrower than this is not waste of money. There are of course exceptions; for instance, to take an extreme case, with a very narrow zigzag entrance, it is quite conceivable that one or two lights and one gun would suffice. There are, however, various places where the electric lights are so few that the defense can have no value other than a moral one. It may make a man think twice before coming in to blow up the dock gates in a row boat, but that is about all its use.

To sum up then: given a well illuminated area 1000 yards wide, the standard to work on should be that for a first-class fortress with a normal entrance, eight guns are required, if each gun can bear over the whole area; but as this can practically never be the case, additional guns are required to counterbalance the small arcs of fire that any of the eight guns might have, or in other words, *the number of guns required is that, the the united arcs of fire of which, will be equal to the arcs of fire of eight guns that could bear over the whole area. For second-class harbors there should be an illuminated area not less than 600 yards, and with this width the number of guns allotted must be based on the assumption that one gun will keep out one boat.*

Guns without auto-sights which are unavoidably mounted low down should only be reckoned at half the value of a gun with an auto-sight.

The foregoing conclusion applies to a harbor with one main entrance. If there is a roadstead outside this entrance where ships may lie, then the roadstead must be defended quite apart from the entrance. Fresh calculations must be made and additional guns will be wanted.

The whole depends on local conditions. For instance with a harbor like this:—



If it is necessary to keep the boats out of A only, then the guns should be all concentrated to bear on the illuminated area there only, or the same number of guns would be required both at B and at C, *i.e.* if both are left open. This latter plan would keep boats out of the whole harbor and none would be required A, although one or two might be put there as an extra precautionary measure. The point is, it is no good dividing up guns that would be sufficient at A between B and C, or indeed putting less at B and C than would be sufficient to stop all the boats attacking at one entrance.

If a boat actually gets into the harbor then any guns that can bear should turn on to it and it should fall an easy prey, as the range would be short and she must slow up.

The guns may hit some friendly shipping or do some damage to one's own side, but this risk should be run as the possible damage pales to what the torpedo boat would do if not promptly attended to.

If no guns mounted can bear inside, the boat must be left to the Navy to deal with, as it is not advisable to mount guns solely for this purpose. They are much better used to keep boats out rather than deal with them when they are in.

Nothing has yet been said about the defense of mine-fields in relation to the allotment of Q.F. guns. This can be dealt with very shortly.

The mines must of course be protected. If any of the guns allotted and mounted for defense against torpedo boats can bear on the mine-fields, all the better; but if not, an extra gun, or guns, should be mounted. The mistake must not be made of mounting guns primarily for defense of mine-fields, and then counting them as anti-torpedo-boat guns, even though they may be most unfavorably situated for stopping a rush in.

FIRE CONTROL AND FIRE DIRECTION

In "Garrison Artillery Training" these are dealt with separately and it is there laid down what details are included under fire control, and what under fire direction. With Q.F. guns, however, each is merged into the other, and they must be dealt with on not quite the same lines. Fire control becomes practically organization previous to fighting and fire direction the actual control of fire during fighting. They will however be considered together.

The auto-sight, more than any other improvement or innovation of recent years, has simplified the anti-torpedo-boat defense. For this, observation of fire has practically lost all, or nearly all, its importance. There is no time to make corrections, nor indeed should they be wanted, any way for range. The gun will hit what the layer aims at, and the gun group commander will no longer experience the horrible sensation that he has been making corrections as the result of observing another group's fire. In fact distribution of fire is of less importance than before the days of auto-sights. Then it was vital. Now it is not. Take an extreme case and suppose there are eight guns and a good lighted area, that twelve boats attack simultaneously, that there is no system of distribution of fire and that unfortunately all the guns turn on to one boat; then that boat instead of being disabled by one gun, say in half a minute, will be disabled by eight guns theoretically in 3¾ seconds and probably in five or six seconds. If the guns unfortunately keep turning on to the same boat, the same thing will happen and allowing 1¼ minutes as the time taken to cross the illuminated area, there is still a probability of all the boats being stopped.

Without an auto-sight this would be impossible, as with many guns on one boat, correction of fire—so necessary without an auto-sight—would be practically impossible, and the boat might go free, the guns shooting short being corrected for over or *vice versa*.

This is not to advocate no system at all, but merely to show it is nothing like so important as it was, and that an exact system in which each gun is told off to its own boat is unnecessary, even if it was possible.

Before dealing with distribution of fire, it is proposed to go into a question of organization which will effect it. A gun with an auto-sight is such a powerful weapon that it is impossible for one officer effectively to control or direct the fire of two guns without losing very valuable time.

More often than not the guns will have to fire at different targets, and even though "independent fire" is given as soon as this is necessary, a certain waste of time must ensue.

Each gun must have its own director (to use a new word so as to avoid confusion with the present gun group commander and gun captain), who should have the powers of the present gun group commander, and his place in action should be where the present gun captain is. He should be responsible for choice of target, line, service of gun, &c. If officers can be spared, he should be an officer. If not, then a reliable N.C.

officer, and in this case there should be an officer as gun group commander for two or even more guns, but the latter should not interfere at all with the fire direction; he should command administratively so to speak, be at hand to assist with casualties, accidents, missfires, and be responsible whether fire should be opened or not. If the fire directors are officers then the gun group commanders are not required.

A boat must be dealt with by a gun and not a group for two very good reasons, the first being that there are not generally enough groups to deal with all the boats, and the second that a gun by itself is more than capable of dealing with one boat. Therefore the gun must be the tactical unit and not the group, and so must have its own fire director.

Now a word as to deflection. It should be avoided with Q.F. guns altogether. If a 12-pdr. is laid on the water line under the funnel as laid down in "Garrison Artillery Training", a destroyer or large sea-going torpedo boat, will on account of the great length occupied by the engines and boilers, be hit in a vital part up to about 1,400 yards, but with an ordinary torpedo boat at ranges over 1,000 yards the shots will fall behind the engines, and so layers should be trained to lay at long ranges on the water line forward and gradually work back as the range shortens and at close range to lay under the foremost funnel. This should bring the mean point of impact in the center of the engine room and boilers.

By doing away with deflection, delay is avoided, as there is no time lost in putting it on, and the par. in "Garrison Artillery Training" "the gun layers will carefully observe the fall of each round in order to correct the deflection" can be deleted. There is no time to do this, and it should not be wanted, and in any case the layer at night is not the best man to make corrections. He has all his work cut out, situated as he is behind the shield, to keep his gun on the target, and the director can observe much better and if necessary tell him to lay more or less forward, as the case may be.

Also if there is no deflection, there is no danger in the excitement of action of forgetting to take it off when a boat stops or turns.

We can now go to distribution of fire, The present systems of distribution advocated are as follows:—

(1) All guns to open on the first boat and then when a second boat appears, a named group or gun to switch on to it, and so on for third and succeeding boats.

This is open to the objection that a needless amount of fire is opened on the first boat, and as every gun is firing there is no gun absolutely ready to turn on to the next boat the second it appears, and waste of time ensues.

Moreover, if two or three boats appear at once there would be room for a little confusion, and so delay as to which boat to fire at.

(2) A named group, generally on the flank, to open fire on the leading boat, and no other group to do so; when the second boat appears another group to fire on that, and so on.

This is taking a risk, however small, needlessly.

Granted that a group, or even a gun, should account for a boat by itself, yet if a boat did get in and the remainder of the guns had not opened fire, the officer responsible for the scheme would have very little to say in his defense. Moreover the same objection holds good as for the last scheme, viz., that with several boats coming in close together it would be difficult for each gun to select its target as arranged.

(3) The zone system, in which the water area is divided up into zones, and each group or gun has its own zone.

This is by itself absurd, as half the guns might not be firing, although a large number of boats might be coming in.

Then there is the system advocated in America where the Q.F. guns are assigned to different lights. Here where two or more boats are illuminated at the same time, the Q.F. guns open fire upon the boats illuminated by the lights to which they are attached. This seems to be a sort of movable zone system, and does not appear satisfactory, and in any case our system of having one illuminated area seems preferable.

None of these systems is good by itself. What is wanted is a combination of them, and the use of common sense.

It is not necessary to go beforehand into too much detail and say that such and such a gun shall bear on say the third, fourth, or fifth boat. The gun group commander, gun captain, director, or whoever is responsible, will waste his time counting which is his boat, and then probably make a mistake. The general principles which should be followed are :—

(a) The boats should be divided roughly into three or four lots, leading, center, and rear; or leading, lead center, rear center, and rear, and fire should be distributed roughly in accordance with the relative position of the guns with one another, *i.e.* if the boats are running past guns from left to right, then right-hand guns should engage leading boats, center guns center boats, and left-hand guns the boats towards the rear, but the number of guns told off to fire at the leading boats should be more than those at center and rear boats.

If again the guns are in line facing the boats coming end-on to them, then the guns on the right should fire on the right-hand boats, center guns at center boats, and left-hand guns at left-hand boats. There may also be certain places which are only under the fire of two or three guns; in this case that particular gun or guns must be made responsible for boats in that zone. The orders issued to it beforehand might be "open fire at the lead center boats, but if any boat appears in such and such waters open fire on it."

(b) If a boat stops in the beam, she has either been damaged or wants to draw fire; in either case, if there are any other boats coming along, leave it until not so busy.

(c) If one boat only comes in, every gun of the defense should not turn on it, neither should it be left to one gun, but according to the range and position enough guns should open fire to make absolutely certain of it. In normal conditions two should be enough; if however the harbor has a wide entrance, and ranges are long, then more guns might be told off.

(d) The gun layer must not go to sleep, even if the guns are so situated that the detachment can get half a minute's warning and are allowed to sleep. There should be at least two gun layers per detachment, and one must be awake. A man cannot jump up from a heavy sleep and lay his gun well.

(e) Finally the fire commander in whose administrative command the Q.F. guns are, or the special officer told off to command the whole of the Q.F. guns, should frequently study with the directors—used in the sense I have proposed—or, the gun group commanders of the present system, the various methods of attack, the different ways boats will try and come in, how the attacks should be met and the fire distributed in each case. Unfortunately there is never any chance of practising this most important maneuver in peace time, except with blank ammunition. The distribution of fire, however, might be tested at maneuvers by the boats carrying some distinguishing mark that could be seen in the searchlight, such as a large number painted on her, or a flag, and then on comparing notes afterwards it could easily be ascertained if each boat had been fired at.

The system of finding the error of the day by firing at an object at a known range, would entail great waste of ammunition. In the case of Port Arthur it would have entailed at least 300 rounds per gun. Once a week should be ample if the sight is tested properly every day. Of course after firing any appreciable number of rounds, the error of the day should be found by this method.

If guns are mounted so low that auto-sights cannot be used, as will sometimes be the case on breakwaters, the same general system should hold good, but as previously stated about double the number of guns that would be sufficient if they had auto-sights, will be required, bearing in mind as well that they will also be exposed in these places and liable to be put out of action by larger vessels than torpedo boats standing in to about 2,000 yards at night. (They might then still be 4,000 yards off the main armament which latter moreover with only its one relief will hardly be in the same alert condition as the Q.F. armament.)

It is an open question whether the naval system of setting the sight at a fixed range—I believe it is about 900 yards—and the layer laying high or low is not preferable to having a setter.

Torpedo boat ranges are short and the gun layers would soon learn how much to lay high or low, whereas the setter at the best rather bothers the gun layer fiddling with the sight, and it is so easy to turn the sight the wrong way.

No mention has been made of foggy or misty weather. If they are not seen until very close in, then to make up for it they will be going much more slowly, and the same armament and organization will be sufficient.

Under these conditions it will be more difficult to see the boats, but the latter will find it equally difficult to feel their way in.

Finally, if the main principles of distribution of fire are understood, and good common sense used by the gun commanders—be they gun group commanders, gun captains, or directors as proposed—then, provided that the harbor has been reasonably lighted and the guns allotted on definite principles according to the requirements of each harbor, and not in a haphazard manner, it will be impossible for any boat to escape its share of attention and reach its objective.

THE ARTILLERY COLLAR

By Veterinarian GERALD E. GRIFFIN, Artillery Corps

MANY artillery officers, on first being connected with the field artillery, are prejudiced against the zinc-plated, steel collar furnished by the Ordnance Department, and this prejudice lingers persistently for a more or less definite period until it finally disappears as the observer becomes convinced of the many good qualities of this collar. So much is he in favor of its use eventually, he would consider it a retrogression to be compelled to revert to the leather substitute.

The explanation of the prejudice is probably due to non-familiarity and the custom of using the leather article in all walks of life where the use of a collar is demanded; also the belief that the constant hammering of a hard, unyielding substance (steel) upon a soft one (muscle) will assuredly produce serious results. This belief is not however borne out by the facts as ascertained by experience.

Having passed through the different stages of doubt, uncertainty, and conviction in this connection and having compared both kinds of collars the one with the other, for several years under the most trying conditions, we have become convinced that the steel collar, when properly cleaned and fitted is superior, for military service, to the leather one, but when improperly adjusted it is inferior in every respect.

This statement may appear presumptious on our part but we believe we have given the subject sufficient study to be reasonably sure of our ground; study on long, heavy, tiresome marches with "green" and "seasoned" horses and under all conditions of weather and service except that of lack of forage, the latter we take it would be the crucial test.

Substitutes for fitting.—We have worked every scheme we could devise and tried many remedies, from the advertised "gall cures" to our own simple applications, to keep horses working in their places in the teams on long marches, but not one of these has been equal to the proper fitting and cleanliness of the collar.

Lead and swing teams.—These teams seldom have collar sores on the superior portion of the neck, except when the traction point of collar is too high, due of course to the fact that they do not have to uphold the weight of, and stand the erratic jerking of, the pole of the carriage. When either of these teams exhibit "galls" it will be noted that the right shoulder of the "off" horse, as a rule, first shows the abrasion, due undoubtedly to the fact that the drivers have a habit of pulling the heads of the "off" horses towards them when urging them along or resuming the road after a "turn out". This, of course, throws the right shoulder of these horses forward and increases the traction upon that side, and if the bearing surface of the collar does not fit where it should, the pressure is concentrated on one particular spot, almost invariably about one inch above the "point" of the shoulder and slightly to the outside due to the constant motion of the shoulder and arm joint and its anterior muscle, which passes over the anterior aspect of same. This action has a tendency to throw the collar upward and outward.

When the first abrasion appears on the "near" horse it will be found in the same locality on the left shoulder, due to the too quick turning of the animal by the driver in changing direction to to the right. Nevertheless if the collars are placed sufficiently high to avoid pressure on the play of the tendon of the muscle mentioned, such abrasions will be slow in appearing, while if the collar is fitted low they often appear on the second day out even when the traction is straight ahead.

It appears unnecessary to mention unequal length of traces, although it has been noticed that drivers and chiefs do not give this part of the fitting as much attention as it deserves.

Wheel teams.—If collars are not fitted sufficiently high on the lead and swing teams they certainly will not be so fitted on the wheel team. It must be remembered that the added weight of the pole on the collars of the wheel horses, especially if the limbers are loaded and cannoneers sit on same faced to the front, presses on the neck to such an extent that the large ligament and muscles of that region are depressed from one to one and one-half inches, depending on the weight, thus causing the bearing surfaces of the inferior portion of the collar to rest on and sometimes below the "point of the shoulder," inducing the abrasions to appear early and remain late.

The "galls" on this team appear first on the "off" horse, and this may be attributed to the habit many drivers have of "nagging" him to keep him up to his work which he dislikes when the collar is too low. The constant plunging into the collar soon makes itself evident.

In fitting collars high enough there is little chance of choking the animal as is claimed; if a collar properly fitted to the muscles of the shoulder has a tendency to choke, the conformation of the animal for artillery purposes is defective.

Sore necks.—Of course every one puts the blame for these on the pole, which after all is only half responsible.

We believe that sore necks are induced by the following causes:

1st. The top connections are too narrow as are also the pads.

2nd. On harnessing, the drivers place the collar in position before locking it, very often engaging a lock of the mane between the sides and the pad. Later on when the animal is called upon to exert himself at a given point, he strains forward and pulls the hair out by the roots, thus starting a point of irritation.

3rd. The heat produced by the sun's rays shining continually on top of the collar during a hot day is astonishing. The hand placed between the pad and the neck at this time is unpleasantly warm; the skin of the neck feels soft and flabby; it has lost its tone and in many cases is congested and unusually sensitive, while in other cases sensation is almost absent.

Sponges saturated with water, unless constantly renewed and at hand when needed, are without good effect (except temporarily); the water as it trickles down inside the pad becomes converted into vapor and actually acts as a warm compress, rendering the skin soft and causing the hair follicles of the mane to become enlarged and the tissues immediately below the pad more flabby still; the hair of the mane, too, becomes matted and twisted, easily retaining dust and sand; this abrasive material soon causes an irritation or "gall," that is very difficult to heal under the existing conditions, due to the lowered tone of the parts. Solutions of vinegar, tannin, etc., as a preventative, are of little value.

The best remedy is a stiff pad or shield of sole leather or other good non-conducting material exceeding the width of top of collar, and attached to the collar hook in center and to two bolts run through holes in flanges of sides of collar about one inch from the bolt of upper extension; this shield to be elevated sufficiently to permit free circulation of air and so arranged that it will not bend downward when collars are being put on or taken off.

4th. Weariness of the horse, particularly the saddle horse, laboring daily at his double task of weight carrier and hauler, causing the head to droop.

Change all saddle horses to the "off" side every second day. A battery horse if properly trained should be able to work easily in any position, in actual service he may be called upon to fill any place at any time.

5th. Downward traction by small teams in lead and swing, and the snapping back of collar on wheelers and its consequent blow to the shoulders, due to stretching of "Mogul" springs and their retraction when suddenly released by the leading teams' ceasing to pull (the "Moguls" are of great benefit to the wheel horses otherwise).

Why should not all horses in a team be of practically the same height and weight and therefore interchangeable? Is it due to the fact that small active horses in front are considered necessary to the maneuverings of the drill ground? In actual warfare a horse must work where he is needed, as a man must. Why not train him now? The advantage in being able to alternate and exchange single horses, as well as pairs, is obvious.

To obviate the downward traction, prevent the snapping back of wheel collars and at the same time render the wheel horse independent, so far as his collar is concerned, of all attachment of traces except his own, the following scheme has been evolved, tested and found to work well.

The new wire trace being cut down to the proper length is permanently fastened to the wheel trace two or three inches posterior to the cinch of saddle. When stretched it exceeds the wheel trace in length, anteriorly, by one or two inches and is suspended from the collar by a carrying loop of twisted wire, or a leather strap, which is long enough to give sufficient play to prevent any pull upon the collar. The trace of the swing team is then attached to the end of this trace instead of to the trace tug of the wheel team, thus changing the point of traction for the leading teams to a place back of the cinch, leaving the wheelers to use their collars independently, which they cannot do under the present arrangement. This supplementary trace to be a part of the wheel harness.

This arrangement will be found to be of great service in protecting the shoulders, neck and even legs of the wheelers.

6th. Defective conformation.

Field artillery officers should inspect the horses for their service. One individual cannot inspect two kinds of horses with advantage. In horse shows they never select a saddle horse man to gauge draught horses.

7th. Taciturn and "grouchy" drivers, cheerless, despondent individuals who soon make the best team the worst in the battery.

A driver should be of a cheerful, good-natured disposition, saving the whip and spur but given to whistling, singing and talking to his horses while marching at ease. It is wonderful how a team brightens up when handled by this kind of a man.

The drivers' pay could be increased with advantage to the service.

8th. Side straps too loose, permitting collars to plunge forward at haltings and going down hill, also when the rear of column "bucks" on account of sudden changes of gait in front; all of which puts the strain belonging to the breech on the superior portion of the neck. In this connection might be mentioned the improper use of, or lack of use of, brakes where the brake is indicated.

9th. Pole weight and its constant "jiggling".

10th. Exchanging drivers on the march by permitting cannoneers to take the drivers' place temporarily for practice or to give the former an opportunity to rest on the trail or limber.

11th. Poor drivers in lead or swing, or those given to saving their horses, thus putting all the work on the wheelers.

12th. Careless supervision and lack of disciplinary measures on part of chiefs of sections.

Actual experience.—While acting as driver, for information, it was noticed at the end of a day's march the fatigue experienced in driving lead or swing was about that induced by riding our own mounts at the rear of the column, yet irritation and mental depression were present and commented upon by the surgeon.

After a day's driving (on several occasions) of even the best wheel team in the battalion, the fatigue was most pronounced, and the irritation and mental depression well marked, due undoubtedly to the jumping of the pole and the constant effort of the team to minimize its effect; this effort is not so noticeable in old artillery horses but it goes on instinctively. It is very noticeable in half-seasoned horses, while "green" ones resist every movement of the pole and readily become fatigued, leg weary, dispirited and thin. As a rule the lead and swing drivers with a lax chief of section help to pull down the wheelers; they develop a tendency to "loaf" and slacken traces. I have known some of these men trying to square their ill feeling for the wheel driver by thus assisting in pulling down the wheel team.

Mental depression on the drivers' part causes the horse to lose interest in his work; it has been noticed that men of cheerful natures always had the "snappiest" team, which marched into camp in comparatively excellent condition.

The battery commander who sings himself or encourages it on the march, or even whistling, will soon notice an improvement in the spirit of his horses.

Prevention of "galls".—Traces exactly of the same length. Avoid all sudden pulling of the head of "off" horses. Avoid jerking the horse's head. Stead traction by lead and swing.

It is believed that for the "off" horse a snaffle bit with cheek bars and rings would be preferable to the curb and just as effective. The rings of the bit of our watering bridle are too large. When snapped into the "square ring" on the halter, the latter has to be taken up several holes on the crown strap to make the bit fit in the animal's mouth. This brings the nose band too high and causes it to irritate the crests of the upper jaw bone. When taking the bit off men forget to lower the halter, and the result is abrasions of maxillary bones at inferior part of crests. On small horses a knot may have to be made in the crown strap which is often permitted to remain there causing sore poll.

A small ring with cheek bar, retaining the present mode of attachment, appears to be the solution.

Proper fitting of collar.—Under this head no rule can be laid down without going into the anatomy of the parts involved. We would suggest, however, to those interested enough, to examine a picture of a horse showing the superficial layer of muscles (*Horses Saddles and Bridles*, Carter, page 20.) paying particular attention to the trapezium, anti-spinatus and mastoido-humeralis muscles; also examine deep layer with special reference to the position and action of the biceps and its tendon. The position of the ligimintum nuchie and its elasticity might also be considered.

It might be of advantage to remark that in fitting the collar the pad should be large enough to prevent pinching. Some men ruin a pad by squeezing it into a collar too small for it. Too small a pad will cause a space to exist between itself and sides of the collar. This space pinches the horse on the sides of the neck and the bruises thus produced are attributed to bites by other horses.

The point of traction should not be too high or else the pressure on the neck will be great. If the traction point is too low the collar will "ride" the neck, but this is preferable to the high traction.

Once the collar is properly fitted to a horse it should follow him and be used on him whenever it is necessary for him to wear a collar, until he is condemned or dies. His name should be painted on it on the "near side", and it should be as much a part of him as his shoes.

On the march, about the seventh day, horses begin to lose flesh; the majority of collars need adjusting at this time and again at about the sixteenth day.

Cloth pads are of little value except when horses are very thin and collars too large; if they are in use at all the threads should be taken out of the side next the skin otherwise they will be a source of trouble. Canvas pad covers that could be readily taken off and put on, and washed if necessary, would be a benefit.

Breast straps or breast collars are very useful when "galled" horses cannot be worked in a collar. They can do as much work and with as much ease in the lead and swing with this arrangement as with the regular collar and at the same time permit the abraded part to get well. In fitting, avoid "point" of shoulder and see that there are no irritating threads on the inner side; remembering the heaviness of our traces, the breast strap should be attached to the neck strap by means of a crow's foot, or three radiating straps. Each section should have four of these breast collars.

Airing shoulders at halts, when pole props are down, can do no harm and may be advantageous, but the application of cold water at these times cannot be beneficial.

On arriving in camp and when the harness has been taken off and put away, bathing the shoulders and neck with a salt solution (handful of salt to half a gallon of water), stimulates the skin and acts as a disinfectant; a solution of vinegar, (two ounces to a quart of water), is a good application. All abrasions and puffs should be reported at this time.

Collars should be sponged off after the shoulders are bathed; polishing, scraping, or rubbing of bearing surface with sand or any abrasive material should not be tolerated. This scrubbing soon exposes the steel beneath the zinc coating to the air; it rusts and pits and causes galls inside of a few hours.

During the winter months when horses are not used in harness but are taken out for horse exercise, it would be a good plan to place the collars on all team horses during this exercise and thus keep their shoulders in trim for the spring drills.

Treatments of galls.—Remove the cause, it can always be discovered if searched for; keep the part clean and disinfected with a solution of bi-chloride of mercury, nine grains to a quart of water.

As to the thousand and one cures, gall remedies, lotions, washes, ointments etc., we have tried them all and with about the same results in all cases.

The best gall remedy is the proper fitting of the collar and absolute cleanliness of its bearing surface and that of the skin. As to drugs, select your own astringent if you need one; iron, tannin, quinine, alum, alcohol, talcum powder, borax, etc., or combinations of them may be of advantage.

Puffs.—In cases of puffiness, often observed at the end of a day's march, it should never be permitted to pass unnoticed, trusting that it will have disappeared by morning, or put off with a perfunctory hand rubbing or perhaps the application of alcohol, vinegar or other such remedy; the shoulders of such animals should be water packed by means of a sack with a hole cut in its center, sewed up, stuffed with hay, soaked in water, placed on the shoulders in same manner as collar and retained there by means of a horse cover or other means during the night; more water applied at "taps", if necessary, and removed first thing in the morning so that the animal may go into harness with dry shoulders. This precaution will prevent many a gall.

Sore necks.—Neck abrasions are extremely unsatisfactory things to heal, on account of their low vitality and the constant irritation of the hair of the mane. They are so sensitive that the animal resents the least touch on the part involved. These sores have usually a raw looking, unhealthy appearance, have a tendency to spread and, if deep, to burrow. If severe and extensive they leave a weak spot on healing, that is worthy of watching; it is believed that most of the aggravated cases are due to irritation by hairs.

These neck galls call for the attention of the veterinarian who will have to decide as to the mode of procedure in their treatment, surgical or otherwise.

As a preventative of neck galls I have had the best results by "roaching" the mane under the seat of the neck pad and extending one inch on either side. Of course it is a difficult thing to convince a battery commander that this is necessary as he dislikes to sacrifice the appearance of his horses to this extent, but when the "sore neck report" begins to increase and wheelers are working in the swing or lead with breast collars, or led behind the store wagon doing nothing, he begins to realize that while style may be a desideratum there are other things more essential to a field battery, where the trustworthiness of the motive power contributes no small quota to its success.

I have said nothing of saddle galls ; they are inexcusable in a field battery if the men have been taught to ride properly, the stirrups are of the same length, saddle in its proper place on a properly folded blanket, and the wheel drivers are prohibited from riding with their foot upon the pole to avoid its hitting their leg.

THE BEST SHAPE OF TRAIL FOR LONG RECOIL CARRIAGES

By Major A. E. PIORKOWSKI, I.G.A.

THE "Internationale Revue" for July, 1905, gives two photographs, which we reproduce, of the new English field gun. This material is one of the latest types of the new rapid-fire field artillery, and it is interesting to note that the English appear to have retained of the Ehrhardt guns (some batteries of which were purchased during the Boer war) only those features that have been rejected in nearly all other countries; namely, the tubular form of trail, with the unavoidable placing of the elevating mechanism on one side.

This reappearance of the tubular carriage in England renders timely the following examination of its merits on theoretical grounds, which appeared originally in the "Schweizerische Zeitschrift fuer Artillerie und Genie."

In former times the body of a field gun carriage consisted of two wooden flasks united by transoms. Later and for a number of years the flasks have been made of pressed steel with flanges above and below and tied together by transoms of steel rivetted between. The flanges serve to stiffen the flasks and in most cases are also used to fasten an upper and a lower cover of thin sheet steel. In this manner the body of the carriages forms a closed box of rectangular cross-section. Several gun makers having especially suitable tools and high grade material will press both flasks and the bottom of the carriage from one piece, which thus is given the shape of a trough with flanges above.

Recently various articles on modern guns with long recoil have pronounced the use of a simple steel tube for the body of a carriage more advantageous. It is claimed that such a carriage with tubular trail, besides being more easily manufactured, will at the same time be of very light weight and considerable strength.

But the following remarks will show that this opinion is erroneous and, on the contrary, that with long recoil carriages also a correctly chosen form of box or trough-shaped trail is preferable to the tubular.

The body of the carriage has to fill two main requirements: with the unlimbered long recoil gun it serves, together with axle and wheels, as the frame carrying the cradle and gun, and supports the shock of discharge without change of position of the carriage. With the piece limbered up the body of the carriage being rigidly fastened to the rear axle, is part of the vehicle's frame, transmitting the pulling force from the front, the limber, to the rear axle.

The maximum requirements for these two functions must be examined separately.

I. THE STRESS ON THE BODY OF THE LONG RECOIL CARRIAGE WHEN FIRING

In the firing, the long recoil carriage has to resist the following forces:

1. The weight of the gun acting downward in a vertical line from the (changing) center of gravity.

2. The pressure of the brake, which during the recoil of the gun acts in the hydraulic cylinder and is to be considered as acting in the direction of the axis of the gun because of the reacting pressures in the cradle itself, and

3. The reacting pressures at the trail or spade and below the wheels.

A long recoil field gun must not jump even when fired horizontally. In this position the vertical reaction on the trail is the highest, and the moment of the brake pressure relative to the horizontal through the spade equals the moment of the weight of the gun, 'reducing the reaction pressure on the wheels to zero. The vertical component of the trail pressure then equals the weight of the gun, and the horizontal component of the trail pressure equals the brake pressnre.

The resultant is the total pressure reacting on the spade or the trail.

This can be divided into two components, the one in direction of the body of the carriage, the other normal to it. One acts on the body by compressing, the other by bending it. The bending component, it is easily seen, will always be somewhat less than the weight of the gun, so with an approximate calculation, this weight may be taken as equal to the maximum bending force.

The dangerous cross-section of the carriage is near the elevating gear. Down to this point the body may be considered as a free supported beam, from whose end approximately the gun's weight is suspended.

From the dangerous cross-section to the end of trail the moments of the bending force decrease. It is therefore well to reduce the cross-section accordingly to save weight, and design the body of the carriage as a beam of uniform resistance.

Assuming equal qualities of material, the moment of resistance relative to the horizontal axis of gravity, in the dangerous cross-section especially, determines the resistance and endurance of the carriage. The greater this moment, the smaller the stress on the material produced by firing and, consequently, the higher the endurance.

With the same moment of resistance the smaller the area of the cross-section, the smaller the weight of the carriage.

Let figs. 1 and 2 for instance represent the cross-sections of two carriages, one of two separate flasks, the other in shape of a trough. Both kinds have been made in similar dimensions for long recoil field guns in different countries. Both are of the same thickness of plate, of the same cross-section, and the moment of resistance is for both the same

$$W = \frac{6 \times 24^3 - 5.5 \times 23^3}{6 \times 24} = 223 \text{ cm}^3$$

Putting the weight of gun at about 1000 kg. and the distance of the spade from the elevating gear at 1.80 m., both carriages will suffer a maximum bending stress in the dangerous cross-section:

$$S = \frac{1000 \times 180}{223} = 807 \text{ kg. per cm}^2$$

Now let fig. 3 represent the cross-section, of the same area, of a tubular body of carriage, which then has the same weight, and the same moment of resistance. The outer diameter, under such conditions will be 261.3 mm., and the thickness of wall 4.35 mm. The use of a tube of such diameter and so thin a wall cannot be recommended; and for two reasons:

First, it is hardly possible to give a tube of such cross-section and of nearly 2 m. length, the necessary stiffening transoms, as is always done in carriages with two flasks or trough-shaped carriages. There is always danger that the tube will be dented or deformed by comparatively slight accidental shocks from the side, and its resistance easily reduced.

Second, the use of a tubular carriage makes it necessary to place the elevating gear on one side, and the larger the tube, the further it will be from the center plane.

On the other hand, reducing the diameter of the tube and increasing the thickness of its wall means either reduction of the moment of resistance, *retaining the weight*, or retaining the moment of resistance it means an *increase of weight*.

Taking the case for instance that the thickness of wall and the area of cross-section is to be the same as with the 2 flasks or the trough in figs. 1 and 2, the outer diameter of the tube will be 223 mm., the moment of resistance = 183 cm^3, and the stress on the material 983 kg. per cm^2.

Again, giving the tube a diameter, say, of 131.4 mm., the same moment of resistance of 223 cm^3 could only be obtained by making the thickness of the wall equal half the diameter, in other words to make the body a solid cylinder. Its area of cross-section would then be 3.88 times that of the flasks or trough, and so the weight of the body nearly 4 times as large as that of flasks or trough of a uniform cross-section and having the same moment of resistance.

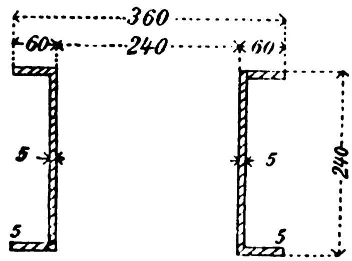


Fig. 1.

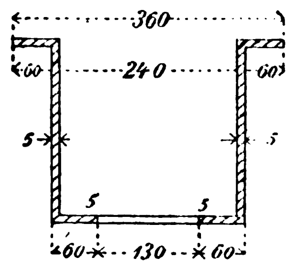


Fig. 2.

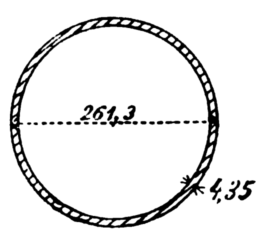
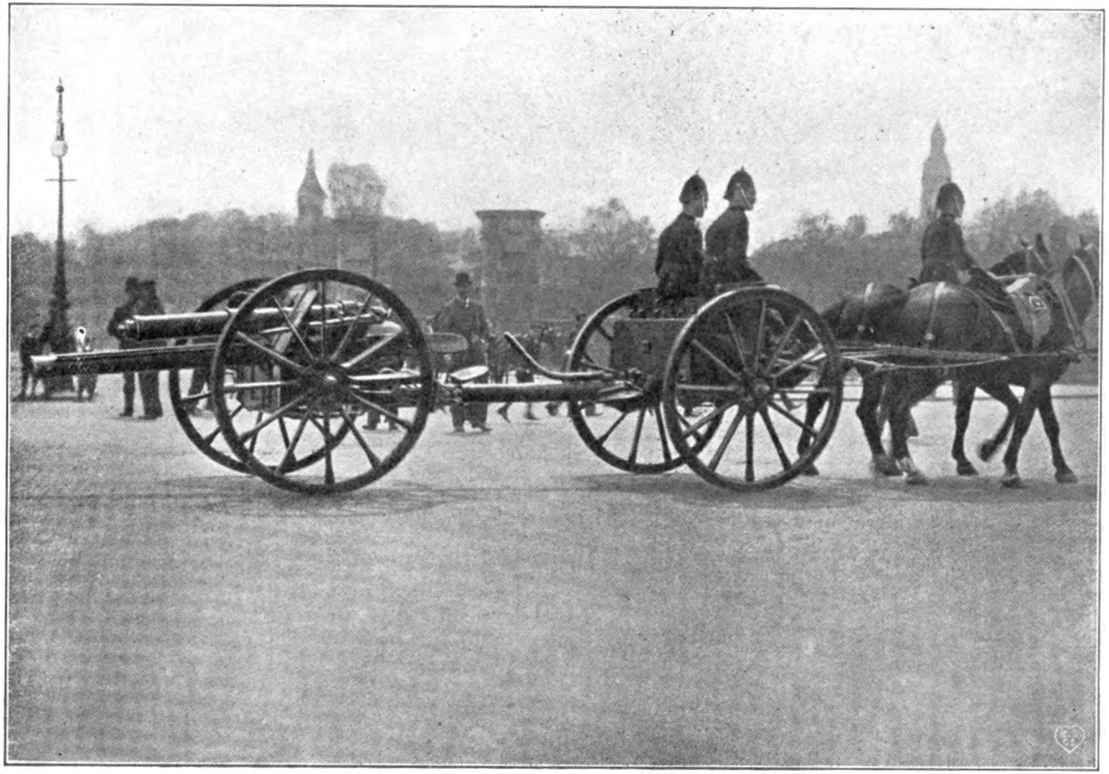


Fig. 3.

A tube of 130 mm. diameter and 5 mm. wall, as has been used in several instances, has a moment of resistance of 59 cm^3; and, under the above assumptions of 1000 kg. weight of gun and 1.8 m. distance from spade to elevating gear, a stress on the material

$$S = \frac{1000 \cdot 180}{59} = 3050 \text{ kg per cm}^2$$

or about 3.8 times as high as the flasks or trough, while the area of cross-section (and also the weight of the body) is only 38% less as for the flasks of uniform section. It is true a stress on the material of the amount of 3000 kg. per cm^2 will



The New English Field Gun.

The New English Field Gun.

not in reality be reached under the assumed condition, because the bending component even in a horizontal position of the gun will always be a little smaller than the weight of the gun. But if the body of the carriage is lengthened by a telescoping arrangement, the bending component will undoubtedly grow larger than the weight of the gun. The lever on which this component acts, will then be at least 2.40 m.; and the pressure of the trail must evidently approach the weight of gun very closely; for the artificial prolonging of the trail can only have a reason, where with a shorter carriage a lifting of the wheels above the ground would be unavoidable.

As for the *admissible* stresses on the material it ought to be remembered that they may be higher in rolled and then pressed material, as in flasks or troughs, than in drawn tubes. The tubes have to be made of comparatively soft steel, and although the strength and elasticity are increased by the drawing process, yet it is not so easy to equal the high qualities of rolled and pressed sheet steel.

In exceptional cases a stress as high as 3000 kg. per cm^2 may be attempted with excellent material, but to subject such an important part as the body of a field carriage, to such a test, repeated at every round of fire, seems too great a risk.

In designing a field carriage every kilogram of additional weight must be carefully considered. The task is to unite greatest possible resistance with least weight. In this respect the flask and trough-shape construction enjoy the advantage that they can be constructed as beams of uniform resistance, that is, they can be made tapering towards the trail. With a tube this is impossible, or nearly so. By this tapering a saving of about 10% of the weight for uniform cross-section is obtained.

II. THE PRINCIPAL STRESSES ON THE BODY OF THE CARRIAGE IN DRAFT

When the gun is limbered up and on the road, the body of the carriage is subjected to a variety of stresses. Aside from accidental shocks, the highest stresses probably occur when, on a bad road, the limber is turned at a right angle, and the carriage wheels sunk deep in the ruts can change their direction only with great difficulty, or not at all.

Then the whole power of the horses, by means of the limber hook, applies to the end of the trail normal to the central vertical plane.

In this case also the carriage is strained to bend, only this time by a horizontal force. The task, therefore, is to give to the body of the carriage at the most dangerous point, which now is immediately in front of the axle (not abreast of the elevating mechanism), a cross-section of greatest moment of resistance in relation to a vertical axis of gravity.

Computing this moment of resistance for the cross-section of two flasks, gives

$$W = \frac{1}{6}(36^2-24^2) + \frac{2.8}{6}(25^2-24^2) = 308 \text{ cm}^3$$

and for the cross-section of the trough

$$W = \frac{1}{12}(36^2-24^2) + \frac{1}{12}(25^2-13^2) + \frac{2.8}{6}(25^2-24^2) = 286 \text{ cm}^3.$$

So that the moments of resistance relative to a vertical axis of gravity are even greater than those relative to the horizontal axis of gravity ($W = 223$ cm^3). As for the tube-shaped carriage the moment of resistance relative to a vertical axis is the same as computed above, there results an even greater superiority of the flasks or trough-shaped gun carriage, over the tube-shaped one, when on the march.

Bending forces in directions essentially differing from the above will hardly occur in practice; it suffices therefore to compute extreme stresses in relation to a vertical and a horizontal axis.

Next to the principal advantage of greater resistance with less weight there ought to be mentioned several minor and merely practical advantages of the flasks and trough-shaped carriages over those of tube shape, as follows:

All fixings can be fastened more readily to the flat surfaces than to the curved ones.

The elevating apparatus can be placed in the middle, while with a tube it must be on one side.

A tool box can be placed between the flasks or in the trough, whilst in a tube there is no room for such.

Regarding the cost of production, it may be admitted that one single drawn-tube carriage can be made at a less cost than a single pressed flask carriage or trough carriage, but this advantage decreases quickly when a number of carriages of similar model is to be made. With several batteries of the same model the difference in price disappears altogether.

A model of the tubular form of field carriage was extensively tested by the U. S. Ordnance Department, in 1901-1902; and the following objections to this material are noted, quoting from the report of the Chief of Ordnance:

"The Ehrhardt elevating mechanism worked exceedingly hard toward the end of the firings on this platform. Investigation showed that the inner elevating screw was bent, top to the right. This screw has at its upper end a horizontal shank which extends to the right and supports the traversing table. The screw was bent by the cross strain brought upon it when the gun was in its recoiled position. It was taken to the machine shop and straightened so as to work satisfactorily.

"*The carriage system.*—The *elevating screw* is placed at the side of the trail and is subjected to a bending moment, which caused the screw to work badly and necessitated shop repair. The *telescoping form of trail* can give rise to a loss of time in operation at critical moments, and is subject to be rendered inoperative, as regards closing, more especially by any injury to the finished sliding surface. The *tubular trail* does not lend itself readily to a suitable attachment to the axle, and the form of this attachment, combined with the method of pivoting the cradle, is apparently a source of weakness in the construction."

THE ALTITUDE FACTOR

By Professor PHILIP R. ALGER, U. S. Navy

IN the July-August number of the Journal of the United States Artillery, in an article by Captain Alston Hamilton, a method of determining the value of the altitude factor (f) is presented which is claimed to be more accurate than that originally brought into use by Colonel Ingalls, and much superior to the one used by the writer in his Exterior Ballistics. It is hoped that the following brief explanation and comparison of the three methods may be of some interest.

Ingalls' method.—The temperature of the air is assumed to be the same at all heights, so that the weight of unit volume of the air is proportional to its pressure per unit area. Thus, calling w_0, p_0 and w, p the weight per cubic foot and the pressure per square foot of the air, at the level of the gun and at any height h respectively, we have

$$\frac{w}{w_0} = \frac{p}{p_0} \qquad (1)$$

But $dp = -w\,dh$, and so we have

$$\frac{dp}{p} = -\frac{w_0}{p_0}\,dh \qquad (2)$$

the integration of which between proper limits gives

$$\log_e \frac{p}{p_0} = -\frac{w_0}{p_0}\,h \qquad (3)$$

$$\frac{p}{p_0} = \frac{w}{w_0} = e^{-\frac{w_0}{p_0}h} \qquad (4)$$

or, putting $\frac{p_0}{w_0} = H$,

$$f = \frac{w_0}{w} = e^{\frac{h}{H}} \qquad (5)$$

in which H is the "height of the homogeneous atmosphere," or the height of a column of air of specific weight w_0 which would cause the pressure p_0 at its base.

Colonel Ingalls gave H the value 27800 feet, corresponding to a temperature of 60° F.

Hamilton's method.—The well known fact that the temperature falls with increase of altitude is taken account of by assuming that the height of atmosphere considered is all at a temperature which is the mean between the temperatures at its bottom and top, the former being the temperature at the gun and the latter calculated on the supposition that there is a drop of temperature of 1° F. for each 300 feet ascent. That this is what Captain Hamilton's formula really is may be shown by its deduction, which follows.

Putting equation (3) in the form $h = \frac{p_0}{w_0} \log_e \frac{p_0}{p} = \frac{p_0}{w_0} \log_e f$; recollecting that $\frac{p_0}{w_0} = H =$ about 26280 feet (for dry air at 32° F.); and changing from Naperian to common logarithms, we have

$$h = \frac{H}{\mu} \log_{10} f = 60520 \log_{10} f \qquad (6)$$

But this is the height of a column of air at 32° F., and so, supposing the true temperature of all the air to be $\frac{t + t'}{2}$, in which t is the temperature at the base and t′ that at the top of the column, we obtain

$$h = 60520 \left\{ 1 + .002034 \left(\frac{t + t'}{2} - 32 \right) \right\} \log_{10} f \qquad (7)$$

in which, of course, $.002034 = \frac{1}{491}$ is the coefficient of expansion of air for 1° F.

It is now only necessary to put $t' = t - \frac{h}{300}$, thus assuming a drop of 1° F. for each 300 feet ascent, and to make a small correction in the constants to take account of the moisture in the air,* and (7) reduces to Hamilton's formula:

$$\log_{10} f = \frac{h}{56518 \left\{ 1 + .0023066 \left(t - \frac{h}{600} \right) \right\}} \qquad (8)$$

Alger's method.—The hypothesis of the "convective equilibrium" of the atmosphere, proposed by Sir William Thompson (Manchester Memoirs, 1865) is adopted as more nearly representing normal conditions than that of "isothermal equilibrium." This amounts to neglecting the conductivity of the air, which is very small, and supposing that the expansion

* Captain Hamilton does not state what percentage he takes for the relative humidity, but presumably it is 50 per cent since that is the standard condition on which the ballistic tables are based.

of the air, when it rises from a point of higher to one of lower pressure, is adiabatic. In other words, the temperature at any height is supposed to be that which the surface air would have if it expanded adiabatically (without gain or loss of heat) from the surface pressure to the pressure at the given height.

Since the adiabatic formula is $p\,v^{\gamma} = p_0 v_0^{\gamma}$ (in which $\gamma = 1.408$ is the ratio of the specific heats), we have

$$v = \frac{v_0 p_0^{1/\gamma}}{p^{1/\gamma}}, \text{ whence}$$

$$dp = -\,w dh = -\frac{1}{v}\,dh = -\frac{p^{1/\gamma}}{v_0 p_0^{1/\gamma}}\,dh \tag{9}$$

$$\frac{dp}{p^{1/\gamma}} = -\frac{1}{v_0 p_0^{1/\gamma}}\,dh \tag{10}$$

the integration of which between proper limits gives

$$\frac{\gamma}{\gamma-1}\left(p_0^{\frac{\gamma-1}{\gamma}} - p^{\frac{\gamma-1}{\gamma}}\right) = \frac{h}{v_0 p_0^{1/\gamma}} \tag{11}$$

$$\frac{\gamma}{\gamma-1}\left\{1 - \left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right\} = \frac{h}{v_0\, p_0} = \frac{h}{H} \tag{12}$$

or, substituting $\left(\frac{v_0}{v}\right)^{\gamma-1}$ for its equivalent $\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}$,

$$\frac{\gamma}{\gamma-1}\left\{1 - \left(\frac{v_0}{v}\right)^{\gamma-1}\right\} = \frac{h}{H} \tag{13}$$

$$\left(\frac{v_0}{v}\right)^{\gamma-1} = 1 - \frac{\gamma-1}{\gamma}\,\frac{h}{H} \tag{14}$$

and this, since $\frac{v_0}{v} = \frac{w}{w_0} = \frac{1}{f}$, gives us

$$f = \left(1 - \frac{\gamma-1}{\gamma}\,\frac{h}{H}\right)^{-\frac{1}{\gamma-1}} \tag{15}$$

from which, putting $H = 27700$ and $\gamma = 1.408$, we obtain the formula of Table III., Alger's Exterior Ballistics,

$$f = \left(1 - .29\,\frac{h}{H}\right)^{-2.451} \tag{16}$$

This formula was, I believe, the first one which took account of the fall of temperature with height in ballistic work, and, as I shall proceed to show, it amounts to the same thing as assuming a uniform drop of 1° F. for each 186 feet ascent, Ingalls' formula assuming no drop, and Hamilton's assuming a drop of 1° for each 300 feet ascent.

Let k be the true height of the atmosphere, so that at the height k the absolute temperature is zero. Then if θ_0 is the ground temperature and θ that at the height h (both absolute), we have, supposing a uniform drop,

$$\theta = \theta_0 \left(1 - \frac{h}{k}\right) \tag{17}$$

But $\frac{pv}{\theta} = \frac{p}{w\theta} = \frac{p_0 v_0}{\theta_0} = \frac{H}{\theta_0}$, whence we obtain

$$\frac{p}{w} = H \frac{\theta}{\theta_0} = H \left(1 - \frac{h}{k}\right) \tag{18}$$

Also, since $dp = -wdh$, $\frac{dp}{p} = -\frac{w\,dh}{p}$, and so we have

$$\frac{dp}{p} = -\frac{dh}{H\left(1 + \frac{h}{k}\right)} \tag{19}$$

the integration of which between proper limits gives

$$\log \frac{p}{p_0} = \frac{k}{H} \log \left(1 - \frac{h}{k}\right) \tag{20}$$

$$\frac{p}{p_0} = \left(1 - \frac{h}{k}\right)^{\frac{k}{H}} \tag{21}$$

But, we also have

$$f = \frac{w_0}{w} = \frac{p_0 \theta}{p \theta_0} = \frac{p_0}{p}\left(1 - \frac{h}{k}\right) \tag{22}$$

$$\frac{p}{p_0} = \frac{1}{f}\left(1 - \frac{h}{k}\right) \tag{23}$$

and so (21) reduces to

$$f = \left(1 - \frac{h}{k}\right)^{1 - \frac{k}{H}} \tag{24}$$

and (24), if we put $k = \frac{\gamma}{\gamma - 1} H$, reduces to the formula (15) already deduced on the convective equilibrium hypothesis.

The values of H and k used by the writer correspond to a surface temperature of 59° F. and a drop of 1° F. for about 186 feet ascent, but any other rate of drop can just as well be taken account of, by giving k the corresponding value, and any surface temperature can also be allowed for by giving H the value corresponding to that temperature. The value of the exponent

$1 - \frac{k}{H}$ would appear to be independent of the ground temperature, since any variation of the latter should affect the value of k in the same proportion as it affected the value of H.

Taking Hamilton's assumed drop of 1° F. for 300 feet ascent to be correct, the value of H for 59° F. being 27700 and that of k for the same temperature being $k = 518 \times 300 = 155400$, we would have $1 - \frac{k}{H} = -4.61$, and the correct value for f would be

$$f = \left(1 - \frac{h}{k}\right)^{-4.61} \qquad (25)$$

$$\log f = -4.61 \log \left(1 - \frac{h}{k}\right) \qquad (26)$$

in which k is to be given the value obtained by multiplying the absolute temperature (Fahr.) at the ground by 300.

This formula (26) gives considerably smaller values for f than those tabulated by Captain Hamilton, and, unless some flaw can be found in its deduction, it would appear to discredit the accuracy of his method.

In this connection, it would be interesting to learn the basis of Captain Hamilton's statement regarding Alger's tabulated values of f,—that they "would for considerable values of h lead to error of immense proportions,"—and his further statement that Ingalls' formula "is the best at present in use." If these things have been demonstrated by actual firings, it is one thing; if they are assumed because Ingalls' formula gives results nearer Captain Hamilton's than Alger's does, that is quite another thing.

Finally it is to be remarked that the correction of f for humidity and temperature can only be justified if we accept the belief that momentary variations of their values *at the ground* are accompanied by similar variations throughout the whole height of the atmosphere.

THE ALTITUDE FACTOR

A REPLY

By Captain ALSTON HAMILTON, Artillery Corps

THE formula deduced by Professor Alger and used as the basis of his table is defective as follows:

(a) It assumes *adiabatic* expansion.

(b) It assumes *dry* air.

(c) When reduced to a barometric formula it fails to tally with universally accepted results, verified by actual measurement.

(d) As a corollary it involves a rate of decrease of temperature with altitude which has experimental contradiction at every turn.

(e) It involves as a corollary the flat ignoring of the following for which my authority is Sir William Thompson himself: 'the condensation of vapor in the air is the chief cause of the cooling effect being so much less than that which would be experienced by dry air.'*

(f) In the tables for the reduction of temperature to sea level (Smithsonian Meteorological Tables) the *possible* rates of change of temperature with altitude range from 1° in 200 feet for *very low* humidity to 1° in 900 feet for exceedingly humid and otherwise abnormal conditions.

It will be noted that Professor Alger's assumption of a mean drop of 1° in 186 feet falls below the lowest of these.

(g) For the following I give as my authority Professor S. E. Tillman, supported, if I mistake not by Professor Ferrel, the eminent meteorologist:†

"In the normal condition the temperature of the atmosphere decreases as the altitude increases at the rate of about 1° F. for every 300 feet when the mean annual temperature is considered. The temperature of the crust of the earth increases at the rate of about 1° F. for every 55 feet of descent below the surface. This interior heat has no perceptible effect upon the temperature of the air."

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* Mem. Lit. Phil. Society, Manchester. Vol. ii, 3rd series, p. 131.

† See also article on the Himalayas, Encyc. Brit., by Lt. Genl. Richard Strachey, R.E., C.S.I., F.R.S., referred to below.

(h) Professor Tillman further states*

"Notwithstanding the poor conducting power of gases and liquids we know that they can be cooled and warmed very readily. This is due to the fact, already mentioned, that they expand by heat and rise while the colder fluid descends and thus are established the convection currents previously discussed."

(i) Compare with these facts, which are *patent*, the following from Professor Alger's article in this number of the JOURNAL: "This amounts to neglecting the conductivity of the air, which is very small, and supposing that the expansion of the air, when it rises from a point of higher to one of lower pressure, is adiabatic." That this is tantamount to Sir William Thompson's hypothesis of the "convective equilibrium," especially in view of the statements of Sir William Thompson and Professor Tillman, I am sure that none of my readers will admit, and Professor Alger's further use of the ratio of the specific heats for DRY AIR is in flat, but probably unconscious, defiance of Sir William Thompson's dictum above quoted (e).

This is the more pertinent since Sir William Thompson's authority is the sole basis of Professor Alger's formula.

My formula is justified as follows:

(a) It is based upon Rühlmann's barometric formula to which Mr. Buchan, F.R.S.E.† *after a consideration of Sir William Thompson's Manchester Memoir*, which he regards as contributory to Rühlmann's formula, gives preference as follows: "The following formula by Rühlmann is given as the simplest and best, being based upon the most recent results which have been arrived at," etc. My formula is directly deduced from the barometric formula used in Johnson's Surveying, edition of 1902, which is essentially Rühlmann's and the correction for humidity is based upon a table of humidity and temperature coefficients given therein (p 134) for which U. S. Coast and Geod. Survey is given as authority and for which, in turn, Professor Ferrel is responsible (Meteorological Researches Part iii;—Barometric hypsometry and reduction of barometer to sea level, Report U. S. Coast and Geod. Survey, 1881; Appendix 10.)

That humidity and temperature should be considered is shown as follows:

* "Heat" p. 76.

† Article on Barometer, Encyc. Brittanica.

"Dr. A. Guyot* in treating of the humidity factor in connection with hypsometrical tables took the following position: 'To introduce a separate correction for the expansion of aqueous vapor is, in the writer's view, a doubtful improvement. The laws of distribution and transmission of moisture through the atmosphere are too little known, and its amount, especially in mountainous regions, is variable and depends too much upon local winds and local condensation to allow a reasonable hope of obtaining the mean humidity of the layer of air between the two stations by means of hygrometrical observations made at each of them. These doubts are confirmed by the experience of the author and of many other observers, which shows that, on an average, Laplace's method works not only as well as the other, but more uniformly well. At any rate the gain, if there be any, is not clear enough to compensate for the undesirable complication of the formula.'

Since this position was taken by Dr. Guyot forty years ago there has been no such advance in our knowledge as to impair the practical conclusion in conformity with which he constructed his hypsometrical table. Accordingly, in treating this portion of the formula in the construction of the present tables it has been deemed advantageous to retain the method adopted by Guyot and to† *incorporate the humidity factor in the temperature term,* thereby assuming the air to contain the average degree of humidity corresponding to the actually prevailing condition of temperature.

In evaluating the humidity factor as a function of the air temperature the tables given by Professor Ferrel have been adopted."‡

I have used this method which virtually dispenses with the psychrometer reading at the upper point, *even where it is available.* This weight of authority, confirmed still further by the authority of contemporary engineers like Johnson, Wright and Ziwet, seems to leave no doubt as to the matter.

That the temperature is transmitted instantaneously from the surface to great heights I have never maintained. Neither is a reading taken every moment. That convection currents heat the upper air in conformity with ground temperatures I resolutely maintain.

If further evidence is needed I refer the reader to the article of Lieut. Genl. Richard Strachey, R.E., C.S.I., F.R.S.

*"Smithsonian Tables, Meteorological and Physical."
† The italics are mine.
‡ Smithsonian Meteorological Tables, 1896.

on the Himalayas (Encyc. Brittanica) in which each altitude has its summer and winter range of temperature defined, a partial resumé of data for which I give :

	7000 ft.	9000	12000	15000
Summer	Mean 65	not given	above 32°	not above 32°
Winter	" 44	32	not given	below 32°

Whether the drop in temperature from the ground temperature occurs altogether due to convection currents, or whether it is in part affected by the amount of heat received from the sun in a given time is not material: the dependence of the upper upon the ground temperature is assured and the assumption of a mean ground temperature of 59° is unwarranted.

In conclusion I desire to call attention to the fact that I have changed my tables* in order to correct the density ratios for temperature.

As deduced, my formula gave f as the ratio of the pressures; it was thus a barometric formula. Since the densities are dependent not alone on the pressures but on the temperatures, corrective factors for temperature had to be applied to the values. This was done by the use of an assumed mean humidity. The table, as now corrected, has the following traits:

1. It is correctly *deduced from experimental facts.*

2. It has incorporated in it a corrective factor thus giving the value of log f_a from the *mean height* whereas f_a is that value of f_a actually wanted; i.e. that for the *height of mean density.*

3. It does not assume a mean temperature but is different for summer and winter, as it obviously should be.

4. It is entered with the argument $h = F \cdot y_0$ in which F is dependent on the form of the trajectory, as it should be.

The importance of the new method, broadly considered, is far-reaching.

Add to this that the use of negative heights enables us to handle the inclined trajectory with facility and accuracy, and no doubt as to the value of my method should exist.

It would interest Professor Alger to know the basis of my statement regarding his tables : that basis was a comparison with Rühlmann's and Babinet's formulas, the absence of a correction for ground temperature, the assumption of $\frac{2}{3}y_0$ as the height of mean density. Actual firings can prove nothing for this reason : as I have pointed out in my article in July-August

* This occurred to me while reading Professor Alger's article on the Altitude Factor, at the point at which he was considering the drop in temperature of 1° in 300 feet.

number of JOURNAL, practically every component of the ballistic coefficient is now crudely determined. Why befog the discussion by the introduction of additional uncertain elements? The elements should each, so far as is practicable, be determined *separately and correctly*; and THEN, *those elements which can only be determined empirically*, found in that way.

If his criterion of reliability is concurrence with firing results (with other elements uncertain), why not assume such a value of γ or k, or both, as would most nearly fit the results already gotten by the use of other incorrect factors? This would in my opinion involve many f-tables, to cover satisfactorily existing data; and the name of γ and k would be legion.

The humidity at the surface is propagated by convection to a reasonable height such as occurs in direct fire.* Therefore for direct fire the altitude factor is very properly used in connection with the $\frac{\delta_1}{\delta}$ tables for a given humidity at the surface.

For high angle fire, however, I am printing in this number a $\frac{\delta_1}{\delta}$ table, (r.h. 50%) for use with mortars.

Comparison of values for 10000 feet and standard conditions.

Alger's	1.312
Hamilton's	1.378
Ingalls'	1.433
	3)4.123
	1.374

It is interesting to note that though independently deduced my result for this *particular* value of the temperature 60° is almost an exact mean between the isothermal and adiabatic expansions. Neither adiabatic nor isothermal expansion is justified as an assumption,—as has been shown. They represent the extremes between which the true values must lie.

Now take Hamilton's for t = 100 and h = 10000

$$\log f_a = 1.3425$$

and for t = 0 and h = 10000

$$\log f_a = 1.4456$$

The former is nearer Alger's; the latter nearer Ingalls'. This again illustrates that my formula is flexible and enables us to accurately eliminate f from ballistic firings.

* Otherwise how could there be condensation?

My formula has not been tried yet; but I look forward with confidence to more stability in the value of c with a given range, velocity, elevation and atmospheric conditions, for then we may take account of variable elements heretofore given *average* values.

In his review of Professor Alger's Exterior Ballistics, Colonel Ingalls found that, following it, the atmosphere would disappear at about 18 miles height. Of course, if the *adiabatic* expansion of dry air were assumed, this would necessarily follow. It is well known that the height of the atmosphere is at least 40 miles. Colonel Ingalls' assumption of isothermal expansion would give its disappearance at an infinite height.

In my opinion the following are the facts of the case:

1. The truth lies in between.
2. The rate of change is not uniform but is sensibly so up to the greatest heights explored, and decreases gradually as it approaches the upper limit of the air.

The initial rate of change then could not be fairly carried *ad extremis*, which on my assumption would give about 30 miles, but as no law except the local one deduced from experiment, is assumed, no prediction regarding the disappearance of the atmosphere, can be made from my formula.

PROFESSIONAL NOTES

ITALIAN COAST ARTILLERY MATERIAL

To within recent years the Italian coast artillery material comprised:—

1. The 22-caliber 12.6-inch gun; projectile, armor-piercing shell weighing 765 lbs. with a bursting charge of 9 lbs. and a 475 lb. shell containing a bursting charge of 18 lbs. The service charge is about 187 lbs. of progressive powder.

2. The 9.5-inch "long" and "short" guns, 24 and 19 calibers, firing a 330 lb. armor-piercing shell with bursting charge of 24 lbs., and a 275 lb. shell with an explosive charge of 9.9 lbs. The muzzle velocities are, respectively, 1477 and 1595 f.s., with the service charge of 68 lbs. of progressive powder.

3. The 11-inch short howitzer, 10.2 calibers, mounted on a fortress carriage, which fires a semi-armor-piercing shell, weighing 478 lbs., with a bursting charge of 17.6 lbs.,

(*a*) with 6 charges in barbette batteries situated more than 325 feet above sea level;

(*b*) with 8 charges in barbette batteries located on heights less than 325 feet, and also in those with indirect aiming, having a parapet less than 15 feet;

(*c*) with 14 charges in batteries with indirect aiming, having a parapet higher than 15 feet.

The charges of large-grained powder vary from 11 to 44 lbs., and the zones overlap from 220 to 440 yards. There is also a hydropneumatic carriage, of the Armstrong type, with which 14 charges are used.

4. The 11-inch long howitzer, 19 calibers, on fortress carriage, which fires a semi-armor-piercing shell, and a steel torpedo shell weighing 472 lbs., containing a bursting charge of 40.8 lbs. of pertite, with 6 charges varying between 16.7 lbs. and 93.7 lbs. With a muzzle velocity of 1378 f.s., the maximum range is 11,750 yards.

5. The 9.5-inch howitzer, 10.5 calibers, resulting from the transformation of the 8.7-inch smoothbore howitzer, which fires a 262 lb. torpedo shell containing 17.6 lbs. of guncotton.

All these guns are of the built-up type, consisting of a tube with one or two layers of hoops; the fermeture is of the screw system with obturating ring.

As to the rapidity of loading, it requires 2 min. for the 9.5-inch; 3 min. for the 12-inch; 1 min. 30 secs. for the 9.5-inch howitzer; and 2 min. for the 11-inch howitzers.

All the carriages have chassis with rear truck-wheels and hydraulic brake for checking recoil. For bursting charges of projectiles, the following is used:

1. Black powder; 2. wet gun-cotton in parallepipedon-shaped grains for the 12.6-shell, the 9.5-inch torpedo shell and the 11-inch shells, and in the form of disks for the torpedo shell; 3. pertite (picric acid).

The service charges are made up of progressive powder and prismatic powder. In recent years the Italian government has completed its coast artillery material by the following pieces for special installations:

1. The 15.7-inch gun, mounted in armored turret, firing a 2028 lb. armor-piercing projectile with a muzzle velocity of 1805 f.s.

2. The 6-inch gun of 34 calibers, which fires: armor-piercing shell, weight 98.1 lbs.; semi-armor-piercing steel shell, weight 100 lbs.; torpedo shell, weight 100 lbs. containing a bursting charge of 10.6 lbs. of guncotton; hardened cast-iron shell, weight 98.6 lbs.; and shrapnel with a combination fuze. The charge consists of balistite enclosed in a metallic case.

The carriage is provided with a steel shield 2.99 inches thick.

3. The 11-inch howitzer, model A, of 12.5 calibers, resulting from the transformation of the 9-inch gun, made by Armstrong; it has 8 charges, 6.6 lbs. to 56 lbs.

4. The Krupp 11-inch howitzer, 12.5 calibers, with wedge fermeture; projectiles, cast-iron shell and semi-armor-piercing steel shell, weight 760 lbs., containing a bursting charge of 54.4 lbs. The service charges, 6 in number, vary from 15.4 lbs. to 57.3 lbs.

5. The 11-inch howitzer, model B, of 9 calibers, resulting from the transformation of the 10-inch and 9-inch guns, made by Armstrong.

Instruments for laying.— 1. The ordinary sight, graduated in millimeters and ranges up to 7,650 yards, for the 9.5-inch and 12.6-inch guns.

2. The automatic sight, which enables the elevation to be given the gun by laying on the waterline, without knowing the range.

3. The quadrant with level, graduated up to 85 degrees with a vernier reading to $\frac{1}{20}$ of a degree.

4. The "direction sight" for howitzers, used for laying in azimuth.

5. The elevation indicator, for howitzers, consists of an arc graduated in degrees and tenths of a degree, fixed to one cheek of the carriage and a pointer forming one piece with the trunnion (from 0° to 45° for the ordinary carriage and from 45° to 75° for the hydropneumatic carriage).

6. Graduated circles fixed either to platforms, or to the lower carriage, for giving direction in azimuth.

7. Convergence data, or calculated information, which permit the firing data for each of the pieces of a battery to be immediately determined, when those for one piece are known (our difference chart).

Laying.—Two methods of laying are employed: individual laying and prepared laying.

In individual laying, the gunner aims directly on the target giving both the elevation and direction by means of the automatic sight, taking as his point of aim the bow of the ship at the height of the waterline.

Fire is executed by piece at the command of the gunner.

In prepared laying, the gunner concerns himself only with the direction, the elevation being given the piece by other numbers. The point of aim is always the bow of the ship and fire is executed at command by battery or by half-battery salvos.

Prepared laying is regulated by the position-finding service, which takes into account the travel of target during time of flight. This manner of laying, which applies to guns or howitzers, may be direct or indirect; the former is used when it is possible for the gunner to follow the target, but the firing is controlled by the battery commander by means of the range-finding service. The indirect method is employed during the daytime in howitzer batteries, the parapet of which prevents seeing the target, and at night in both gun and howitzer batteries.

Position finding service.—In each battery the range and position finding service is put under the orders of an officer. It consists of:

(*a*) for each battery furnished with a vertical base range finder, model 1886 or 1886-1901, an observer, two assistants and two telephone men;

(*b*) for each battery provided with a horizontal base system with two stations, model 1886, an observer, two assistants and two telephone men at the primary, an assistant observer and two telephone men at the secondary;

(*c*) for each battery provided with a horizontal base system of three stations, model 1901, (when the field of fire exceeds 130°), an observer, three assistants and two telephone men at the primary, two assistant observers and four telephone men for the secondaries;

(*d*) for each Passino position finder, an observer, three assistants and two telephone men.

The horizontal-base range finders used are of the model invented by Major Braccialini. Since their adoption for service, these instruments have been greatly improved, and the most recent type is to-day in use in the Japanese coast batteries for 11-inch howitzers.

The new installation consists of two stations connected by telephone. The secondary station, S, is provided with an angle measuring instrument. The optical axis of the telescope is directed on the ship in a continuous manner, and the readings (every $\frac{1}{20}$°) are transmitted electrically and automatically to the primary P.

At the other extremity of the base is the primary which contains the following instruments:

1. An apparatus for receiving angles, connected electrically to S, which moves continuously (correspondingly to the axis of telescope at S) a glass ruler on which is engraved a line; this line, then, remains always parallel to the line, *S — target*.

2. The position finder proper consisting of a telescope which is constantly directed on the target by an observer, and thereby causes the corresponding movement of a glass ruler on which is engraved a line passing through the axis of the instrument.

The intersection of these two right lines gives the range and direction from the battery to the target, this data being read by a reader by means of special apparatus.

The approximation is about 10 meters in range and about $\frac{1}{10}$ degree in direction.

3. A chronometer with time-interval bell system regulated in such a manner that the interval between two successive strokes of the bell corresponds, for a position of the point to be hit, to the time of flight increased by the time which elapses between the signal "fire" and the discharge of the piece, (t + 2) seconds.

4. A special computer attached to the chronometer gives mechanically the sum of the angular deviation of the piece from the center of the battery

and the angular deviation corresponding to the lateral displacement of the target during the time (t + 2) seconds.

5. A mechanical transmitter of orders, etc., communicates electrically to each piece of the battery, the charge, the elevation, the azimuth (properly corrected) and the signal "fire".

Near each piece is a receiver for these data, a kind of box having four windows, in which appear the firing data and the signal "fire".

After having had the target tracked for some moments in order to determine the course followed, a predicted point is determined for which a plotter transmits to the batteries the firing data corrected for convergence and arbitrary corrections based on a previous ranging. Then the chronometer is adjusted and the total angular deflection, corresponding to that of the battery increased by that necessary to take into account the speed of the target, is determined mechanically. At the primary instrument the azimuth of the line *battery-target* is corrected by this angle. At the same time the observer notes the distance traversed by the ship between two successive strokes of the bell; the signal "fire" is given when the target passes at the prescribed azimuth and at the range of the point to be hit, read by the observer. All these operations require only 30 seconds and a single installation can direct simultaneously the fire of three batteries of howitzers with indirect laying.

Drill consists of numerous exercises in aiming and laying, performed in conjunction with the navy and including the annual practice; but the larger part of the firing is executed by making use of 7-cm. and 9-cm. tubes placed in the guns.—*Revue de l'Armee Belge.*

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KRUPP'S 12-CENTIMETER FIELD HOWITZER

MODELS A AND B ON LONG RECOIL FIELD CARRIAGE

With reference to the published report of the Swiss trials of Krupp's field howitzers, we take pleasure in giving here a description of this gun.

I. GENERAL DESCRIPTION

1. The *barrel* is made of forged nickel steel and is composed of a tube and jacket. The rear of the jacket receives the breech mechanism and has a lug below to which the cylinder of the recoil brake is attached. To guide the gun on the cradle, it has two clamps gliding along guide rods on the cradle. The interior of the barrel shows the chamber, forcing cone and rifled part.

2. The *breech mechanism* is a horizontal block in its latest development as a guide-shaft-block with continuous pull motion.

3. The *carriage* consists of lower carraige, cradle bearer and cradle.

On the cradle the barrel slides back and forward. An hydraulic brake takes up the recoil of the gun. The counter recoil is effected by a single spiral spring.

(a) The *lower carriage*. The body of the carriage is formed of two flasks of pressed steel plate, held together by transoms and top plates. The trail holds the trail eye, the rigid spur, and two handles.

For rapid loading the right flask has a two-armed lever, the shorter arm provided with a roller moves against the cradle from below, and lifts it with the gun into the horizontal position. After loading the lever is turned, the roller moves downward and cradle and gun follow until the position determined by the elevating apparatus is reached again. The elevating gear is released automatically while the cradle and gun are moved from the firing position into the loading position and back again.

The road brake, which also may be used for checking the recoil whilst firing, has two handwheels by means of which the brake can be put on or released by the crew when marching, or by the men serving the breech-block when in firing position. The two brake shoes will always apply equal pressure even if unequally worn off, or with wheel tires out of shape.

(b) *Cradle and cradle bearer.* The gun when recoiling slides on the cradle whose lower pintle is supported by the cradle bearer. The cradle bearer has trunnions seated on the lower carriage. Thus the gun turns horizontally round the pintle of the cradle, and vertically round the trunnions at the cradle bearer.

The cradle is a trough made of forged steel, the upper rims forming guides for the gun. The hydraulic brake is inside the cradle, perfectly protected against mud and dust.

A frame which carries the pintle, runs around the cradle. A second frame at the rear end of the cradle carries in two eyes, right and left, the traversing gear moved by a horizontal shaft and handwheel. The traversing screw by its nut moves the rear end of the cradle and turns it round the pintle.

The front end of the cradle is protected by a cap made of steel.

The hydraulic brake consists of the cylinder and its prolongation, the piston and piston rod, and the counter-recoil brake. The gun is returned into position by one or several return springs, which by a screw spanner have a certain initial compression.

4. The *sighting apparatus.* A telescopic sight is used, provided with means for aiming at an auxiliary aiming point, and to correct for difference of level of wheels.

5. *Limber.* The limber is designed for easy transportation and small weight. The pole is of sheet steel, hollow and rivetted. The whiffletrees also are of steel.

The limber chest contains 8 baskets with 2 projectiles and 2 powder cartridges each, carrying 16 rounds.

It also contains a chest for the tools and accessories. A foot board and foot board box are fastened to the limber frame. Pioneer's tools are fastened to the front of the limber chest. 3 men can sit on the limber.

II. DIFFERENCES BETWEEN MODELS A AND B

Howitzer model A has a long jacket reaching to the muzzle; model B has a shorter jacket, its front end fixed on the A tube.

The carriage of model A has one spring column round the recoil cylinder inside the cradle; model B has 2 spring columns outside right and left of the cradle.

Model A has a cranked axletree, model B a straight axle.

The maximum elevation with model A is 40°, with model B 43°.

NUMERICAL DATA

		Model A	Model B
1. *In general*			
Weight of barrel and breech mechanism	lbs	1129	1034
" " unlimbered gun	"	2700.6	2612.5
" " gun and limber	"	4623	4566
Muzzle velocity with maximum charge,	f.s.	984	984
Maxinum range	yards	7000	7000
2. *Gun barrel*			
Caliber	inches	4.72	4.72
Length	"	56.7	56.7
	calibers	12	12
Number of grooves		36	36
Depth " "	inches	0.059	0.059
Width " "	"	0.274	0.274
" " lands	"	0.138	0.138
Diameter between lands	"	4.72	4.72
" " grooves	"	4.838	4.838
End twist	"	70.86	70.86
	calibers	15	15
Weight of breech mechanism	lbs	146.6	132.3
3. *Gun carriage*			
Height of line of fire	inches	40.94	40.94
Width of track	"	58.27	58.27
Diameter of wheels	"	48.42	48.42
Width of tire	"	2.95	2.95
Length of axle	"	71.33	71.33
Limits of elevation		+ 40 — 5	+ 43 — 5
Limits of traversing, right and left, each		2°	2°
Weight of carriage with accessories	lbs	1572	1578.5
Pressure of trail on the ground	"	152	198
" " " " " trail eye	"	106	148
4. *Ammunition*			
Weight of projectile, (shell, torpedo shell, shrapnel)	lbs	46.3	46.3
Maximum powder charge	"	1.08	1.08
Kind of powder		W.P. c/89	
Weight of metallic case	"	2.976	2.976
" " primer screw	"	0.143	0.143
" " cartridge	"	4.255	4.255
5. *Limber*			
Weight of empty limber	"	992	1023
" " accessories and tools	"	121	121
Number of rounds in limber		16	16
Weight of ammunition in limber	"	809	809
" " packed limber	"	1922	1953

EXTRACT FROM RANGE TABLE

There are 5 different weights of powder charges for shell, their cartridge bags made of powder tissue.

The maximum angles of fall to be reached with shell at different ranges are shown in the following table, giving also elevation and 50% dispersion.

Charge lbs.	Range yds.	Elevation degrees and $\frac{1}{16}$ degree	Angle of fall degrees and minutes	50% Dispersion	
				Width yds.	Length yds.
0.452	1968	23^{13}	25° 36′	3.1	14.2
0.452	2406	35^{00}	38° 10′	4.6	18.6
0.540	2515	22^{3}	24° 6′	4.6	17.5
0.540	3281	39^{8}	43° 33′	8.5	25.2
0.672	3390	23^{8}	26° 3′	7.3	24.1
0.672	4265	40^{00}	45° 2′	12.6	35.0
0.838	4374	23^{1}	26° 56′	9.1	33.9
0.838	5392	36^{15}	43° 57′	13.2	45.9
1.080	5468	21^{5}	25° 57′	9.4	40.5
1.080	6961	40^{00}	49° 30′	14.2	54.8

Schweizerische Zeitschrift fuer Artillerie und Genie.

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NOTES ON FIELD ARTILLERY MATERIAL, 1905

Ordnance materials.—Ten years ago the whole engineering world was revolutionized by the introduction of nickel steel, which united the best qualities of ordinary steel with the toughness of bronze. Several new alloys of steel are now claiming the attention of the gun manufacturer.

Vanadium steel contains about 0.3 per cent of vanadium. This admixture is said to have the effect of rendering the steel perfectly homogeneous and closer in grain than ordinary steel, securing a great increase in hardness and tenacity with only slightly reduced toughness. Experiments on the small scale have given an increase in tenacity of no less than 90% over ordinary steel. Vanadium is exceedingly expensive, and the manufacture of the new steel has hardly yet reached the commercial stage. But we shall probably, in the near future, see it extensively applied to the manufacture of gun-shields.

Wolfram steel is no novelty, but is again coming to the front in consequence of the increased supply of tungsten or wolfram available. It may possibly come into use for the manufacture of steel shrapnel bullets capable of piercing ordinary gun-shields. Bullets of ordinary steel are objectionable on account of their lightness, which reduces the effective range from the point of burst. But wolfram has a specific gravity of no less than 18.6, and, when alloyed with steel in the proportion of 15%, gives a hard dense metal with a specific gravity of 9.5, or the same as that of mixed metal bullets. Pure wolfram cannot be made into bullets, except by enclosing it in metallic capsules, as it has hitherto been produced only in the form of granular powder.

Molybdenum steel is said to have qualities similar to those of vanadium steel. It is not yet on the market.

Krupp's spring steel has attracted much attention in the engineering world. According to official Government tests, this steel, in the form of flat wire gun-springs, has a tenacity of 137 tons to the square inch with an elastic limit of 88 tons. These figures are very remarkable, as nothing approaching these results has hitherto been obtained in England or America.

At the recent automobile exhibition in Paris practically all the cars were on Krupp springs.

Radior is a new bronze invented by an Italian engineer, Professor Travaglini of Pisa. It is said to be stronger than manganese bronze and practically incorrodible. The French Navy are trying this alloy for screw propellers, and it is expected to be used in the construction of the new Italian gun-carriage.

Shield.—The effort of gun makers have been directed towards reconciling complete protection with invisibility. Thus, it is stated that the new field gun submitted by Krupp to the German Government has a shield only 4 feet high, with a folding flap at top capable of being raised to a height of 6 feet when under shrapnel fire.

Modern gun-shields are of very hard metal, which enables ths thickness to be kept down to about 0.14 inch. Thus the Ehrhardt shield is of nickel-chrome steel with a tenacity of 106 tons to the square inch.

Sights.—The favorite sight seems at present to be the Korrodi panorama sight, combined with the independent line of sight. This sight is especially well adapted for use behind a shield, as the layer can lay on an aiming point to a flank or to the rear without having to go outside the wheels or around to the front. Moreover the telescope, being bent upwards, gives a high line of sight over the top of the shield, enabling the gun to be layed direct from the rear crest position which is now so much favored.

Ammunition.—The French are experimenting with a combined shrapnel and high-explosive shell. The idea is simple ; the bullets are packed in a high-explosive composition (such as ammonal) instead of resin. When the shell is burst in air by the time arrangement of the T. and P. fuze, the composition simply burns without exploding ; when the percussion arrangement of the fuze acts on impact, it fires a primer which detonates the composition, causing the shrapnel to burst like a high-explosive shell. This projectile is specially intended for attacking shielded guns.

The Germans still adhere to H.E. shell as well as shrapnel for their new equipment, but (like most other nations) have abandoned picric acid (lyddite or melinite) for field shell as being difficult to detonate without a dangerously large fulminate primer. In fact it may be said that the principal Continental nations which use H.E. shell (Germany, France, Austria, Italy, and Switzerland) use ordinary smokeless gunpowder as the burster for their H.E. shells.

Smoke composition.—Messrs. Ehrhardt seem to be the only firm who can produce a shrapnel with black powder smoke composition free from prematures ; this they effect by very carefully consolidating the bullets by pressure so that they do not grind together. All other makers use either phosphoric acid or red amorphous phosphorus in fine dust, mixed with an equal quantity of fine-grain black powder. This substance is less sensitive to friction than powder and gives a dense white cloud of smoke.

Telescopes, Telephones &c.—The Japanese used prismatic telescopes, of the type in which the body of the telescope is vertical, the light being reflected downwards by a prism at top, and again reflected to the (horizontal) eye-piece by a second prism at the bottom of the tube. This telescope is similar to the "optical eye" of a submarine, in that it can be used from behind cover without exposing the observer.

Telephones were freely used by both sides, in the recent war, for controlling fire. On the Yalu (May 1, 1904) the Japanese field howitzer division was engaged at a range of 4,000 yards, making effective fire without suffering a single casualty; the fire was directed by telephone from a distant flank.

At Liao-yang, one Russian brigade was successfully fought from behind cover, the Colonel directing the fire by telephone from an observing station.

The instruments now used are loud-speaking micro-telephones, in which the secondary current, not the primary, passes over the wire. Messrs. Mix and Genest of Berlin have brought out several different patterns adapted to military use.

A similar pattern of telephone has been tried in England this year, and has given satisfaction. The line wire weighs only 7 lbs. per mile.

Observation ladders.—The new Danish equipment includes a pyramidal observation ladder which can be mounted on the caisson; it weighs only 48 lbs., and raises the observer's eye to 10 feet. The Germans have for some years had an observation ladder carried in the "observation wagon" attached to each Field Artillery Brigade, which also carries telegraph instruments, telephones, and signalling stores. The German ladder is similar to an ordinary step-ladder, with a seat and small table at top; it raises the observer's eye to about 14 feet.—*Journal Royal Artillery.*

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GUN-FIRE AND ARMOR

The Paris Journal has received from its correspondent at Kobe, Japan, a report of Rojestvensky, commander of the Russian fleet in the battle of the Sea of Japan, of which the London Times publishes the following translation.

Admiral Rojestvensky said that he had at first intended to proceed direct to the Far East, but was obliged to put in at several ports for different reasons and the material obstacles which he had to overcome were immense. On arriving at the Strait of Tsu Shima he knew perfectly well that he was about to meet the whole Japanese fleet. He never thought of avoiding battle, as he had come precisely with that object. He admitted, however, that he had not foreseen such a disaster. Continuing the Admiral said:

"Three detachments, each composed of four ironclads, came in line. Four cruisers followed, and then came five small cruisers, nine torpedo boats, and six transports. Our twelve battleships were attacked by twelve Japanese ironclads. During the first half-hour our men fired pretty well. As a matter of fact, they had somewhat more experience and training than people were pleased to admit. It was during the first phase of the battle that we inflicted all their losses upon the Japanese. But our men were suddenly demoralized by the terrible effect of the Japanese fire, and then all was lost. If these same Russian crews had had to deal with Japanese crews of equal value at the beginning of the war, the result would doubtless have been very different.

"Admiral Togo's men, all veterans and accustomed to the thunder of battle, remained unaffected, continuing their fire with composure, and riddling with mathematical precision the first ship of each of our four columns. In two hours the Japanese victory was complete. One after the other all our ships had been disabled. Unfit for action, foundering, with their guns dismounted, powerless, and covered with dead, our fleet had ceased to exist at 3 p.m. on May 27.

"The Japanese victory was entirely won by their guns. In any case the effects of the firing were utterly different from what had been expected. None of our ironclads were pierced by the shells, but the repeated shock of the projectiles bursting against them disjointed their steel plates. The rivets sprang, and the water, rushing in by the holes thus opened, shifted the center of gravity of the vessels, causing them to upset and sink."

"Admiral Rojestvensky went on to say that the greatest danger for battleships was the sheet of fire in which the ships were enveloped in consequence of the explosion of the shells. The paint that covered everything on board was extremely dangerous. The torpedo boats played quite a secondary part in the battle. He was absolutely certain that no submarine had taken part in the engagement. He did not conclude, however, that they would be useless in future wars, as they might render valuable service in preventing a blockade. The small guns of 37mm. and 50mm. were, he said, completely useless. In future no ironclad would have guns of less than 75mm., and even few of that caliber. The real guns for fighting would be those of 305 and 240 mm."

In these simple statements we have a summary of battle experience with modern naval implements which affords a flood of light on the related questions of gun-fire and armor. Rojestvensky awards full credit to the skill of the Japanese—"their victory," he says, "was entirely won by their guns," which they handled "with mathematical precision." It is evident from his testimony, however, that the penetrative force of the Japanese projectiles amounted practically to nothing, and that the decisive results were caused by the hammering shock of exploding shells against the sides of his ships.

The experience of Rojestvensky's fleet presents a simple but highly important lesson, which is just this: That a naval vessel clad in armor which is impenetrable to projectiles of a given type may nevertheless be put out of action by the shock from the impact of these same projectiles. The joints in her armor are vulnerable to the sledge-like blows of exploding shells which, when delivered continuously and accurately, as was done by the Japanese, may force the plates of the ship apart and open the way for a fatal inrush of water. Whether the terrific shock of the projectiles against the sides of the ship would cause any serious disarrangement of her machinery has not yet been determined, but such results would not seem unlikely under a hammering sufficiently powerful to disjoint her armor plates. Rear Admiral George W. Melville, U.S.N., in advance of experiences in the Far East, expressed the belief that the furious hammering of bursting shells against the sides of an armor-clad vessel might, if long-continued, not only demoralize her crew, but seriously disarrange and perhaps disable her machinery. His view appears to have been verified to a considerable extent by the results of the Japanese gun-fire on Rojestvensky's ships. It seems likely, therefore, that the effect of Rojestvensky's full report, when published, will be to arouse new interest in the discussion on the undetermined problem of projectile versus armor.

The destruction of the Russian ships in the manner described by Admiral Rojestvensky also brings forward the vexed question as to the relative merits of gun calibers. Recent years have witnessed a general tendency in the direction of large calibers and the adoption of the 12-inch type as the maximum. The United States, however, in pursuance of ordnance development, devised for coast defense and constructed a sixteen-inch gun which has withstood all tests and completely fulfilled the expectations of the builders. The cost of this piece and the time required to build it were so great, however, that no further construction of the same type has been undertaken, and Army ordnance experts have tacitly agreed upon the twelve-inch caliber as the maximum. The remarkable results accomplished with the sixteen-inch gun in practical tests have nevertheless suggested that a desirable type might be evolved through a compromise between the sixteen-inch and the twelve-inch calibers—in other words, a fourteen-inch gun. It should be understood, however, that the sixteen-inch gun was designed specially for service in coast defense, and it may be asked why we should not trust entirely to the twelve-inch type if the sixteen-inch be regarded as undesirable. The answer to that question is that the greatest power to be developed from the twelve-inch caliber can be obtained only through the medium of the greatest possible velocity, and that requires the use of such heavy charges that the gun is likely to wear out in a limited number of rounds. The erosion in the bore of the large guns, due to the use of smokeless powder, is one of the most difficult problems with which the ordnance experts have to deal. The use of the powder charges required to produce the velocity which the gun is capable of withstanding virtually limits the life of a ten-inch gun to 250 or 300 rounds. In large guns the erosion in the bore, due to heavy charges, proceeds so rapidly that after fifty or sixty rounds have been fired the rifling is so worn that the projectile no longer receives the rotary motion so necessary to steadiness of flight, and the result is a loss of accuracy. Because of this rapid erosion, it has become a question whether the guns should not be used at a less power than their strength would permit in order to prolong their usefulness. It must be kept in mind, however, that in using the gun at reduced power, the energy of the projectile would be reduced by a sacrifice of the very quality which it loses soonest in flight—namely, velocity. In a word, reduced power means reduced velocity and reduced velocity means reduced efficiency. As against that policy it is quite possible, as the Chief of Ordnance pertinently observes, "to retain the superiority of the gun over anything which it is called upon to attack by using larger calibers for given work and by building guns of larger size than is now customary, experimental construction as well as theory and natural foresight having shown that the present conventional maximum used need by no means be accepted as a limit."

The correct solution of this problem of gun calibers in relation to trajectories and projectile velocities is of vital importance to seacoast defense. We have no doubt it will be correctly solved in due season. Meanwhile, in view of the increased erosion of rifle chambers in large guns, due to the use of smokeless powder, it seems perfectly clear that ordnance construction should not be bound hard and fast to the twelve-inch type as the maximum caliber. Great strides in gun-making have been made since the days of Bomford and Rodman, yet the fact remains that Rodman enunciated every principle relating to the gun and its powder that is embodied in our present ordnance construction. When we get back to first principles and proceed upon the proposition that armor-clad ships may be destroyed not only by projectile penetration of their armor, but also by the impact of heavy masses caused by shells striking their sides, we shall merely have exemplified a lesson which Rodman taught. —*Army and Navy Journal.*

LESSONS OF THE RUSSO-JAPANESE WAR: ARMAMENT

The *Ruskii Invalid* has published a series of unsigned articles on the lessons of the late war in the Far East. The following is a summary of one dealing with the armament of both combatants:—

The rifle.—The Russian rifle, Model 1891, behaved well, according to all reports, and only criticisms of detail have been made with regard to it. For example, after prolonged firing, the handling of the breech became hard, and had to be eased with oil. The cleaning-rod, which is normally screwed on, was apt to become lost when firing if it had been forgotten to screw it on. The front-sights were sometimes lost. When the breech was dirty or dusty the extractor was not always strong enough to extract the empty cartridge case; the catch of the extractor should be made with more grip. It is to be hoped that a breech system may be adopted where it would be impossible to close the breech without noticing if the magazine was empty; the Japanese rifle had such an arrangement. The cartridges were irreproachable.

R. F. guns.—The Russian R. F. guns were most satisfactory as regards precision and rapidity of fire, and their range was superior to that of the Japanese guns. The shrapnel was most efficacious. These guns suffered very little damage; for instance, during eight days of continuous hot fighting at the battle of Sha-ho, the 48 guns of the 35th Artillery Brigade had only two injuries, the one to a compressor and the other due to the action of the gas on the breech. The artillery ammunition was perfect. The shrapnel did not fulfil all requirements owing to its lack of explosive power, which caused it to be useless against walls and entrenchments. Explosive shell is indispensable against localities and earthworks. Against the latter even explosive shell is not always effective, unless the ground is frozen or when the parapet is made of sand bags. The *Ruskii Invalid* mentions the case of a house serving as an observation post, which was completely demolished in one hour by 64 Japanese explosive shells.

Field mortars.—The field mortar has neither sufficient range nor precision to fight against R.F. field artillery. It was only employed, so to speak, for directing plunging fire on special objectives whilst the field artillery kept up shrapnel fire. Both the material and the moral effects of shrapnel fire by field artillery are far greater. What is required is a gun throwing explosive shell on obstacles, with a range approximate to that of the field gun, as mobile as the latter, and which can use the same methods of fire.

Employment of large caliber guns.—Large caliber siege guns were used by both sides for different reasons. The Russians used them because they had no explosive shell for field guns. The Japanese probably used them in February (*a*) to make a demonstration against the Russian center, and to hold it under constant threat of an attack; (*b*) to reinforce on their center their field artillery, which was inferior in range and rapidity to the Russian; (*c*) to oppose the Russian siege artillery; (*d*) and especially to render their field artillery of their center available to assist their left wing, which should make the decisive effort. These conjectures are confirmed by the following arguments:—

1. There only remained a small number of field guns at their center at the end of February.

2. When the Russian siege artillery was withdrawn, the 12-cm. shrapnel, which the Japanese sent from time to time behind Ling-chin-pu, no longer appeared.

Judging by the explosives, the Japanese used old guns of various calibers; carrying all sorts of projectiles, with different fuzes and explosives. It might be supposed that their intention was to abandon these guns, if the Russian center had taken the offensive, and that they would have retired towards Liao-yang, drawing the Russians after them, in order to facilitate the task of Nogi's army. The fire of these guns, unaccompanied by shrapnel fire, produced merely a moral effect, and caused only insignificant losses.

On the Russian side the siege guns did not produce quite the effect that might have been anticipated, in consequence of the bad organization of the command. The heavy batteries were not placed under the orders of the commanders of adjacent troops, who were obliged to ask for the special authorization of the higher command when favorable objectives for their fire presented themselves.

In conclusion, when one's power of action may be added to by using larger caliber weapons than that of field guns, there is no reason why one should deprive oneself of them. But the employment of siege artillery in field service, to-day as formerly, cannot be regarded as normal. The presence of large caliber guns in the battles of the present war constitute special cases. At Tin-sent-chen the Japanese were able to convey them by water. At Mukden they were only able to take their large guns and heavy ammunition by means of the railway, near which they kept them. At Liao-yang and in the battles in October on the Sha-ho the Japanese had hardly any guns of large caliber, and it cannot be seriously said that they made use of them. Siege guns, including 11-inch coast guns, had no decisive influence whatever in the battles round Mukden. For four days the Japanese kept up a continuous fire on Gu-an-tun and Kau-chen-pu; nevertheless these villages were evacuated by their garrisons only on the order from the Commander-in-Chief to retire to Mukden. The garrisons evacuated them of their own accord and without being compelled to do so. "We only abandoned our strong positions on the Sha-ho because they were turned, because the enemy maneuvered us out of them, and in no way on account of the action of his artillery."

Machine guns.—"Machine guns have acquired an enormous importance. Our troops preferred them to artillery. It is to be hoped that there will be 12 to 16 to every division, and that they will form distinct units, and not be attached to regiments." The Japanese brass cartridge bands were more practical than canvas ones. Infantry require machine guns that can be carried by hand. In the offensive, nothing equals them for resisting counter-attacks, on account of their material power and their moral effect.

Armes blanches.—These rendered good service, and the sword as well as the lance. The sword is an encumbrance in the artillery. It impedes the gunners when serving the guns, and might advantageously be replaced by a dagger.

Hand grenades.—The effect of hand grenades is confirmed. They are most useful both in attack and defense, especially so to throw on an enemy obliged to remain in a ditch. Their effect is essentially a moral one. A kind should be made that would burst with certainty on touching the ground. The type which appears to be the most handy would be that of small spherical grenades; the Japanese used those with a diameter of 5 cm.

—*La France Militaire.*

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DAMAGED RUSSIAN WARSHIPS AT PORT ARTHUR

We append a report of the damage which was found to have been done to the Russian warships at Port Arthur after the Japanese took possession of the town, harbor, and ships. These notes were made by a naval architect, and throw considerable light on the effect of the actions fought in the Gulf of Pechili when the Russians attempted sorties, and also show the results of the bombardment of the town and ships by the Japanese from the heights surrounding the town. The 28-centimeter shells, which did most damage, were fired from 203-Meter Hill, at a distance of some four miles. The angle at which they fell on the ships—some 30 degrees with the vertical—made the conditions for accurate shooting by no means favorable. Although the number of wasted shots is unknown, it is noteworthy that those that took effect were numerous. Little use can be made of the experience gained in this particular case for future guidance, as the conditions were so unusual and outside the range of any probable repetition of circumstances.

As to the damage done, it will be seen by a study of details that the explosive effect of the shells was less noticeable than might have been expected. Some shells were picked up unexploded by those engaged on the salvage work, and the general appearance of the positions at which it was apparent the shells had spent their force, raised some doubt whether an explosion had actually taken place in every case; the destruction of parts of the structure in the immediate neighborhood was not at all remarkable. In the case of some of the shells which struck the Peresviet, their force was evidently spent on reaching the protective deck, and they failed to penetrate it; some small damage was done to the deck by them, to the extent of very obvious bulging of the deck downwards where they struck or exploded; but a general destruction of surrounding portions of structure did not appear. As will be seen, four or five shells penetrated the protective deck, but even these became spent without serious tearing up of the parts below. One remark made to our special correspondent in this respect was that the Japanese Army did not, like the Navy, use Shimose powder. Had Shimose powder been used from 203-Meter Hill the damage to the ships would have been much more serious than it was.

The two classes of damage done must be considered in estimating the chances of effective and economical repair—viz., that done by the Japanese fire and that done by the Russians in their endeavors to make the ships useless for the future. From what has already been stated it may be gathered that little work will be needed to repair the injury caused by the 28-centimeter shells fired by the Japanese. Possibly more detailed damage was done by smaller shells during the general attack of Port Arthur, or in the earlier engagements of the ships; but this damage is in the superstructures, casings, funnels, and other light portions of the ships' structure; and considerable as it is, the repairs needed will bear but a small ratio to the total value involved. Of the damage done by the Russians, omitting that on the Bayan, there was apparently only one hole through armor, the holes for the most part being below armor.

We reproduce the detailed report :—

On June 30 the battleships Peresviet, Poltava, Retvisan, Pobieda and the protected cruiser Pallada were all laying roughly where shown in the various illustrated periodicals—viz., in West Basin, between the railway station and the harbor entrance.

From the Peresviet the bearings of Quail Hill were about N. ; of 203-Meter Hill, E. by N. (angle of the two about 75 degrees), Peresviet heading roughly N., line of keel a little to the W. of Quail Hill. Pumping operations had just brought her off the ground; slight list (2 degrees or 3 degrees) to starboard; sponsons at bottom of lower 6-inch gun casemates just about awash (draught therefore some 10 ft. deeper than normal).

Poltava, aground, with 2 degrees list to starboard, heading roughly E. by S. ; line of keel astern directed slightly S. of 203-Meter Hill (angle with Quail Hill, 75 degrees to 80 degrees). Water within 3 ft. or 4 ft. of upper deck.

Retvisan, aground, with about 5 degrees list to starboard, a little ahead of the Poltava; heading the same. The upper deck aft was immersed (capstan about half out of water) ; stem-head about 4 ft. above water.

Pobieda, aground, with about 10 degrees list to starboard, heading roughly N. by W., almost in line with Quail Hill, 65 degrees N. of 203-Meter Hill, stem-head 9 ft. or 10 ft. above water.

Pallada, aground, with about 5 degrees list to port, heading roughly S. by E. (reverse of Pobieda) ; stem-head, 10 ft. to 12 ft. above water; level of main deck aft, starboard side, just awash.

As these four ships were all aground, the height of water, of course, varied with the tide.

Armored cruiser Bayan was in E. basin, S. side, heading roughly E.N.E. Pumping operations had brought her nearly clear of the water, her draught being reported 22 ft. 8 inches against 22 ft. normal draught. Torpedo transport Amur laying at the head of dry dock, on her port beam ends (list, 60 degrees to 70 degrees).

DAMAGE TO PERESVIET

Damage to armored deck.—Twelve holes appeared through the upper deck (reduced to 11 through main deck), made apparently by 28-centimeter shells. Of these, four continued down through the armored deck. All fell at an angle of some 30 degrees from vertical, direction forward to aft, and slightly port to starboard. The armored deck was pierced by shells :—(1) Just before foremast ; deck about $1\frac{1}{2}$ inches thick ; and plate under mast step torn, thickness apparently 1-inch. (2) A little more forward and towards starboard side of ship. (3) In passage on starboard side of boiler casing abreast of aftermost funnel. Shell had come through funnel and casing. Thickness of deck $\frac{1}{2}$ inch + $1\frac{1}{4}$ inches = $1\frac{3}{4}$ inches. (4) A little more forward and towards starboard side, slope of armor deck pierced just above a coal-scuttle ; thickness not more than $\frac{5}{8}$ inch + $1\frac{1}{4}$ inches = nearly 2 in.

Below the armored deck it was not possible at the time to penetrate ; it is reported that none of the four shells above detailed made their way out through the ship's side. (5) Another shell struck the hurricane deck about 30 ft. from the bow ; went down through hurricane, upper, and main decks, and then met side of ship at level of lower deck. Here it either passed out or was deflected back into the ship ; at any rate, it made the whole D found by the divers (see below). (6) Still another shell went through the hurricane and upper decks until it came in contact with the plating (1¼-in.) at rear of after casemate, port side. There it exploded and tore a large hole, some 3 ft. by 3 ft., in the plating mentioned, and did not pierce the main deck. Three shells are reported to have been picked up unexploded. This accounts for six out of eleven shells that penetrated the main deck. The others were less easy to trace.

Effects of bursting shells.—In the case of shell (6) just mentioned, the damage done by the explosion is easily seen. In other cases the wreckage done to the structure by the bursting of large shells seemed not very serious. The same remark does not apply to smaller shells ; in the Peresviet, and perhaps more in some of the other ships, the upper structures, funnels, casings, deck-houses, &c., are riddled with holes and tears of all shapes and sizes.

Effects of fire (conflagration).—The hurricane deck of the Peresviet (steel sheathed with wood) has the wood destroyed by fire for some 60 ft. below the foremast and forward barbette, and 40 ft. near the after bridge; in both cases the full breadth of the ship. It is suggested that the Russians had smeared the deeks with kerosene, and set fire thereto. This vessel is by far the worst damaged in this respect ; Pobieda, which comes next, having only some 30 ft. length of deck destroyed.

Holes reported by divers.—Damage to side armor cannot at present be examined ; if it exists, it is entirely below water. The holes reported by divers lie below the armor shelf, (D) indeed excepted. (A) Hole, 3.5 meters deep by 2 meters long, port side, top about level with armor shelf, center slightly abaft the after end of the forward casemate. The diver reports this as formed from without. (B) Smaller hole, port side, a little further forward, beneath forward barbette. (C) Hole, 2.5 meters long by 0.5 meter deep, about 3.5 meters below normal draught of water, starboard side, nearly abreast of aftermost funnel. (D) The hole caused by shell (5) mentioned above. The 10-inch gun-turrets, both the forward and the after, were damaged by eplosives placed inside ; the heavy plates displaced somewhat, and joints open from this cause.

DAMAGE TO BAYAN

Damage to protective deck.—So far as could found, three 28-centimeter shells had penetrated the protective deck ;— (1) In the after-cabin, just abaft the break in protective deck (it drops to some 3 ft. below lower deck) ; angle of plunge about 30 degrees off vertical ; direction forward to aft, about 3 ft. off center line of ship, starboard side. Thickness of deck about ⅜ in. + 1 in. = 1⅜ in. (2) Abreast of No. 4 boiler casing (numbering from forward). Angle about 15 degrees from vertical, direction forward to aft, and slightly port to starboard. Shell entered side of ship just below upper deck, penetrated main deck, and then protective deck about 3 ft. in from side of ship. Thickness of deck apparently 1 in. (probably 1 in. + ⅜ in. = 1⅜ in.). (3) Just above intermediate cylinder of starboard engines. The shell entered upper deck at or near center line ; angle 20 degrees or 30 degrees to vertical ; direction forward to aft, port to starboard ; hole in protective deck about 6 ft. off center line. Thickness of deck ⅜ in. + 1 in. = 1⅜ in. Shell smashed the top and side of cylinder ; exploded shell said to have been found in crank-pit.

Damage to armored side (above water).—(A) The upper strake of the 3-in. plating (¾-in. + 2¼-in.) forward, port side, was struck at the bottom edge, some 25 ft. from the bow ; the 2¼-in. plates are fastened to the ¾-in. from the inside by tapped screws, about 1⅛-in. in diameter under thread, ¼-in. pitch. The bolts have no head, but are screwed up by a screw-driver notch on the end. The 2¼-in. plate struck by a shell was shattered. The hole was 3 ft. wide. The concussion has caused the 2¼-in. plate below (second plate on port bow, in second strake from the top ; the bottom of this strake about 3 ft. above normal water-line) to draw its fastenings, stripping the threads of the screws in the ¾-in. plate ; some obstruction holds the plate from falling, and it lies at present in place at the lower edge, 18 in. from the side at the upper edge, with an outward inclination.

(B) Upper and lower strakes of 3-in. plating (¾-in. + 2¼-in.) in way of engines, starboard side, driven in. The damaged portion is fully 20 ft. long; the depth extends from the protective to the main deck (and rather more, main-deck stringer being curved upwards).

(C) *Other damage.*—Communication-tube to conning-tower (2 ft. inside diameter, 3-in. thick), shattered from upper deck to main deck, apparently from starboard side. Possibly the shell entered the starboard casemate.
(D) Unarmored side (starboard) in way of after cabin (just abreast of hole I), blown in for a length of 20 ft., and depth from protective deck to above main deck. Bulwark on starboard side shattered in two or more places.
(E) Just abaft after gun-house, for a length of 30 ft., and full breadth of ship, the upper deck is torn up, apparently by explosive placed in between decks by the Russians.

DAMAGE TO POLTAVA

Three holes visible in upper deck, apparently made by 28-centimeter shells. The divers report only one large hole below water (under armor), 6.2 meters long by 2.8 meters deep on starboard side between funnels, but nearer after funnel; top of hole at armor shelf. Hole made from outside.

DAMAGE TO RETVISAN

No large holes at present on the decks that are to be seen. Plenty of smaller holes by perhaps 6-in. shells or fragments. The divers report the following holes, below armor, port side, made from outside :—3 meters by 3 meters, 2.4 meters by 3 meters, 3 meters by 3 meters, 2 meters by 1 meter.

DAMAGE TO POBIEDA

Three or four holes in upper deck, on both port and starboard sides. In this ship there seems less regularity in the direction from which the large shells came than in the other ships. The direction of two was roughly from E. by N. to W. by S., as ship now lies; one shot passed nearly horizontally through a casing; some of these could have struck the ship in her present position; swinging with the tide might account for the two, but the horizontal shot must be traced to a date earlier than December. Foremast was struck just at level of top of conning-tower; it lies now, roughly at right angles, across starboard side of the ship. Fire has destroyed some 30 ft. in length of wood (over steel) of upper deck—full breadth of ship— just abaft forward barbette. The divers report one large hole, 8.5 meters by 4.5 meters, in port side below armor in way of engine room ; also smaller holes. One of these smaller holes, however, appears to be through the 4-in. armor on the starboard side forward; all made from outside.

DAMAGE TO PALLADA

On upper deck there were found six large holes, starboard side; one large shot hole, port side; direction, about aft to forward.

Other damage.—(*a*) Upper deck aft under capstan blown up, full breadth of ship, for 50 ft. or so from stern; worse on starboard side, where a slit of about 10 ft. in length exists, the edge of plates and planks at the slit being thrown up some 4 ft. from normal. Looking below, it appears that the main deck plating was turned up to the level of upper deck; main deck beams twisted and bent in all directions, tearing frames from the shell on the starboard side of the ship. The source of the explosion was evidently somewhere below the main deck (which at the time of observation was awash on starboard side, and some 4 ft. below water on port side). (A) Below A on starboard side, and starting from water-level at main deck, a triangular shaped hole could be seen, widening as it got deeper. (B) Dynamo-room on upper deck between funnels 2 and 3 (counting from forward), and just in front of funnel 3, wrecked by explosion from within.

The divers report the following holes, all an the starboard side, and made from without:—8 meters by 5 meters—the rent A above; 3 meters by 3 meters, just abaft boiler; 8 meters by 4 meters, forward.

Damage done by the Russians to the above ships.—Those who have the salvage work in hand attribute the following to the agency of the Russians in their attempts to render the ships unserviceable in the future:—(1) All the holes below water (for some reason the holes below water in the Peresviet, or some of them, are not attributed to the Russians, but to Japanese fire; the distinction thus made is not sufficiently explained). In some cases torpedo-heads were found attached to the sides of the ships, evidently with the intention of causing damage. It is not understood that any damage is attributed to this cause, the attempt to employ this means having apparently proved futile. Guncotton is supposed to be the explosive that was used effectively (by the Russians) to cause the damage actually found below water. (2) The damage to turrets of the Peresviet. (3) Damage E in Bayan; possibly also damage B and D. (4) Damage A A and B in Pallada. (5) Fire on deck of the Peresviet. In the Peresviet some dynamite cartridges were found in the after magazine, and wires led thereto, evidently with the intention of exploding it. In no case, however, was a magazine successfully exploded.

Stranded ships, &c.—At the entrance of the harbor were five ships on the beach, and about twelve besides; in the latter cases sometimes masts only, sometimes funnels, or funnels and davits; sometimes the side of the ship (lying on her beam ends) were visible. Some thirty-five in all are said to be there. In the West Harbor lay about sixteen large steamers stranded or grounded in shallow water. There are four dredgers (two of these, indeed, afloat) of the ordinary bucket arrangement.—*Engineering.*

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SUBMARINE, TORPEDO AND DEFENSE COMMITTEES, FRANCE

M. Thomson, Minister of Marine, on taking office appointed a Commission to consider the position of the Submarine Committees at each naval port, and of the torpedo and fixed defense sections. On the report of this Committee a decree has now been issued, by which it is ordered that the General Staff of the Navy in Paris will henceforth be charged with the control of all questions relative to the *materiel* of torpedo boats and projectors, and will issue orders to the permanent experimental committee of submarine defenses to be established, relative to the carrying out of all trials and experiments, and the fixing of the needs and requirements of the fleet, ports, and *points d'appui.*

The torpedo flotillas and fixed defenses become executive commands, either under the maritime prefect of the arrondissement, or the naval commanders in Corsica, Algeria, etc.

The torpedo schools are placed under the Rear-Admiral attached to the staff of each port, and the Inspector-General of torpedo-flotillas (Admiral Fournier) will also inspect the submarine flotillas and fixed defenses.

As regards the technical and administrative service of torpedoes at head-quarters, these are now placed under the Direction of Naval Constructions, and the Director of Naval Ordnance; the automobile torpedoes and accessories, such as the Obry apparatus and launching tubes, etc., are also now to be under the department of the Direction of Naval Constructions.

Fixed torpedo mines, etc., are to be under the Naval Ordnance Department; these departments having better means of taking efficient charge of these matters than were possessed by the former submarine committees.

The Obry apparatus.—The Superior Commission for torpedoes and mines has been studying, among other questions, that most interesting one of the Obry torpedo apparatus. The experiments which have been carried on with torpedoes furnished with this apparatus at Toulon during the last five years have proved that the apparatus is capable of giving 95 per cent of good trajectories. With the new torpedoes, which have a range of 2,000 yards or more, its importance becomes even greater, and up to 1,500 yards, except from errors of sighting, the percentage of hits ought not to be less. But the sighting, when ships are under steam, is just when errors are made, which spoil the firing and prevent good trajectories from resulting in good hits. However, with the Obry apparatus, it ought to be possible to hit a ship which kept on her course at an even rate of speed, either from *terra firma* or from torpedo boats laying in wait.

Of 46 torpedoes discharged from the Obry tube before the Commission, 43 struck within 10 yards of the mark, and the remaining three within between 10 and 50 yards of it. Not one has been hopelessly wide of the mark, or gone so far astray as to be dangerous to vessels clear of the range. This cannot be said of torpedoes discharged from other tubes, one of which only recently struck the "Hallebarde," torpedo-boat destroyer, and made a hole on her starboard side. Accidents of this kind have been rather frequent for some time past. The favorable results obtained show that all that is required is that the apparatus should be carefully manipulated and not be entrusted to the hands of unskilled persons.—*Journal R. U. S. I.*

Short Notes

The War office has acquired sites for two additional powerful forts on Dover heights overlooking the naval harbor, which are to be armed with 12-inch guns. The largest guns in Dover at present are the 9-inch in the three new forts.—*United Service Gazette.*

The Bovisand fort, which commands the eastern entrance of Plymouth Sound, is to be re-armed with three 9.2-inch and three 6-inch guns in place of the old pattern 6-inch, of which there were only three.

—*United Service Gazette.*

The forts of the French naval ports which up to the present have been officered by the colonial artillery, formerly known as the marine artillery, will in future be officered by a special corps of naval artillery engineers, which, in the first instance, will be recruited among artillery officers and naval gunnery lieutenants. The new corps will be under the French Minister of Marine.—*United Service Gazette.*

Sea training for artillery officers.—A most important innovation in the professional training of officers of the Royal Garrison Artillery is about to introduced by the War Office, working in conjunction with the Admiralty. It has long been apparent that coast defense work, which is the particular *role* of the Royal Garrison Artillery, must necessarily have a close connection with the operations of the Fleet. It is recognized that the part played by the Navy in this particular work must be of vital importance, and with a view, therefore, to co-ordinate fortress work, as far as possible, with the methods of the Navy, the officers of the Royal Garrison Artillery will shortly be called upon to undergo a course of training at sea. The exact period of this term of training at sea has not been definitely settled by the authorities concerned, but two years, the customary length of a full warship commission, will doubtless be the probable duration of it. The officers selected for training will be attached to battleships and cruisers on various stations, and stand practically in the same position as officers of the Royal Marines, but their work will be exclusively confined to gunnery training on board.—*United Service Gazette.*

Colored glasses for gun layers and observers.—Experiments in the use of yellow spectacles were made by the German Artillery in 1900, and since that year the matter has been the subject of investigation in Russia, where experiments have been carried out both by the Field and Fortress Artillery as well as by doctors.

The result shows that considerable advantage is derived from the use of yellow spectacles both by layers and observers, in both cloudy and bright weather, in picking up and defining distant objects; the eye does not tire so quickly, guns can be laid with the sun in the layer's faces, and the glasses save the men's eyes when the snow is on the ground.

A Doctor Medvedev, who has made a special study of the subject, considers that a yellowish-green or yellowish-orange tint may be better.

The Artillery Committee consider that the experiments made up to date fully establish the value of these yellow spectacles, so that without waiting for the results of further trials they have recommended the issue of the Prussian pattern (so-called No 2) to all batteries in Manchuria at the rate of 18 pairs per battery.

BOOK REVIEWS

Festungskrieg. Eine applikatorische Studie uber den modernen Festungskampf. Heft. I. Die Tatigkeit von Angreifer und Verteidiger bis zum Gewinnen der Einschliessunglinie. Von Schwarte, Major m.d.U. des Generalstabes. 14 + 196p. pl. O. Berlin. Mittler und Sohn. 1905.

The author, a major of the General Staff and military instructor at the War College, appreciating the great importance of the subject of the attack and defense of fortifications in war to-day, has endeavored to discuss the subject in a series of problems, similar to those of field maneuvers, selecting a real theater of operations (the Rhine from Duesseldorf to Mainz) as a base, and the fortifications of Wittenberg to be attacked and defended.

The importance of a well-arranged, effective system of fortifications along the border has been recognized for many years by the nations of Europe, and has led from year to year to a constant improvement and completion of the system originally adopted.

The increased importance attached to the subject recently is evidenced in the literature on the subject, which has been rapidly growing in volume in the last few years.

Most of the treatises, however, are very general in character, treating the subject in broad outline. But the correct application of the principles there set forth demand a knowledge of the conditions of the modern attack of a fortification which but few will probably possess.

Nevertheless, in any future war, probably some portion of every large subdivision of troops will come in contact with fortifications of some kind or other and many will have to learn for the first time the peculiar conditions of the attack and defense of fortifications, so different from the ordinary conditions of a battle-field.

Consequently, all troops should be previously instructed in this most important subject, and this is the purpose of the work before us, namely, to set forth a system of study by means of which the necessary familiarity with the peculiar conditions of this mode of warfare may be acquired.

The present number, Part I., contains the operations of the attack and the defense up to the occupation of the first line by the attack with a view to enclosing the work.

Part II. will discuss the struggle for an outlaying separate fort.

Part III. will consider bombardment at long range.

Part IV. the attack at short range.

In this part the peculiar conditions and means of warfare applicable in the attack and defense of fortifications are illustrated by a concrete example setting forth an actual attack and defense, in all its stages, and involving all the problems that would naturally arise for solution by the officers engaged.

Thé events in the Russo-Japanese war, particularly the siege of Port Arthur, have naturally increased public interest in the subject, and the tendency in the European armies is always to devise practical means of teaching any new subject directly and promptly *to the soldiers and subordinate officers*. The applicatory method pursued in the present work appears to be the most satisfactory to attain this object.

In this method, the *general situation* on a particular day is first described, then the particular situation of one side, say the *Blue*. A problem is then set, somewhat to this effect: What considerations govern the action of the commander-in-chief of *Blue ?* After stating the special situation of the other side, the *Red*, another problem is set similar to that for *Blue*, with an additional one as to the orders and measures taken by *Blue*.

The situation on the following day is then described, and similar problems are framed, involving on successive days the installation of the armament in the fort, the additional forts to be constructed, the further armament for battle, the subdivision of the fortifications into sections and the organization of their garrisons, the reserves, preparations for siege and so on.

The entire subject is discussed in a very thorough manner, and by an authority of note. It constitutes an excellent study for officers of all arms and every rank, and should be in the hand of every officer.

The part thus far issued (Part I) is clearly printed in large type on heavy paper, and the accompanying maps and sketches are all that can be desired.

The Development of Strategical Science During the 19th Century. By Lieut.-General von Caemmerer, German Army. Authorized translation by Karl von Donat. 16+287p. O. London. Hugh Rees, Ltd. 124 Pall Mall, S. W. 1905.

The subject of this book is the theory of war, concerning itself mainly with the leading ideas of strategy in the nineteenth century. In fact, it is more a vigorous criticism of the theories and principles that have been held and advanced by prominent military writers during the century than a purely historical summary of the subject. It is written in a forcible style, favoring the opinions of those with whom the author agrees, notably Clausewitz and Moltke, and unsparing of those with whom he has to differ. At the same time, it does furnish a comprehensive review of the development of strategical science in the past century, and gives scientific reasons for the standpoint from which strategy is to be viewed at the present and in the near future.

Beginning with von Bulow, whose work, "The Spirit of Modern War", was published in 1799, it is shown how bases and lines of communication became the object of operations and what an effect "these ideas of those who looked upon battle as 'the remedy of the desperate' and thought that the real aim of strategy was to gain the object of war without bloodshed", had upon the art of war of the period. Then the new tactics introduced by the French are outlined, showing how the game of war became a more serious proceeding, and the works of Jomini, the exponent of the use of force with the utmost determination, receive careful consideration.

The writings of Archduke Charles, Clausewitz and Willisen are discussed, followed by a chapter on the technics of the nineteenth century, which treats of the new phenomena exercising a decisive influence upon the conduct of great war. The author then examines with keen interest the contrast between Napoleon and Moltke, and the comparison of their respective merits shows how Moltke, the experienced artist in practical strategy, struck new paths for the advance of this science. A consideration of the various modern theories as enunciated in the literature of the second half of the nineteenth century, followed by a chapter on the elaboration of Moltke's system by Schlichting, completes the work.

The book is a handsome one, well printed in large type. It is both interesting and instructive throughout, and should readily meet with the author's wish by appealing "to a threefold class of readers": senior officers, younger officers of the Army, for the study of military history, and the general reader who may wish to inform himself upon the most dramatic subject of international intercourse—the subject of war.

The Truth About the War. By J. Taburno, St. Petersburg. Translated by Victoria von Kreuter. 144 p. maps. O. Kansas City, Mo. Franklin Hudson Publishing Co. 1905.

There is a remarkable frankness about this book that gives the reader an excellent insight into the state of affairs of the Russian forces in Manchuria and the principal operations of the war during the period from the latter part of December 1904 to April 1905.

The author, a writer of some prominence in Russia, went to the seat of war for the very purpose of observing actual conditions, and on his return felt impelled to lay before the Russian public these results of his observations. The part of the war he describes is mainly the battles of Sandepoo and Mukden and the operations in the vicinity of the latter place.

Concisely and clearly the author pictures what he observed and discovered, giving many interesting glimpses of the action behind the scenes. He reveals the weaknesses of the Russian organization and tactics, the incapacity, blunders and mistakes of the leaders, officers, and others who should have known better, sparing no one in criticising their actions.

Several chapters are then devoted to the several institutions of the Army, the supply departments, railway and sanitary service, etc., followed by the author's views as to the cause of the Russian failure, and others giving his impressions as regards the firing, infantry and artillery, the Russian soldier and other details connected with the campaign as he witnessed it.

We notice at times foreign constructions in the translation, and a few typographical errors. But the book engages the attention by the manner in which the author faithfully describes what he has seen, by the impartiality and fearlessness of his opinions both as to the events of the war and the future welfare of the Russian people, and, as a result of his conscientious research, it gives the reader a clear conception of the true condition of affairs, that contributed in a large measure to the Russian disaster.

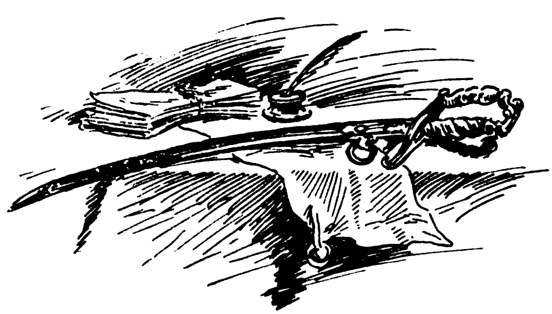
Catechism of Field Training. By Captain Lascelles Davidson. Ed 3. Revised and edited by Major S. T. Banning. 16+260 p. il. S. London. Gale & Polden, Ltd. 1905. Two-and-six.

New editions of the English drill-books, Cavalry, Infantry, Combined Training and Field Artillery Training, having made certain changes necesfary in the course of field training, Major Banning has, in this edition, revised this work to conform to the new regulations.

The book is suggestive in showing the vast amount of work and study that is to be accomplished in the period of the course and in the training of the English soldier. The number of days available for field training is about 24, work is arranged for 21 in the text, and according to the regulations instructions will extend over at least four or five hours daily. "Every available officer, noncommissioned officer, and man, except private soldiers of more than 15 years' service, bandsmen and those exempted from the annual course of musketry, will be present, and will be relieved from all other duties while under instruction". But even under such circumstances iu would seem that only the closest application would enable one successfully to complete the course here outlined, in such a manner as to be of any practical value.

The book is arranged in the form of questions and answers under the various heads, and they cover everything in the nature of field training: the tactical employment of infantry, attack and defense of positions, etc. the three arms, advance and rear guards, convoys, outposts, reconnoitering, hasty entrenchments, camping, knots and lashing, bridging, etc., etc., combined with practical exercises under each head for each day. The book is an encyclopedia of useful information of practical value, with illustrations and explanatory notes and examples.

No doubt the course is covered and the work acomplished, but we fail to see the object of the soldier's cramming the amount of information set forth in the text.



TABLES I., II., III., IV., V., VI.

TABLE I.

Values of log F with $\phi_m = \frac{\phi + \omega}{2}$, as argument.*

ϕ_m	log F	ϕ_m	log F	ϕ_m	log F
°		°		°	
1	9.82384	31	9.81464	61	9.77619
2	9.82378	32	9.81398	62	9.77408
3	9.82372	33	9.81325	63	9.77188
4	9.82365	34	9.81251	64	9.76953
5	9.82357	35	9.81171	65	9.76716
6	9.82348	36	9.81084	66	9.76470
7	9.82338	37	9.80996	67	9.76223
8	9.82327	38	9.80909	68	9.75967
9	9.82315	39	9.80821	69	9.75686
10	9.82302	40	9.80733	70	9.75389
11	9.82288	41	9.80645	71	9.75089
12	9.82271	42	9.80550	72	9.74780
13	9.82251	43	9.80441	73	9.74453
14	9.82227	44	9.80325	74	9.74139
15	9.82199	45	9.80209	75	9.73807
16	9.82169	46	9.80085	76	9.73480
17	9.82136	47	9.79955	77	9.73159
18	9.82100	48	9.79824	78	9.72835
19	9.82061	49	9.79692	79	9.72526
20	9.82020	50	9.79560	80	9.72263
21	9.81976	51	9.79421	81	9.71933
22	9.81931	52	9.79281	82	9.71667
23	9.81884	53	9.79127	83	9.71383
24	9.81836	54	9.78958	84	9.71063
25	9.81786	55	9.78789	85	9.70757
26	9.81736	56	9.78618	86	9.70501
27	9.81685	57	9.78433	87	9.70260
28	9.81632	58	9.78247	88	9.70079
29	9.81579	59	9.78046	89	9.69966
30	9.81525	60	9.77837	90	9.69897

* Values of $\frac{\phi_m}{\phi}$ with ϕ and log B′ as arguments.

ϕ	log B′ .10	.20	.30	.40
5	1.14	1.30	1.50	1.74
10	1.13	1.28	1.47	1.69
15	1.12	1.27	1.44	1.63
20	1.12	1.25	1.40	1.56
25	1.11	1.23	1.36	1 50
30	1.10	1.21	1.32	1.42

Reduce ϕ to degrees and decimals and find ϕ_m in degrees and decimals from

$$\phi_m = \left(\frac{\phi_m}{\phi}\right) \times \phi$$

log B′ need be taken for this purpose only to the nearest hundredth.

TABLE II. 0 to — 1000 feet.

Values of log f_n with h and t as arguments.

h(ft.)	t	0°	Δ_t	10°	Δ_t	20°	Δ_t	30°	Δ_t	40°	Δ_t	50°	Δ_t	60°	Δ_t	70°	Δ_t	80°	Δ_t	90°	Δ_t	100°
—100	9.9	9855	3	9858	3	9861	3	9864	3	9867	3	9870	3	9873	2	9875	3	9878	2	9880	2	9882
—200		9710	6	9716	7	9723	6	9729	6	9735	5	9740	5	9745	5	9750	5	9755	5	9760	5	9765
—300		9565	10	9575	9	9584	9	9593	9	9602	8	9610	8	9518	8	9626	7	9633	7	9640	7	9647
—400		9420	13	9433	13	9446	12	9458	11	9469	11	9480	11	9491	10	9501	10	9511	9	9520	9	9529
—500		9275	16	9291	16	9307	15	9372	14	9336	14	9350	13	9363	13	9376	12	9388	12	9400	11	9411
—600		9130	19	9149	19	9168	18	9186	17	9203	17	9220	16	9236	16	9252	14	9266	14	9280	14	9294
—700		8985	22	9007	23	9030	21	9051	19	9070	20	9090	19	9109	18	9127	17	9144	16	9160	16	9176
—800		8840	26	8866	26	8890	24	8916	22	8938	22	8960	22	8982	21	9003	19	9022	18	9040	18	9058
—900		8695	29	8724	29	8753	27	8780	26	8806	24	8830	24	8854	24	8878	21	8899	21	8920	21	8941
—1000		8550	32	8582	32	8614	30	8644	29	8673	27	8700	27	8727	26	8753	24	8277	23	8800	23	8823
Δ_h		145		142		139		136		133		130		127		125		122		120		118

Interpolation formula: $\log f_n = \log f_0 - \Delta_h \left\{\frac{h - h_0}{100}\right\} + \Delta_t \left\{\frac{t - t_0}{10}\right\}$.

NOTE: In the column headed t, appear the characteristic and first digit of the mantissa which are common to all the logarithms of f_n on this page. In the columns headed 0°, 10°, etc., appear the remaining four digits of log f_n.

Thus log f_n for —400 feet and 40° is 9.99469, f_n between 0 and —1000 feet being less than unity.

TABLE II. 0 to + 6000 feet

Values of log f_a with h and t as arguments *

h / t	1000	Δ_t	Δ_h	2000	Δ_t	Δ_h	3000	Δ_t	Δ_h	4000	Δ_t	Δ_h	5000	Δ_t	Δ_h	6000
0°	.01473	33	1492	.02965	68	1531	.04496	102	1560	.06056	138	1579	.07635	176	1615	.09250
10°	.01440	32	1457	.02897	66	1497	.04394	99	1524	.05918	133	1541	.07459	169	1577	.09036
20°	.01408	31	1423	.02831	63	1464	.04295	95	1490	.05785	129	1505	.07290	164	1538	.08828
30°	.01377	30	1391	.02768	60	1432	.04200	92	1454	.05654	124	1472	.07126	158	1503	.08629
40°	.01347	29	1361	.02708	58	1400	.04108	88	1422	.05530	119	1438	.06968	152	1468	.08436
50°	.01319	28	1331	.02650	55	1370	.04020	84	1391	.05411	114	1405	.06816	146	1436	.08252
60°	.01292	27	1303	.02595	53	1341	.03936	81	1361	.05297	109	1373	.06670	140	1404	.08074
70°	.01265	26	1277	.02542	50	1313	.03855	78	1333	.05188	105	1342	.06530	134	1374	.07904
80°	.01239	25	1253	.02492	48	1285	.03777	74	1306	.05083	101	1313	.06396	128	1345	.07741
90°	.01214	24	1230	.02444	45	1259	.03703	71	1279	.04982	97	1286	.06268	122	1317	.07585
100°	.01190	23	1209	.02399	43	1233	.03632	68	1253	.04885	93	1261	.06146	116	1291	.07437

* This value of log f is that pertaining to the *height of mean density*; it is corrected for mean humidity, change of temperature with altitude, and is *not* obtained by using the *mean height*. It is entered with h, the *mean height*, as argument, the relation between this and the height of mean density having been ascertained, and the mean height being readily found is used as argument. This $h = F \cdot y_o$, in which F is a function of the elevation in degrees. The other argument, t, is the *surface temperature*.

For interpolation between 0 and 1000 feet find log f_a for 1000 feet for the given temperature. Calling this log f_0, we have

$$\log f_a = \frac{h}{1000} \times \log f_0$$

TABLE II. 6000 to 11000 feet.

Values of log f_a with h and t as arguments.

h	6000	Δ_t	Δ_h	7000	Δ_t	Δ_h	8000	Δ_t	Δ_h	9000	Δ_t	Δ_h	10000	Δ_t	Δ_h	11000
t																
0°	.09250	215	1650	.10900	254	1664	.12564	294	1705	.14269	336	1734	.16003	379	1753	.17756
10°	.09035	207	1611	.10646	245	1624	.12270	285	1663	.13933	324	1691	.15624	365	1709	.17333
20°	.08828	199	1573	.10401	236	1584	.11985	274	1624	.13609	313	1650	.15259	353	1666	.16925
30°	.08629	192	1536	.10165	228	1546	.11711	265	1585	.13296	302	1610	.14906	340	1625	.16531
40°	.08437	185	1500	.09937	220	1509	.11446	254	1548	.12994	290	1572	.14566	328	1595	.16151
50°	.08252	178	1455	.09717	211	1475	.11192	244	1512	.12704	279	1534	.14238	315	1547	.15785
60°	.08074	170	1422	.09506	203	1442	.10948	235	1477	.12425	267	1498	.13923	302	1511	.15434
70°	.07904	163	1399	.09303	194	1410	.10713	224	1435	.12158	256	1463	.13621	289	1476	.15097
80°	.07741	156	1368	.09109	186	1380	.10489	214	1413	.11902	245	1430	.13332	277	1442	.14774
90°	.07585	148	1338	.08923	177	1352	.10275	204	1382	.11657	233	1398	.13055	264	1410	.14465
100°	.07437	140	1309	.08746	168	1325	.10071	194	1353	.11424	222	1367	.12791	251	1380	.14171

To find f_a use the following interpolation formula (following Lissak)

$$\log f_a = \log f_0 + \frac{h - h_0}{1000} \Delta_{h_0} - \frac{t - t_0}{10} \Delta_{t_0} - \frac{h - h_0}{1000} \cdot \frac{t - t_0}{10} \left\{ \Delta_{h_0} - \Delta_{h_1} \right\}$$

In which log f_0 is the value of log f_a for the tabular values (h_0 and t_0) of h and t next below the given ones. Δ_{h_0} and Δ_{t_0} are opposite h_0 and t_0 in the Δ_h and Δ_t columns, Δ_{h_1} is in the Δ_h column next below Δ_{h_0}.

TABLE III.

Values of $\frac{\delta_{,}}{\delta}$ for a psychrometer depression of 0°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1	.936	.903	.873	.846	51	1.043	1.008	.974	.943
2	.938	.905	.875	.848	52	1.045	1.010	.976	.945
3	.940	.907	.877	.850	53	1.048	1.012	.978	.947
4	.942	.909	.879	.851	54	1.051	1.015	.981	.949
5	.944	.911	.881	.853	55	1.053	1.017	.983	.951
6	.946	.913	.883	.855	56	1.056	1.019	.985	.953
7	.948	.915	.885	.857	57	1.058	1.021	.988	.955
8	.950	.917	.887	.858	58	1.060	1.024	.990	.957
9	.952	.919	.889	.860	59	1.062	1.026	.992	.959
10	.954	.921	.891	.862	60	1.065	1.028	.994	.962
11	.956	.923	.893	.864	61	1.067	1.030	.997	.965
12	.958	.925	.895	.866	62	1.070	1.033	.999	.967
13	.960	.927	.896	.868	63	1.073	1.036	1.002	.970
14	.963	.929	.898	.870	64	1.075	1.038	1.005	.972
15	.965	.931	.900	.872	65	1.078	1.041	1.007	.975
16	.967	.933	.902	.874	66	1.081	1.044	1.010	.977
17	.969	.935	.904	.875	67	1.083	1.046	1.013	.980
18	.971	.937	.906	.877	68	1.086	1.049	1.015	.982
19	.973	.939	.908	.879	69	1.089	1.052	1.017	.985
20	.975	.941	.910	.881	70	1.092	1.055	1.020	.987
21	.978	.943	.912	.883	71	1.094	1.058	1.022	.989
22	.980	.945	.914	.885	72	1.097	1.060	1.025	.992
23	.982	.947	.916	.887	73	1.100	1.063	1.027	.994
24	.984	.949	.919	.889	74	1.103	1.065	1.030	.997
25	.986	.951	.921	.890	75	1.105	1.068	1.032	.999
26	.988	.953	.923	.892	76	1.108	1.070	1.035	1.001
27	.990	.955	.925	.894	77	1.111	1.073	1.037	1.004
28	.992	.957	.927	.896	78	1.113	1.075	1.040	1.006
29	.994	.959	.929	.898	79	1.116	1.078	1.042	1.009
30	.996	.961	.931	.900	80	1.118	1.080	1.045	1.011
31	.999	.963	.933	.902	81	1.121	1.083	1.047	1.014
32	1.001	.966	.935	.904	82	1.124	1.086	1.050	1.017
33	1.003	.968	.937	.906	83	1.127	1.089	1.053	1.020
34	1.005	.970	.939	.908	84	1.130	1.092	1.056	1.022
35	1.008	.972	.941	.910	85	1.133	1.095	1.059	1.025
36	1.010	.975	.943	.912	86	1.136	1.098	1.062	1.028
37	1.012	.977	.945	.914	87	1.139	1.101	1.064	1.031
38	1.014	.979	.947	.916	88	1.142	1.104	1.067	1.033
39	1.016	.981	.949	.918	89	1.145	1.107	1.070	1.036
40	1.018	.983	.951	.920	90	1.149	1.110	1.073	1.039
41	1.021	.986	.953	.922	91	1.152	1.113	1.076	1.042
42	1.023	.988	.955	.924	92	1.156	1.117	1.079	1.045
43	1.025	.990	.957	.926	93	1.159	1.120	1.083	1.048
44	1.027	.992	.959	.928	94	1.162	1.123	1.086	1.051
45	1.030	.994	.961	.930	95	1.166	1.126	1.089	1.054
46	1.032	.996	.963	.932	96	1.169	1.129	1.092	1.057
47	1.034	.999	.966	.934	97	1.172	1.133	1.096	1.060
48	1.036	1.002	.968	.936	98	1.176	1.136	1.099	1.063
49	1.039	1.004	.970	.938	99	1.179	1.139	1.102	1.066
50	1.041	1.006	.972	.941	100	1.182	1.142	1.105	1.069

TABLE III.

Values of $\frac{\delta'}{\delta}$ for a psychrometer depression of 1°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1	.936	.903	.873	.846	51	1.042	1.007	.973	.942
2	.938	.905	.875	.848	52	1.044	1.009	.975	.944
3	.940	.907	.877	.850	53	1.047	1.011	.977	.946
4	.942	.909	.879	.851	54	1.050	1.014	.980	.948
5	.944	.911	.881	.853	55	1.052	1.016	.982	.950
6	.946	.913	.883	.855	56	1.055	1.018	.984	.952
7	.948	.915	.885	.857	57	1.057	1.020	.987	.954
8	.950	.917	.887	.858	58	1.059	1.023	.989	.956
9	.952	.919	.889	.860	59	1.061	1.025	.991	.958
10	.954	.921	.891	.862	60	1.064	1.027	.993	.961
11	.956	.923	.893	.864	61	1.066	1.029	.996	.964
12	.958	.925	.895	.866	62	1.069	1.032	.998	.966
13	.960	.927	.896	.868	63	1.072	1.035	1.001	.969
14	.962	.928	.898	.869	64	1.074	1.037	1.004	.971
15	.964	.930	.899	.871	65	1.077	1.040	1.006	.974
16	.966	.932	.901	.873	66	1.080	1.043	1.009	.976
17	.968	.934	.903	.874	67	1.082	1.045	1.012	.979
18	.970	.936	.905	.876	68	1.085	1.048	1.014	.981
19	.972	.938	.907	.878	69	1.088	1.051	1.016	.984
20	.974	.940	.909	.880	70	1.091	1.054	1.019	.986
21	.977	.942	.911	.882	71	1.093	1.057	1.021	.988
22	.979	.944	.913	.884	72	1.096	1.060	1.024	.991
23	.981	.946	.915	.886	73	1.098	1.063	1.026	.993
24	.983	.948	.918	.888	74	1.101	1.066	1.028	.995
25	.985	.950	.920	.889	75	1.103	1.068	1.030	.997
26	.987	.952	.922	.891	76	1.107	1.070	1.033	.999
27	.989	.954	.924	.893	77	1.109	1.072	1.035	1.002
28	.991	.956	.926	.895	78	1.111	1.074	1.038	1.004
29	.993	.958	.928	.897	79	1.114	1.076	1.040	1.007
30	.995	.960	.930	.899	80	1.116	1.078	1.043	1.009
31	.998	.962	.932	.901	81	1.119	1.081	1.045	1.012
32	1.000	.965	.934	.903	82	1.122	1.084	1.048	1.015
33	1.002	.967	.936	.905	83	1.125	1.087	1.051	1.018
34	1.004	.969	.938	.907	84	1.128	1.090	1.054	1.020
35	1.007	.971	.940	.909	85	1.131	1.093	1.057	1.023
36	1.009	.974	.942	.911	86	1.134	1.096	1.060	1.026
37	1.011	.976	.944	.913	87	1.137	1.099	1.062	1.029
38	1.013	.978	.946	.915	88	1.140	1.102	1.065	1.032
39	1.015	.980	.948	.917	89	1.143	1.105	1.068	1.034
40	1.017	.982	.950	.919	90	1.147	1.108	1.071	1.037
41	1.020	.985	.952	.921	91	1.150	1.111	1.074	1.040
42	1.022	.987	.954	.923	92	1.154	1.114	1.077	1.043
43	1.024	.989	.956	.925	93	1.157	1.117	1.081	1.046
44	1.026	.991	.958	.927	94	1.160	1.120	1.084	1.049
45	1.029	.993	.960	.929	95	1.164	1.123	1.087	1.052
46	1.031	.995	.962	.931	96	1.167	1.126	1.090	1.055
47	1.033	.998	.964	.933	97	1.170	1.129	1.094	1.058
48	1.035	1.001	.967	.935	98	1.173	1.132	1.096	1.060
49	1.038	1.003	.969	.937	99	1.176	1.135	1.099	1.063
50	1.040	1.005	.971	.940	100	1.179	1.139	1.102	1.066

TABLE III.

Values of $\frac{\delta'}{\delta}$ for a psychrometer depression of 2°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1	.936	.903	.873	.846	51	1.041	1.006	.972	.941
2	.938	.905	.875	.848	52	1.043	1.008	.974	.943
3	.940	.907	.877	.850	53	1.047	1.010	.976	.945
4	.942	.909	.879	.851	54	1.049	1.013	.979	.947
5	.944	.911	.881	.853	55	1.051	1.015	.981	.949
6	.946	.913	.883	.855	56	1.054	1.017	.983	.951
7	.948	.915	.885	.857	57	1.056	1.019	.986	.953
8	.950	.917	.887	.858	58	1.058	1.022	.988	.955
9	.952	.919	.889	.860	59	1.060	1.024	.990	.957
10	.954	.921	.891	.862	60	1.063	1.026	.992	.960
11	.956	.923	.893	.864	61	1.065	1.028	.995	.963
12	.958	.925	.895	.866	62	1.068	1.031	.997	.965
13	.960	.927	.896	.868	63	1.071	1.034	1.000	.968
14	.962	.928	.897	.869	64	1.073	1.036	1.003	.970
15	.964	.930	.899	.871	65	1.076	1.039	1.005	.973
16	.966	.932	.901	.873	66	1.079	1.042	1.008	.975
17	.968	.934	.903	.874	67	1.081	1.044	1.011	.978
18	.970	.936	.905	.876	68	1.084	1.047	1.013	.980
19	.972	.938	.907	.878	69	1.086	1.049	1.014	.982
20	.974	.940	.909	.880	70	1.089	1.052	1.017	.984
21	.977	.942	.911	.882	71	1.091	1.055	1.019	.986
22	.979	.944	.913	.884	72	1.094	1.057	1.022	.989
23	.981	.946	.915	.886	73	1.097	1.060	1.024	.991
24	.983	.948	.918	.888	74	1.100	1.062	1.027	.994
25	.985	.950	.920	.889	75	1.102	1.065	1.029	.996
26	.987	.952	.922	.891	76	1.105	1.067	1.032	.998
27	.989	.954	.924	.893	77	1.108	1.070	1.034	1.001
28	.991	.956	.926	.895	78	1.110	1.072	1.037	1.003
29	.993	.958	.928	.897	79	1.113	1.075	1.039	1.006
30	.995	.960	.930	.899	80	1.115	1.077	1.042	1.008
31	.997	.962	.932	.900	81	1.118	1.080	1.044	1.011
32	.999	.964	.934	.902	82	1.121	1.083	1.047	1.014
33	1.001	.966	.936	.904	83	1.124	1.086	1.050	1.017
34	1.003	.968	.938	.906	84	1.127	1.089	1.053	1.019
35	1.006	.970	.940	.908	85	1.130	1.092	1.056	1.022
36	1.008	.973	.942	.910	86	1.133	1.095	1.059	1.025
37	1.010	.975	.944	.912	87	1.136	1.098	1.061	1.028
38	1.012	.977	.946	.914	88	1.139	1.101	1.064	1.030
39	1.014	.979	.948	.916	89	1.142	1.104	1.067	1.033
40	1.016	.981	.950	.918	90	1.145	1.106	1.069	1.035
41	1.019	.984	.952	.920	91	1.148	1.109	1.072	1.038
42	1.021	.986	.954	.922	92	1.152	1.113	1.075	1.041
43	1.023	.988	.956	.924	93	1.155	1.116	1.079	1.044
44	1.025	.990	.958	.926	94	1.158	1.119	1.082	1.047
45	1.028	.992	.960	.928	95	1.161	1.121	1.084	1.049
46	1.030	.994	.962	.930	96	1.164	1.124	1.087	1.052
47	1.032	.997	.964	.932	97	1.167	1.128	1.091	1.055
48	1.034	1.000	.966	.934	98	1.171	1.131	1.094	1.058
49	1.037	1.002	.968	.936	99	1.174	1.134	1.097	1.061
50	1.039	1.004	.970	.939	100	1.177	1.137	1.100	1.064

TABLE III.

Values of $\frac{\delta_{\prime}}{\delta}$ for a psychrometer depression of 3°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1	.935	.902	.872	.845	51	1.041	1.006	.972	.941
2	.937	.904	.874	.847	52	1.043	1.008	.974	.943
3	.939	.906	.876	.849	53	1.046	1.010	.976	.945
4	.941	.908	.878	.850	54	1.049	1.013	.979	.947
5	.943	.910	.880	.852	55	1.051	1.015	.981	.949
6	.945	.912	.882	.854	56	1.054	1.017	.983	.951
7	.947	.914	.884	.856	57	1.056	1.019	.986	.953
8	.949	.916	.886	.857	58	1.058	1.022	.988	.955
9	.951	.918	.888	.859	59	1.060	1.024	.990	.957
10	.953	.920	.890	.861	60	1.063	1.026	.992	.960
11	.955	.922	.892	.863	61	1.065	1.028	.995	.963
12	.957	.924	.894	.865	62	1.068	1.031	.997	.965
13	.959	.926	.895	.867	63	1.070	1.033	.999	.967
14	.961	.927	.896	.868	64	1.072	1.035	1.002	.969
15	.963	.929	.898	.870	65	1.075	1.038	1.004	.971
16	.965	.931	.900	.872	66	1.077	1.040	1.006	.973
17	.967	.933	.902	.873	67	1.079	1.042	1.009	.976
18	.969	.935	.904	.875	68	1.082	1.045	1.011	.978
19	.971	.937	.906	.877	69	1.085	1.048	1.013	.981
20	.973	.939	.908	.879	70	1.088	1.051	1.016	.983
21	.976	.941	.910	.881	71	1.090	1.054	1.018	.985
22	.978	.943	.912	.883	72	1.093	1.056	1.021	.988
23	.980	.945	.914	.885	73	1.096	1.058	1.023	.990
24	.982	.947	.917	.887	74	1.098	1.060	1.025	.992
25	.984	.949	.919	.888	75	1.100	1.063	1.027	.994
26	.986	.951	.921	.890	76	1.103	1.065	1.030	.996
27	.988	.953	.923	.892	77	1.106	1.068	1.032	.999
28	.990	.955	.925	.894	78	1.108	1.070	1.035	1.001
29	.992	.957	.927	.896	79	1.111	1.073	1.037	1.004
30	.994	.959	.929	.898	80	1.113	1.075	1.040	1.006
31	.997	.961	.931	.900	81	1.116	1.078	1.042	1.009
32	.999	.964	.933	.902	82	1.119	1.081	1.045	1.012
33	1.001	.966	.935	.904	83	1.122	1.084	1.048	1.015
34	1.003	.968	.937	.906	84	1.125	1.087	1.051	1.017
35	1.006	.970	.939	.908	85	1.128	1.090	1.054	1.020
36	1.008	.973	.941	.910	86	1.131	1.093	1.057	1.023
37	1.010	.975	.943	.912	87	1.134	1.096	1.059	1.026
38	1.012	.977	.945	.914	88	1.137	1.099	1.062	1.028
39	1.014	.979	.947	.916	89	1.140	1.102	1.065	1.031
40	1.016	.981	.949	.918	90	1.144	1.105	1.068	1.034
41	1.019	.984	.951	.920	91	1.147	1.108	1.071	1.037
42	1.021	.986	.953	.922	92	1.150	1.111	1.073	1.039
43	1.023	.988	.955	.924	93	1.153	1.114	1.076	1.042
44	1.025	.990	.957	.926	94	1.156	1.117	1.079	1.045
45	1.028	.992	.959	.928	95	1.159	1.119	1.082	1.047
46	1.030	.994	.961	.930	96	1.162	1.122	1.085	1.050
47	1.032	.997	.964	.932	97	1.165	1.125	1.088	1.053
48	1.034	1.000	.966	.934	98	1.168	1.128	1.091	1.055
49	1.037	1.002	.968	.936	99	1.171	1.131	1.094	1.058
50	1.039	1.004	.970	.939	100	1.174	1.134	1.097	1.061

TABLE III.

Values of $\frac{\delta_{\prime}}{\delta}$ for a psychrometer depression of 4°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1					51	1.040	1.005	.971	.940
2					52	1.042	1.007	.973	.942
3					53	1.045	1.009	.975	.944
4					54	1.048	1.012	.978	.946
5					55	1.050	1.014	.980	.948
6					56	1.053	1.016	.982	.950
7					57	1.055	1.018	.985	.952
8	.949	.916	.886	.857	58	1.057	1.021	.987	.954
9	.951	.918	.888	.859	59	1.059	1.023	.989	.956
10	.953	.920	.890	.861	60	1.062	1.025	.991	.959
11	.955	.922	.892	.863	61	1.064	1.027	.994	.962
12	.957	.924	.894	.865	62	1.067	1.030	.996	.964
13	.959	.926	.895	.866	63	1.069	1.032	.998	.966
14	.961	.928	.896	.868	64	1.071	1.034	1.001	.968
15	.963	.930	.898	.870	65	1.074	1.037	1.003	.970
16	.965	.931	.900	.872	66	1.076	1.039	1.005	.972
17	.967	.933	.902	.873	67	1.078	1.041	1.008	.975
18	.969	.935	.904	.875	68	1.081	1.044	1.010	.977
19	.971	.937	.906	.877	69	1.083	1.046	1.012	.979
20	.973	.939	.908	.879	70	1.086	1.049	1.014	.981
21	.976	.941	.910	.881	71	1.088	1.052	1.016	.983
22	.978	.943	.912	.883	72	1.091	1.054	1.019	.986
23	.980	.945	.914	.885	73	1.094	1.057	1.021	.988
24	.982	.947	.917	.887	74	1.097	1.059	1.024	.991
25	.984	.949	.919	.888	75	1.099	1.062	1.026	.993
26	.986	.951	.921	.890	76	1.102	1.064	1.029	.995
27	.988	.953	.923	.892	77	1.105	1.067	1.031	.998
28	.990	.955	.925	.894	78	1.107	1.069	1.034	1.000
29	.992	.957	.927	.896	79	1.110	1.072	1.036	1.003
30	.994	.959	.929	.898	80	1.112	1.074	1.039	1.005
31	.996	.960	.930	.899	81	1.115	1.077	1.041	1.008
32	.998	.963	.932	.901	82	1.118	1.080	1.044	1.011
33	1.000	.965	.934	.903	83	1.121	1.083	1.047	1.014
34	1.002	.967	.936	.905	84	1.124	1.086	1.050	1.016
35	1.005	.969	.938	.907	85	1.127	1.089	1.053	1.019
36	1.007	.972	.940	.909	86	1.130	1.092	1.056	1.022
37	1.009	.974	.942	.911	87	1.133	1.095	1.058	1.025
38	1.011	.976	.944	.913	88	1.136	1.098	1.061	1.027
39	1.013	.978	.946	.915	89	1.139	1.101	1.064	1.030
40	1.015	.980	.948	.917	90	1.142	1.103	1.067	1.032
41	1.018	.983	.950	.919	91	1.145	1.106	1.069	1.035
42	1.020	.985	.952	.921	92	1.148	1.109	1.071	1.037
43	1.022	.987	.954	.923	93	1.151	1.112	1.075	1.040
44	1.024	.989	.956	.925	94	1.154	1.115	1.078	1.043
45	1.027	.991	.958	.927	95	1.157	1.117	1.080	1.045
46	1.029	.993	.960	.929	96	1.160	1.120	1.083	1.048
47	1.031	.996	.963	.931	97	1.163	1.123	1.086	1.051
48	1.033	.999	.965	.933	98	1.166	1.126	1.089	1.053
49	1.036	1.001	.967	.935	99	1.169	1.129	1.092	1.056
50	1.038	1.003	.969	.938	100	1.172	1.132	1.095	1.059

TABLE III.

Values of $\frac{\delta_1}{\delta}$ for a psychrometer depression of 5°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
1					51	1.039	1.004	.970	.939
2					52	1.041	1.006	.972	.941
3					53	1.044	1.008	.974	.943
4					54	1.046	1.010	.977	.946
5					55	1.048	1.013	.979	.948
6					56	1.051	1.015	.981	.950
7					57	1.053	1.017	.983	.952
8					58	1.055	1.020	.986	.954
9					59	1.058	1.022	.988	.956
10					60	1.061	1.024	.990	.958
11					61	1.063	1.027	.992	.960
12	.956	.922	.890	.860	62	1.066	1.029	.994	.963
13	.958	.924	.892	.862	63	1.068	1.031	.997	.965
14	.960	.926	.894	.864	64	1.071	1.033	1.000	.967
15	.962	.928	.896	.866	65	1.073	1.036	1.002	.969
16	.964	.930	.898	.868	66	1.075	1.038	1.004	.971
17	.966	.932	.900	.870	67	1.078	1.041	1.007	.974
18	.968	.934	.902	.872	68	1.080	1.043	1.009	.976
19	.970	.936	.904	.874	69	1.082	1.046	1.011	.978
20	.972	.938	.906	.876	70	1.085	1.048	1.013	.980
21	.974	.940	.908	.878	71	1.087	1.051	1.016	.982
22	.976	.942	.911	.880	72	1.090	1.053	1.018	.985
23	.978	.944	.913	.882	73	1.093	1.056	1.021	.987
24	.980	.946	.915	.884	74	1.095	1.058	1.023	.991
25	.982	.948	.917	.886	75	1.097	1.061	1.026	.993
26	.984	.950	.920	.888	76	1.100	1.063	1.028	.996
27	.986	.952	.922	.890	77	1.103	1.066	1.031	.998
28	.988	.954	.924	.892	78	1.105	1.068	1.033	1.000
29	.990	.956	.926	.894	79	1.108	1.071	1.036	1.002
30	.993	.958	.928	.897	80	1.111	1.073	1.038	1.004
31	.995	.960	.930	.899	81	1.113	1.076	1.041	1.007
32	.997	.962	.932	.901	82	1.116	1.078	1.044	1.009
33	.999	.965	.934	.903	83	1.119	1.081	1.046	1.012
34	1.001	.967	.936	.905	84	1.122	1.084	1.049	1.014
35	1.004	.969	.938	.907	85	1.125	1.087	1.051	1.017
36	1.006	.971	.940	.909	86	1.128	1.090	1.054	1.019
37	1.008	.974	.942	.911	87	1.131	1.092	1.056	1.022
38	1.010	.976	.944	.913	88	1.134	1.095	1.059	1.024
39	1.012	.978	.946	.915	89	1.137	1.098	1.061	1.027
40	1.015	.980	.948	.917	90	1.140	1.101	1.064	1.030
41	1.017	.982	.950	.919	91	1.143	1.104	1.066	1.032
42	1.019	.984	.952	.921	92	1.146	1.107	1.069	1.035
43	1.022	.986	.954	.923	93	1.149	1.109	1.072	1.038
44	1.024	.989	.956	.925	94	1.152	1.112	1.075	1.040
45	1.026	.991	.958	.927	95	1.155	1.115	1.078	1.043
46	1.028	.993	.960	.929	96	1.158	1.118	1.081	1.046
47	1.031	.995	.962	.931	97	1.161	1.121	1.084	1.049
48	1.033	.997	.964	.933	98	1.164	1.124	1.087	1.051
49	1.035	.999	.966	.935	99	1.167	1.127	1.090	1.054
50	1.037	1.002	.968	.937	100	1.170	1.130	1.093	1.057

TABLE III.

Values of $\frac{\delta_\prime}{\delta}$ for a psychrometer depression of 6°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
20	.971	.937	.905	.875	60	1.060	1.023	.989	.957
21	.973	.939	.907	.877	61	1.062	1.026	.991	.959
22	.975	.941	.910	.879	62	1.065	1.028	.993	.962
23	.977	.943	.912	.881	63	1.067	1.030	.996	.964
24	.979	.945	.914	.883	64	1.070	1.032	.999	.966
25	.981	.947	.916	.885	65	1.072	1.035	1.001	.968
26	.983	.949	.919	.887	66	1.074	1.037	1.003	.970
27	.985	.951	.921	.889	67	1.077	1.040	1.006	.973
28	.987	.953	.923	.891	68	1.079	1.042	1.008	.975
29	.989	.955	.925	.893	69	1.081	1.045	1.010	.977
30	.992	.957	.927	.896	70	1.084	1.047	1.012	.979
31	.994	.959	.929	.898	71	1.086	1.050	1.015	.981
32	.996	.961	.931	.900	72	1.089	1.052	1.017	.984
33	.998	.964	.933	.902	73	1.092	1.055	1.020	.986
34	1.000	.966	.935	.904	74	1.094	1.057	1.022	.990
35	1.003	.968	.937	.906	75	1.096	1.060	1.025	.992
36	1.005	.970	.939	.908	76	1.099	1.062	1.027	.995
37	1.007	.972	.941	.910	77	1.102	1.065	1.030	.997
38	1.009	.974	.943	.912	78	1.104	1.067	1.032	.999
39	1.011	.976	.945	.914	79	1.107	1.070	1.035	1.001
40	1.014	.979	.947	.916	80	1.110	1.072	1.037	1.003
41	1.016	.981	.949	.918	81	1.112	1.075	1.040	1.006
42	1.018	.983	.951	.920	82	1.115	1.077	1.043	1.008
43	1.021	.985	.953	.922	83	1.118	1.080	1.045	1.011
44	1.023	.988	.955	.924	84	1.121	1.083	1.048	1.013
45	1.025	.990	.957	.926	85	1.124	1.086	1.050	1.016
46	1.027	.992	.959	.928	86	1.126	1.088	1.052	1.017
47	1.029	.994	.961	.930	87	1.129	1.090	1.054	1.020
48	1.031	.996	.963	.932	88	1.132	1.093	1.057	1.022
49	1.033	.998	.965	.934	89	1.135	1.096	1.059	1.025
50	1.035	1.001	.967	.936	90	1.138	1.099	1.062	1.028
51	1.038	1.003	.969	.938	91	1.141	1.102	1.064	1.030
52	1.040	1.005	.971	.939	92	1.144	1.105	1.067	1.033
53	1.043	1.007	.973	.942	93	1.147	1.107	1.070	1.036
54	1.045	1.009	.976	.945	94	1.150	1.110	1.073	1.038
55	1.047	1.012	.978	.947	95	1.153	1.113	1.076	1.041
56	1.050	1.014	.980	.949	96	1.156	1.116	1.079	1.044
57	1.052	1.016	.982	.951	97	1.159	1.119	1.082	1.047
58	1.054	1.019	.985	.953	98	1.162	1.122	1.085	1.049
59	1.057	1.021	.987	.955	99	1.165	1.125	1.088	1.052
60	1.060	1.023	.989	.957	100	1.168	1.128	1.091	1.055

TABLE III.

Values of $\frac{\delta_{,}}{\delta}$ for a psychrometer depression of 7°.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
20					60	1.059	1.022	.988	.956
21					61	1.061	1.025	.990	.958
22					62	1.064	1.027	.992	.961
23					63	1.066	1.029	.995	.963
24	.979	.945	.914	.883	64	1.069	1.031	.998	.965
25	.981	.947	.916	.885	65	1.071	1.034	1.000	.967
26	.983	.949	.919	.887	66	1.073	1.036	1.002	.969
27	.985	.951	.921	.889	67	1.076	1.039	1.005	.972
28	.987	.953	.923	.891	68	1.078	1.041	1.007	.974
29	.989	.955	.925	.893	69	1.080	1.044	1.009	.976
30	.992	.957	.927	.896	70	1.083	1.046	1.011	.978
31	.994	.959	.929	.898	71	1.085	1.049	1.014	.980
32	.996	.961	.931	.900	72	1.088	1.051	1.016	.983
33	.998	.964	.933	.902	73	1.091	1.054	1.019	.985
34	1.000	.966	.935	.904	74	1.093	1.056	1.021	.989
35	1.003	.968	.937	.906	75	1.095	1.059	1.024	.991
36	1.005	.970	.939	.908	76	1.098	1.061	1.026	.994
37	1.007	.972	.941	.910	77	1.101	1.064	1.029	.996
38	1.009	.974	.943	.912	78	1.103	1.066	1.031	.998
39	1.011	.976	.945	.914	79	1.106	1.069	1.034	1.000
40	1.014	.979	.947	.916	80	1.109	1.071	1.036	1.002
41	1.016	.981	.949	.918	81	1.111	1.074	1.039	1.005
42	1.018	.983	.951	.920	82	1.114	1.076	1.042	1.007
43	1.021	.985	.953	.922	83	1.117	1.079	1.044	1.009
44	1.023	.988	.955	.924	84	1.119	1.081	1.046	1.011
45	1.025	.990	.957	.926	85	1.122	1.084	1.048	1.014
46	1.027	.992	.959	.928	86	1.125	1.087	1.051	1.016
47	1.029	.994	.961	.930	87	1.128	1.089	1.053	1.019
48	1.031	.996	.963	.932	88	1.131	1.092	1.056	1.021
49	1.033	.998	.965	.934	89	1.134	1.095	1.058	1.024
50	1.035	1.001	.967	.936	90	1.137	1.098	1.061	1.027
51	1.037	1.003	.969	.938	91	1.140	1.101	1.063	1.029
52	1.039	1.005	.971	.940	92	1.142	1.104	1.065	1.031
53	1.042	1.007	.973	.942	93	1.145	1.106	1.068	1.034
54	1.044	1.009	.975	.944	94	1.148	1.108	1.071	1.036
55	1.046	1.011	.977	.946	95	1.151	1.111	1.074	1.039
56	1.049	1.013	.979	.948	96	1.154	1.114	1.077	1.042
57	1.051	1.015	.981	.950	97	1.157	1.117	1.080	1.045
58	1.053	1.018	.984	.952	98	1.160	1.120	1.083	1.047
59	1.056	1.020	.986	.954	99	1.163	1.123	1.086	1.050
60	1.059	1.022	.988	.956	100	1.166	1.126	1.089	1.053

TABLE IV.

Values of $\frac{1}{\beta}$ for use wherever Siacci's method is used. Computed for values of φ at intervals of 1° and for values of X in yards at intervals of 100 yards.

In the preparation of this table the writer has been ably assisted by Captain F. E. Harris, Artillery Corps, and by Mr. C. E. Junken, computer for the Artillery Board, in that the former has carefully taken the original data from Siacci's work for replotting the curves and the latter replotted them and took the values of β off to thousandths. In the few instances in which there was material difference between my plottings and his, I have deferred to the superior facilities for computing and to the experience as a computer, of Mr. Junken.

It is believed that the table in its present form is the first set presented to the artillery officer in this country in a form leaving little or no interpolation to be done, or in British Units.

The writer was led to give the values of $\frac{1}{\beta}$ rather than of β in order to avoid a factor in the denominator and its resulting colog.

In the columns of this table, all values in any column and following that affected by an asterisk have been obtained by extrapolation.

TABLE IV.

Values of $\frac{1}{\beta}$, for values of X from 1000 to 6000 yards and for values of φ from 6° to 13°.

X yds.	φ 6°	7°	8°	9°	10°	11°	12°	13°
1000	.998	.997	.996	.995	.994	.993	.991	.989
1100	.998	.997	.996	995	994	.993	.991	.990
1200	.999	.998	.996	.995	.994	.993	.991	.990
1300	.999	.998	.997	.995	.994	.993	.991	.990
1400	.999	.998	.997	.995	.994	.993	.991	.990
1500	1.000	.999	.997	.996	.995	.993	.991	.990
1600	1.000	.999	.997	.996	.995	.993	.991	.990
1700	1.001	.999	.998	.996	.995	.994	.991	.990
1800	1.002	1.000	.998	.997	.995	.994	.991	.990
1900	1.004	1.000	.999	.997	.996	.994	.992	.991
2000	1.007	1.001	.999	.998	.996	.994	.992	.991
2100	1.011	1.003	1.000	.998	.997	.995	.992	.991
2200	1.014	1.006	1.001	.999	.997	.995	.992	.991
2300	1.009	1.009	1.003	1.000	.998	.995	.993	.992
2400	1.007	1.011	1.006	1.001	.998	.996	.993	.992
2500	1.006	1.016	1.009	1.002	.999	.997	.994	.992
2600	1.005	1.018	1.013	1.003	1.000	.997	.994	.992
2700	1.005	1.016	1.017	1.005	1.001	.998	.995	.993
2800	1.004	1.013	1.020	1.008	1.003	.999	.996	.993
2900	1.003	1.011	1.022	1.013	1.005	1.000	.997	.994
3000	1.003	1.009	1.021	1.017	1.008	1.001	.998	.995
3100	1.002	1.007	1.019	1.021	1.012	1.003	.999	.996
3200	1.002	1.006	1.017	1.025	1.017	1.006	1.001	.997
3300	1.001	1.005	1.015	1.027	1.023	1.011	1.003	.998
3400	1.001	1.005	1.013	1.025	1.027	1.016	1.005	1.000
3500	1.001	1.004	1.012	1.023	1.030	1.023	1.008	1.003
3600	1.000	1.003	1.010	1.020	1.032	1.029	1.013	1.006
3700	1.000	1.003	1.008	1.018	1.031	1.033	1.018	1.009
3800	1.000	1.002	1.007	1.016	1.029	1.035	1.025	1.013
3900	1.000	1.002	1.007	1.015	1.026	1.036	1.031	1.018
4000	.999	1.001	1.006	1.013	1.023	1.035	1.035	1.025
4100	.999	1.001	1.005	1.012	1.020	1.033	1.039	1.031
4200	.999	1.001	1.004	1.011	1.019	1.030	1.043	1.037
4300	.999	1.000	1.003	1.010	1.018	1.028	1.043	1.042
4400	.999	1.000	1.003	1.008	1.016	1.027	1.042	1.046
4500	.998	1.000	1.002	1.007	1.015	1.025	1.039	1.049
4600	.998	1.000	1.002	1.007	1.014	1.023	1.036	1.049
4700	.998	.999	1.001	1.006	1.013	1.021	1.033	1.048
4800	.998	.999	1.001	1.005	1.011	1.020	1.030	1.046
4900	.998	.999	1.001	1.004	1.010	1.018	1.028	1.044
5000	.997	.999	1.000	1.003	1.009	1.017	1.027	1.042
5100	.997	.999	1.000	1.003	1.008	1.016	1.025	1.038
5200	.997	.998	1.000	1.002	1.007	1.015	1.023	1.035
5300	.997	.998	.999	1.002	1.006	1.013	1.021	1.032
5400	.997	.998	.999	1.001	1.006	1.012	1.020	1.030
5500	.997	.998	.999	1.001	1.005	1.011	1.018	1.028
5600	.997	.998	.999	1.001	1.004	1.010	1.017	1.027
5700	.997	.997	.998	1.000	1.003	1.009	1.016	1.025
5800	.997	.997	.998	1.000	1.003	1.008	1.014	1.024
5900	.997	.997	.998	1.000	1.002	1.007	1.013	1.022
6000	.996	.997	.998	.999	1.002	1.006	1.012	1.020

TABLE IV. (Continued.)

X from 6000 to 11000; φ from 6° to 13°.

X yds.	φ 6°	7°	8°	9°	10°	11°	12°	13°
6000	.996	.997	.998	.999	1.002	1.006	1.012	1.020
6100	.996*	.997	.998	.999	1.001	1.005	1.011	1.019
6200	.996	.997	.997	.999	1.001	1.004	1.010	1.017
6300	.996	.997	.997	.998	1.000	1.003	1.009	1.016
6400	.996	.997	.997	.998	1.000	1.003	1.008	1.014
6500	.996	.996	.997	.998	1.000	1.002	1.007	1.013
6600	.996	.996*	.997	.998	.999	1.002	1.007	1.012
6700	.996	.996	.997	.997	.999	1.001	1.006	1.011
6800	.996	.996	.997	.997	.999	1.001	1.005	1.010
6900	.996	.996	.997	.997	.998	1.001	1.004	1.009
7000	.996	.996	.996	.997	.998	1.000	1.004	1.008
7100	.996	.996	.996*	.997	.998	1.000	1.003	1.007
7200	.996	.996	.996	.997	.998	1.000	1.002	1.007
7300	.996	.996	.996	.997	.997	.999	1.002	1.006
7400	.996	.996	.996	.996	.997	.999	1.001	1.005
7500	.996	.996	.996	.996*	.997	.999	1.001	1.004
7600	.995	.995	.996	.996	.997	.998	1.000	1.004
7700	.995	.995	.996	.996	.997	.998	1.000	1.003
7800	.995	.995	.996	.996	.997	.998	1.000	1.002
7900	.995	.995	.996	.996	.997	.997	.999	1.002
8000	.995	.995	.996	.996	.996	.997	.999	1.001
8100	.995	.995	.995	.996	*.996	.997	.999	1.000
8200	.995	.995	.995	.996	.996	.997	.998	1.000
8300	.995	.995	.995	.995	.996	.997	.998	1.000
8400	.995	.995	.995	.995	.996	.996	.998	.999
8500	.995	.995	.995	.995	.996	.996	.997	.999
8600	.995	.995	.995	.995	.996	.996	.997	.999
8700	.995	.995	.995	.995	.996	.996	.997	.998
8800	.995	.995	.995	.995	.996	.996	.997	.998
8900	.995	.995	.995	.995	.996	.996	.997	.998
9000	.995	.994	.995	.995	.996	.996	.996	.997
9100		.994	.995	.995	.996	.996	.996	.997
9200		.994	.995	.995	.995	.996	.996	.997
9300		.994	.994	.995	.995	.996	.996	.997
9400		.994	.994	.995	.995	.995	.996	.997
9500		.994	.994	.994	.995	.995	.996	.996
9600			.994	.994	.995	.995	.996	.996
9700			.994	.994	.995	.995	.996	.996
9800			.994	.994	.995	.995	.996	.996
9900			.994	.994	.995	.995	.996	.996
10000			.994	.994	.995	.995	.995	.996
10100				.994	.995	.995	.995	.996
10200				.994	.995	.995	.995	.996
10300				.994	.995	.995	.995	.996
10400				.994	.995	.995	.995	.996
10500				.994	.995	.995	.995	.995
10600					.994	.995	.995	.995
10700					.994	.995	.995	.995
10800					.994	.995	.995	.995
10900					.994	.995	.995	.995
11000					.994	.994	.995	.995

TABLE IV. (Continued.)

X from 1000 to 6000; φ from 14° to 21°.

X yds.	14°	15°	16°	17°	18°	19°	20°	21°
1000	.987	.985	.983	.981	.979	.977	.975	.972
1100	.988	.985	.983	.981	.979	.977	.976	.972
1200	.988	.986	.983	.981	.979	.977	.976	.972
1300	.988	.986	.983	.981	.979	.978	.976	.972
1400	.988	.986	.983	.981	.979	.978	.976	.972
1500	.988	.986	.984	.982	.980	.978	.976	.972
1600	.989	.986	.984	.982	.980	.978	.976	.972
1700	.989	.987	.984	.982	.980	.978	.977	.972
1800	.989	.987	.984	.982	.980	.978	.977	.973
1900	.989	.987	.984	.982	.980	.979	.977	.973
2000	.990	.988	.984	.982	.980	.979	.977	.973
2100	.990	.988	.985	.983	.980	.979	.977	.973
2200	.990	.988	.985	.983	.980	.979	.978	.973
2300	.990	.989	.985	.983	.980	.979	.978	.974
2400	.991	.989	.986	.983	.981	.979	.978	.974
2500	.991	.989	.986	.983	.981	.979	.978	.974
2600	.991	.990	.987	.984	.981	.980	.978	.974
2700	.991	.990	.987	.984	.981	.980	.978	.975
2800	.992	.990	.987	.984	.981	.980	.979	.975
2900	.992	.991	.988	.985	.982	.981	.979	.976
3000	.992	.991	.988	.985	.982	.981	.979	.976
3100	.993	.991	.989	.986	.982	.981	.979	.977
3200	.994	.992	.989	.986	.983	.981	.979	.977
3300	.995	.992	.990	.987	.983	.981	.980	.978
3400	.996	.993	.991	.987	.983	.982	.980	.978
3500	.997	.994	.991	.988	.984	.982	.980	.978
3600	.999	.995	.992	.988	.984	.982	.980	.979
3700	1.001	.996	.993	.989	.985	.983	.981	.979
3800	1.004	.997	.994	.990	.986	.983	.981	.979
3900	1.008	.999	.995	.991	.987	.983	.981	.980
4000	1.012	1.001	.996	.992	.988	.984	.982	.980
4100	1.017	1.004	.998	.993	.989	.984	.982	.980
4200	1.022	1.008	1.000	.995	.990	.985	.982	.981
4300	1.028	1.013	1.003	.997	.991	.986	.983	.981
4400	1.033	1.018	1.007	.999	.993	.987	.984	.981
4500	1.038	1.025	1.011	1.001	.995	.988	.984	.982
4600	1.045	1.032	1.016	1.004	.997	.989	.985	.982
4700	1.052	1.039	1.022	1.007	1.000	.991	.986	.983
4800	1.055	1.046	1.029	1.011	1.003	.994	.987	.984
4900	1.056	1.052	1.036	1.017	1.007	.997	.989	.985
5000	1.055	1.056	1.043	1.024	1.011	1.000	.992	.987
5100	1.054	1.060	1.049	1.030	1.016	1.003	.995	.989
5200	1.052	1.063	1.056	1.037	1.023	1.007	.998	.991
5300	1.049	1.064	1.063	1.044	1.030	1.012	1.002	.994
5400	1.047	1.064	1.069	1.052	1.038	1.018	1.006	.997
5500	1.044	1.063	1.073	1.059	1.048	1.027	1.011	1.000
5600	1.042	1.061	1.074	1.066	1.057	1.036	1.017	1.004
5700	1.039	1.057	1.074	1.072	1.065	1.046	1.025	1.009
5800	1.037	1.054	1.073	1.078	1.073	1.057	1.034	1.014
5900	1.035	1.051	1.071	1.082	1.081	1.066	1.044	1.021
6000	1.032	1.048	1.067	1.083	1.087	1.074	1.055	1.030

TABLE IV. (Continued.)

X from 6000 to 11000; φ from 14° to 21°.

X yds.	14°	15°	16°	17°	18°	19°	20°	21°
6000	1.032	1.048	1.067	1.083	1.087	1.074	1.055	1.030
6100	1.030	1.045	1.064	1.083	1.092	1.082	1.065	1.040
6200	1.028	1.043	1.060	1.081	1.093	1.091	1.074	1.049
6300	1.027	1.040	1.057	1.078	1.094	1.096	1.082	1.060
6400	1.025	1.037	1.054	1.074	1.094	1.101	1.091	1.071
6500	1.023	1.034	1.050	1.070	1.093	1.104	1.098	1.082
6600	1.021	1.032	1.047	1.065	1.092	1.105	1.104	1.093
6700	1.019	1.030	1.045	1.062	1.088	1.105	1.109	1.102
6800	1.017	1.028	1.043	1.058	1.085	1.104	1.112	1.110
6900	1.016	1.027	1.040	1.055	1.080	1.101	1.115	1.116
7000	1.014	1.025	1.038	1.052	1.075	1.098	1.116	1.121
7100	1.013	1.024	1.035	1.048	1.072	1.094	1.116	1.125
7200	1.012	1.022	1.032	1.046	1.068	1.091	1.115	1.126
7300	1.011	1.020	1.030	1.044	1.065	1.087	1.112	1.127
7400	1.010	1.018	1.029	1.042	1.062	1.082	1.109	1.127
7500	1.009	1.017	1.027	1.040	1.058	1.079	1.105	1.126
7600	1.009	1.015	1.026	1.036	1.055	1.075	1.100	1.124
7700	1.008	1.014	1.024	1.034	1.052	1.072	1.095	1.120
7800	1.007	1.013	1.022	1.031	1.048	1.068	1.091	1.115
7900	1.006	1.012	1.020	1.029	1.045	1.065	1.086	1.111
8000	1.005	1.011	1.018	1.028	1.043	1.062	1.082	1.107
8100	1.005	1.010	1.016	1.026	1.041	1.059	1.079	1.104
8200	1.004	1.009	1.015	1.025	1.038	1.056	1.075	1.100
8300	1.003	1.008	1.014	1.024	1.035	1.053	1.072	1.095
8400	1.003	1.007	1.013	1.022	1.033	1.049	1.068	1.091
8500	1.002	1.006	1.012	1.020	1.031	1.046	1.065	1.087
8600	1.001	1.005	1.011	1.019	1.029	1.043	1.062	1.083
8700	1.000	1.004	1.010	1.018	1.028	1.041	1.058	1.079
8800	1.000	1.003	1.009	1.016	1.026	1.038	1.056	1.075
8900	.999	1.003	1.008	1.015	1.024	1.035	1.053	1.072
9000	.999	1.002	1.007	1.014	1.022	1.033	1.049	1.068
9100	.999	1.001	1.006	1.012	1.020	1.031	1.046	1.065
9200	.998	1.001	1.005	1.011	1.019	1.029	1.044	1.062
9300	.998	1.000	1.004	1.010	1.018	1.027	1.042	1.058
9400	.998	1.000	1.003	1.009	1.016	1.026	1.039	1.055
9500	.997	.999	1.003	1.008	1.015	1.024	1.036	1.052
9600	.997	.999	1.002	1.007	1.014	1.022	1.034	1.049
9700	.997	.998	1.001	1.006	1.012	1.020	1.032	1.046
9800	.997	.998	1.001	1.005	1.011	1.019	1.030	1.044
9900	.997	.998	1.000	1.004	1.010	1.017	1.028	1.042
10000	.996	.997	1.000	1.003	1.009	1.016	1.026	1.040
10100	*.996	.997	.999	1.002	1.008	1.015	1.024	1.037
10200	.996	.997	.999	1.002	1.007	1.014	1.022	1.035
10300	.996	.997	.998	1.001	1.006	1.013	1.020	1.033
10400	.996	.997	.998	1.001	1.005	1.011	1.019	1.031
10500	.996	.996	.997	1.000	1.004	1.010	1.017	1.029
10600	.996	.996	.997	1.000	1.003	1.009	1.016	1.027
10700	.996	.996	.997	.999	1.002	1.008	1.015	1.025
10800	.995	.996	.997	.999	1.002	1.007	1.013	1.022
10900	.995	.996	.997	.998	1.001	1.006	1.012	1.020
11000	.995	.996	.996	.998	1.000	1.005	1.011	1.018

TABLE IV. (Continued.)

X from 11000 to 15000; φ from 15° to 22°.

X yds.	15°	16°	17°	18°	19°	20°	21°	22°
11000	.996	.996	.998	1.000	1.005	1.011	1.018	1.031
11100	.995	.996	.998	1.000	1.004	1.010	1.017	1.029
11200	.994	.995	.997	.999	1.003	1.009	1.015	1.027
11300	.993	.994	.996	.998	1.002	1.008	1.014	1.025
11400	.992	.994	.996	.998	1.002	1.007	1.013	1.023
11500	.991	.993	.995	.997	1.001	1.006	1.012	1.021
11600	.991	.993	.995	.997	1.000	1.005	1.011	1.020
11700	.990	.992	.994	.996	1.000	1.004	1.010	1.019
11800	.990	.992	.994	.996	.999	1.003	1.009	1.017
11900	.989	.991	.993	.995	.998	1.002	1.008	1.016
12000	.989	.991	.993	.995	.998	1.001	1.007	1.015
12100	.988	.990	.992	.994	.997	1.001	1.006	1.013
12200	.988	.990	.992	.994	.997	1.000	1.005	1.012
12300	.988	.990	.992	.994	.996	.999	1.004	1.011
12400	.987	.989	.991	.993	.996	.999	1.003	1.010
12500	.987	.989	.991	.993	.995	.998	1.002	1.008
12600	.986	.988	.990	.992	.994	.997	1.001	1.007
12700	.986	.988	.990	.992	.994	.997	1.001	1.006
12800	.985	.987	.989	.991	.993	.996	1.000	1.005
12900	.985	.987	.989	.991	.993	.996	.999	1.004
13000	.985	.987	.989	.991	.993	.995	.999	1.003
13100		.986	.988	.990	.992	.995	.998	1.002
13200		.986	.988	.990	.992	.994	.997	1.001
13300		.986	.988	.990	.992	.994	.997	1.001
13400		.985	.987	.989	.991	.993	.996	1.000
13500		.985	.987	.989	.991	.993	.996	.999
13600		.985	.987	.988	.990	.992	.995	.998
13700		.985	.987	.988	.990	.992	.995	.997
13800		.984	.986	.988	.989	.991	.994	.997
13900		.984	.986	.987	.989	.991	.993	.996
14000		.984	.986	.987	.988	.990	.993	.996
14100			.985	.987	.988	.990	.992	.995
14200			.985	.987	.988	.990	.992	.995
14300			.985	.986	.987	.989	.991	.994
14400			.984	.986	.987	.989	.991	.994
14500			.984	.986	.987	.989	.991	.994
14600			.984	.986	.987	.989	.991	.993
14700			.984	.986	.987	.988	.990	.993
14800			.983	.985	.986	.988	.990	.993
14900			.983	.985	.986	.988	.990	.992
15000			.983	.985	.986	.988	.990	.992

TABLE IV. (Continued.)

X from 1000 to 6000; φ from 22° to 30°.

X yds.	22°	23°	24°	25°	26°	27°	28°	29°	30°
1000	.969	.966	.963	.960	.956	.952	.949	.945	.941
1100	.969	.966	.963	.961	.956	.952	.949	.945	.941
1200	.969	.966	.963	.961	.956	.952	.949	.945	.941
1300	.969	.966	.963	.961	.956	.952	.949	.945	.941
1400	.969	.966	.963	.961	.957	.952	.949	.945	.941
1500	.969	.967	.964	.961	.957	.952	.949	.945	.941
1600	.969	.967	.964	.961	.957	.953	.949	.945	.941
1700	.969	.967	.964	.961	.957	.953	.950	.945	.941
1800	.969	.967	.964	.961	.957	.953	.950	.945	.941
1900	.970	.967	.964	.962	.957	.953	.950	.946	.941
2000	.970	.967	.964	.962	.957	.953	.950	.946	.941
2100	.970	.967	.964	.962	.958	.953	.950	.946	.941
2200	.970	.967	.964	.962	.958	.953	.950	.946	.942
2300	.970	.968	.964	.962	.958	.954	.951	.946	.942
2400	.970	.968	.964	.962	.958	.954	.951	.946	.942
2500	.971	.968	.965	.962	.958	.954	.951	.946	.942
2600	.971	.968	.965	.963	.959	.954	.951	.946	.942
2700	.971	.968	.965	.963	.959	.954	.951	.947	.942
2800	.972	.968	.965	.963	.959	.955	.951	.947	.942
2900	.972	.969	.965	.963	.960	.955	.952	.947	.942
3000	.972	.969	.965	.963	.960	.955	.952	.947	.942
3100	.972	.969	.966	.963	.960	.955	.952	.948	.943
3200	.973	.969	.966	.963	.961	.956	.952	.948	.943
3300	.973	.969	.966	.963	.961	.956	.952	.948	.943
3400	.973	.969	.966	.964	.961	.956	.952	.949	.943
3500	.973	.970	.967	.964	.961	.957	.953	.949	.943
3600	.974	.970	.967	.964	.962	.957	.953	.949	.943
3700	.974	.970	.967	.964	.962	.957	.953	.950	.943
3800	.975	.971	.968	.965	.962	.958	.953	.950	.943
3900	.976	.971	.968	.965	.962	.958	.954	.950	.944
4000	.976	.972	.968	.965	.962	.959	.954	.950	.944
4100	.977	.972	.969	.966	.963	.959	.954	.951	.944
4200	.978	.973	.969	.966	.963	.960	.955	.951	.945
4300	.978	.973	.969	.966	.963	.960	.955	.951	.945
4400	.979	.974	.970	.967	.964	.961	.955	.952	.945
4500	.980	.974	.970	.967	.964	.961	.956	.952	.946
4600	.980	.975	.971	.968	.964	.962	.956	.952	.946
4700	.981	.976	.972	.968	.965	.962	.957	.953	.947
4800	.981	.977	.972	.969	.965	.962	.957	.953	.947
4900	.982	.978	.973	.969	.965	.963	.958	.954	.948
5000	.982	.979	.974	.970	.966	.963	.959	.954	.948
5100	.983	.980	.975	.971	.966	.964	.960	.954	.949
5200	.984	.981	.976	.972	.967	.964	.961	.955	.949
5300	.986	.982	.977	.973	.968	.965	.962	.955	.950
5400	.988	.983	.978	.974	.968	.965	.962	.956	.950
5500	.991	.984	.979	.975	.969	.966	.963	.957	.951
5600	.994	.986	.980	.976	.970	.967	.964	.958	.951
5700	.998	.989	.982	.977	.971	.968	.965	.959	.952
5800	1.002	.992	.984	.978	.973	.969	.966	.960	.953
5900	1.007	.996	.986	.980	.975	.970	.967	.961	.954
6000	1.013	1.000	.989	.982	.977	.971	.968	.962	.955

TABLE IV. (Continued.)

X from 6000 to 11000; φ from 22° to 30°.

X yds.	22°	23°	24°	25°	26°	27°	28°	29°	30°
6000	1.013	1.000	.989	.982	.977	.971	.968	.962	.955
6100	1.020	1.004	.992	.984	.979	.972	.969	.962	.956
6200	1.029	1.009	.996	.987	.981	.973	.970	.963	.958
6300	1.038	1.015	1.000	.991	.984	.975	.972	.965	.960
6400	1.049	1.023	1.007	.995	.988	.977	.974	.967	.962
6500	1.060	1.032	1.015	1.001	.992	.978	.976	.969	.963
6600	1.072	1.043	1.025	1.009	.997	.981	.979	.971	.965
6700	1.082	1.056	1.035	1.017	1.003	.986	.981	.974	.968
6800	1.093	1.070	1.046	1.027	1.009	.991	.984	.978	.971
6900	1.103	1.082	1.057	1.038	1.017	.998	.988	.982	.974
7000	1.111	1.094	1.068	1.048	1.027	1.006	.992	.986	.978
7100	1.119	1.105	1.080	1.059	1.036	1.015	.999	.991	.983
7200	1.126	1.115	1.092	1.071	1.047	1.025	1.008	.997	.988
7300	1.133	1.124	1.104	1.082	1.058	1.034	1.017	1.004	.995
7400	1.136	1.131	1.116	1.094	1.070	1.045	1.028	1.013	1.004
7500	1.138	1.138	1.126	1.106	1.081	1.056	1.038	1.022	1.013
7600	1.139	1.144	1.136	1.117	1.093	1.067	1.049	1.032	1.022
7700	1.139	1.148	1.144	1.129	1.105	1.079	1.060	1.042	1.032
7800	1.138	1.149	1.151	1.139	1.116	1.091	1.072	1.052	1.043
7900	1.135	1.150	1.156	1.148	1.126	1.103	1.083	1.064	1.054
8000	1.131	1.150	1.160	1.156	1.136	1.115	1.095	1.075	1.065
8100	1.127	1.149	1.162	1.163	1.147	1.127	1.107	1.087	1.076
8200	1.122	1.147	1.163	1.168	1.156	1.139	1.119	1.099	1.087
8300	1.117	1.144	1.163	1.171	1.164	1.151	1.131	1.111	1.099
8400	1.113	1.140	1.162	1.172	1.171	1.161	1.143	1.124	1.111
8500	1.109	1.136	1.160	1.174	1.176	1.171	1.153	1.136	1.123
8600	1.105	1.131	1.157	1.174	1.181	1.180	1.164	1.148	1.135
8700	1.101	1.126	1.154	1.172	1.183	1.186	1.175	1.159	1.148
8800	1.096	1.121	1.149	1.170	1.184	1.190	1.185	1.170	1.161
8900	1.092	1.116	1.144	1.167	1.184	1.193	1.192	1.181	1.174
9000	1.088	1.112	1.139	1.163	1.183	1.195	1.196	1.190	1.186
9100	1.084	1.107	1.134	1.159	1.181	1.196	1.200	1.198	1.199
9200	1.080	1.103	1.129	1.153	1.176	1.196	1.203	1.203	1.211
9300	1.076	1.100	1.125	1.148	1.172	1.195	1.206	1.208	1.218
9400	1.073	1.096	1.120	1.144	1.167	1.192	1.208	1.212	1.222
9500	1.070	1.093	1.115	1.139	1.163	1.189	1.208	1.215	1.225
9600	1.066	1.088	1.111	1.134	1.159	1.186	1.206	1.218	1.228
9700	1.063	1.083	1.106	1.130	1.155	1.182	1.205	1.219	1.230
9800	1.060	1.079	1.103	1.126	1.151	1.178	1.202	1.220	1.231
9900	1.058	1.075	1.098	1.121	1.147	1.173	1.199	1.219	1.232
10000	1.055	1.072	1.094	1.117	1.142	1.168	1.195	1.218	1.232
10100	1.052	1.068	1.091	1.112	1.136	1.164	1.190	1.217	1.231
10200	1.049	1.066	1.086	1.107	1.131	1.159	1.186	1.214	1.230
10300	1.046	1.063	1.082	1.103	1.127	1.154	1.181	1.211	1.229
10400	1.044	1.060	1.079	1.098	1.123	1.149	1.175	1.207	1.228
10500	1.042	1.058	1.075	1.094	1.119	1.144	1.170	1.202	1.226
10600	1.040	1.056	1.072	1.091	1.114	1.139	1.164	1.196	1.222
10700	1.037	1.053	1.068	1.086	1.109	1.134	1.159	1.190	1.216
10800	1.035	1.050	1.065	1.082	1.105	1.129	1.153	1.185	1.211
10900	1.033	1.047	1.062	1.079	1.101	1.124	1.148	1.179	1.205
11000	1.031	1.044	1.059	1.075	1.096	1.120	1.143	1.174	1.200

TABLE IV. (Continued.)

X from 11000 to 15000; φ from 23° to 30°.

X yds.	23°	24°	25°	26°	27°	28°	29°	30°
11000	1.044	1.059	1.075	1.096	1.120	1.143	1.174	1.200
11100	1.042	1.056	1.072	1.092	1.116	1.138	1.168	1.194
11200	1.040	1.054	1.069	1.089	1.112	1.133	1.162	1.188
11300	1.038	1.051	1.066	1.086	1.108	1.128	1.157	1.183
11400	1.036	1.049	1.063	1.082	1.104	1.124	1.152	1.178
11500	1.034	1.046	1.061	1.078	1.100	1.120	1.147	1.173
11600	1.032	1.044	1.058	1.075	1.096	1.116	1.142	1.168
11700	1.030	1.041	1.055	1.071	1.092	1.112	1.137	1.163
11800	1.028	1.039	1.052	1.068	1.088	1.108	1.132	1.158
11900	1.026	1.037	1.049	1.065	1.084	1.104	1.128	1.153
12000	1.024	1.035	1.947	1.062	1.080	1.100	1.124	1.148
12100	1.023	1.033	1.045	1.059	1.076	1.096	1.119	1.143
12200	1.021	1.031	1.043	1.056	1.073	1.092	1.115	1.138
12300	1.020	1.029	1.041	1.053	1.070	1.088	1.111	1.133
12400	1.018	1.028	1.039	1.051	1.067	1.084	1.107	1.128
12500	1.016	1.026	1.037	1.048	1.064	1.080	1.103	1.123
12600	1.015	1.024	1.036	1.046	1.061	1.077	1.099	1.118
12700	1.013	1.022	1.034	1.043	1.058	1.074	1.095	1.113
12800	1.012	1.020	1.032	1.041	1.055	1.071	1.091	1.109
12900	1.011	1.018	1.030	1.039	1.052	1.068	1.087	1.105
13000	1.010	1.017	1.028	1.037	1.049	1.065	1.083	1.101
13100	1.008	1.015	1.026	1.035	1.047	1.062	1.079	1.097
13200	1.007	1.014	1.025	1.033	1.045	1.059	1.076	1.093
13300	1.006	1.013	1.023	1.031	1.043	1.057	1.073	1.089
13400	1.005	1.011	1.021	1.029	1.042	1.055	1.070	1.085
13500	1.004	1.010	1.019	1.027	1.040	1.052	1.067	1.081
13600	1.003	1.009	1.017	1.025	1.038	1.050	1.064	1.078
13700	1.002	1.008	1.016	1.024	1.036	1.047	1.061	1.075
13800	1.001	1.007	1.015	1.023	1.035	1.045	1.058	1.072
13900	1.000	1.006	1.013	1.022	1.033	1.043	1.055	1.069
14000	.999	1.005	1.012	1.021	1.031	1.041	1.052	1.066
14100	.998	1.004	1.011	1.019	1.029	1.039	1.050	1.063
14200	.998	1.003	1.009	1.018	1.027	1.037	1.048	1.060
14300	.997	1.003	1.008	1.017	1.026	1.036	1.046	1.057
14400	.997	1.002	1.006	1.015	1.024	1.034	1.044	1.054
14500	.996	1.001	1.005	1.013	1.023	1.033	1.042	1.051
14600	.996	1.000	1.004	1.012	1.021	1.031	1.040	1.048
14700	.995	.999	1.003	1.011	1.020	1.030	1.038	1.046
14800	.995	.999	1.002	1.010	1.018	1.029	1.036	1.044
14900	.994	.998	1.001	1.009	1.017	1.028	1.034	1.042
15000	.994	.997	1.000	1.008	1.016	1.027	1.033	1.040

TABLE V.

Values of f_w. W_x is wind component in miles per hour. R, range in yards.

$$\varphi_m = \frac{\varphi + \omega}{2}.$$

$\frac{W_x T}{R}$	φ_m 0°	10°	20°	30°	40°	50°	60°	70°
—.10	1.053	1.052	1.050	1.047	1.042	1.036	1.027	1.016
—.09	1.048	1.047	1.045	1.042	1.038	1.032	1.024	1.014
—.08	1.042	1.042	1.040	1.038	1.034	1.029	1.022	1.013
—.07	1.037	1.036	1.035	1.033	1.029	1.025	1.019	1.011
—.06	1.032	1.031	1.030	1.028	1.025	1.022	1.016	1.010
—.05	1.026	1.026	1.025	1.023	1.021	1.018	1.013	1.008
—.04	1.021	1.021	1.020	1.019	1.017	1.014	1.011	1.006
—.03	1.016	1.016	1.015	1.014	1.013	1.011	1.008	1.005
—.02	1.011	1.010	1.010	1.009	1.008	1.007	1.005	1.003
—.01	1.005	1.005	1.005	1.005	1.004	1.004	1.003	1.002
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
+.01	.995	.995	.995	.996	.996	.997	.997	.998
+.02	.990	.991	.991	.991	.992	.993	.995	.997
+.03	.986	.986	.987	.987	.988	.990	.992	.995
+.04	.981	.981	.982	.983	.984	.987	.990	.994
+.05	.976	.976	.977	.978	.980	.983	.987	.992
+.06	.971	.972	.973	.974	.977	.980	.984	.990
+.07	.966	.967	.968	.970	.973	.977	.982	.989
+.08	.962	.962	.964	.966	.969	.974	.979	.987
+.09	.957	.958	.959	.961	.965	.970	.976	.986
+.10	.952	.953	.955	.957	.961	.967	.974	.984

TABLE VI.

Values of colog d^2 and of colog d.

d (in.)	colog d^2	colog d	d (in.)	colog d^2	colog d
0.303	1.03711	.51856			
0.38	0.84043	.42022			
0.40	0.79588	.39704			
0.44	0.71309	.35655			
0.45	0.69357	.34679			
1.00	0.00000	.00000			
1.65	9.56503	9.78252			
2.00	9.39794	9.69897			
2.95	9.06036	9.53018			
3.00	9.04576	9.52288			
3.20	8.98970	9.49485			
4.00	8.79588	9.39794			
4.7244	8.65131	9.32566			
5.0	8.60206	9.30103			
6.0	8.44370	9.22185			
7.0	8.30980	9.15490			
8.0	8.19382	9.09691			
9.0	8.09151	9.04576			
10.0	8.00000	9.00000			
11.0	7.91721	8.95861			
12.0	7.84164	8.92082			
13.0	7.77211	8.88606			
15.0	7.64782	8.82391			
16.0	7.59176	8.79588			

$\frac{\delta_1}{\delta}$ FOR MORTAR FIRE.

50% Relative Humidity.

t°	28″	29″	30″	31″	t°	28″	29″	30″	31″
0	.932	.899	.869	.842	50	1.035	1.000	.967	.936
1	.934	.901	.871	.844	51	1.037	1.002	.969	.937
2	.936	.903	.873	.846	52	1.040	1.004	.971	.939
3	.938	.905	.875	.848	53	1.042	1.006	.973	.941
4	.940	.907	.877	.849	54	1.044	1.008	.975	.943
5	.942	.909	.879	.851	55	1.046	1.010	.977	.945
6	.944	.911	.881	.853	56	1.048	1.012	.979	.947
7	.946	.913	.883	.855	57	1.050	1.014	.981	.949
8	.948	.915	.885	.856	58	1.052	1.016	.983	.951
9	.950	.917	.887	.858	59	1.055	1.018	.985	.953
10	.952	.919	.889	.860	60	1.057	1.020	.987	.955
11	.954	.921	.891	.862	61	1.059	1.022	.989	.956
12	.956	.923	.893	.864	62	1.061	1.025	.991	.958
13	.958	.925	.895	.866	63	1.063	1.027	.993	.960
14	.960	.927	.897	.869	64	1.065	1.029	.995	.962
15	.962	.929	.899	.870	65	1.067	1.031	.997	.964
16	.964	.931	.901	.872	66	1.070	1.033	.999	.966
17	.966	.933	.903	.873	67	1.072	1.035	1.001	.968
18	.969	.935	.905	.875	68	1.074	1.037	1.003	.970
19	.971	.937	.907	.877	69	1.076	1.040	1.005	.972
20	.973	.939	.909	.879	70	1.079	1.042	1.007	.974
21	.975	.941	.911	.881	71	1.081	1.044	1.009	.976
22	.977	.943	.913	.883	72	1.083	1.046	1.011	.978
23	.979	.945	.915	.885	73	1.086	1.048	1.013	.980
24	.981	.947	.917	.887	74	1.088	1.050	1.015	.982
25	.983	.949	.919	.889	75	1.090	1.052	1.018	.984
26	.985	.951	.921	.890	76	1.092	1.054	1.020	.986
27	.987	.953	.923	.892	77	1.094	1.056	1.022	.988
28	.989	.955	.925	.894	78	1.096	1.058	1.024	.990
29	.991	.957	.927	.895	79	1.099	1.060	1.026	.992
30	.993	.959	.929	.897	80	1.101	1.063	1.028	.994
31	.995	.961	.930	.899	81	1.103	1.065	1.030	.996
32	.997	.962	.932	.901	82	1.105	1.067	1.032	.998
33	1.000	.965	.934	.903	83	1.107	1.070	1.034	1.000
34	1.002	.967	.936	.905	84	1.110	1.072	1.036	1.002
35	1.004	.970	.938	.907	85	1.112	1.074	1.038	1.005
36	1.006	.972	.940	.909	86	1.115	1.076	1.041	1.007
37	1.008	.974	.942	.911	87	1.117	1.079	1.043	1.009
38	1.010	.976	.943	.912	88	1.120	1.081	1.045	1.011
39	1.012	.978	.945	.914	89	1.122	1.083	1.047	1.013
40	1.014	.979	.947	.916	90	1.125	1.086	1.049	1.015
41	1.016	.981	.949	.918	91	1.127	1.088	1.052	1.017
42	1.018	.983	.951	.920	92	1.129	1.091	1.054	1.019
43	1.020	.985	.953	.922	93	1.131	1.092	1.056	1.021
44	1.022	.987	.955	.924	94	1.134	1.094	1.058	1.024
45	1.025	.989	.957	.926	95	1.136	1.096	1.060	1.026
46	1.027	.992	.959	.928	96	1.139	1.099	1.063	1.028
47	1.029	.994	.961	.930	97	1.142	1.101	1.065	1.030
48	1.031	.996	.963	.932	98	1.144	1.104	1.067	1.032
49	1.033	.998	.065	.934	99	1.147	1.106	1.070	1.034
50	1.035	1.000	.967	.936	100	1.149	1.109	1.072	1.036

JOURNAL

OF THE

UNITED STATES ARTILLERY

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

VOL. 24 No. 3 NOVEMBER—DECEMBER, 1905 WHOLE No. 76

A CONTRIBUTION TO INTERIOR BALLISTICS

BY COLONEL JAMES M. INGALLS, U. S. ARMY, RETIRED

CHAPTER I.

COMBUSTION OF A GRAIN OF POWDER UNDER CONSTANT PRESSURE.

IN what follows it is assumed that the powder grain is of some regular geometrical form to which the elementary rules of mensuration can be applied. Also, that the combustion takes place in successive parallel layers and, the pressure being constant, with a uniform velocity. Many forms of grain have been adopted by different manufacturers in this and foreign countries; but they may all be divided into two groups;—those burning with a continuously decreasing surface, and those in which the surface of combustion may increase (or decrease) to a certain stage, the grain then breaking up into other forms entirely dissimilar to the original, and which then burn with a rapidly decreasing surface. To the first group belong spherical, sphero-hexagonal, cubical and indeed all solid grains of whatever form, and cylindrical grains with an axial perforation. To the latter group belong the multi-perforated grains, so called, employed by both army and navy.

Notation.—Let

l = thickness of layer burned in time t.

l_0 = one-half the least dimension of the grain. Since the combustion takes place on all sides of the grain at once, it may be assumed that when $l = l_0$ all grains of the first group are totally consumed. This of course is not the case with m.p. grains.

s_0 = the initial surface of combustion of the grain.

s = surface of combustion at time t, corresponding to l.

s' = surface of combustion when $l = l_0$; or, as it may be called, the *vanishing surface.*

V_0 = the initial volume of the grain.

V = the volume of grain burned at time t. That is, the volume comprised between the surfaces s_0 and s.

F = fraction of grain burned in time t. That is $F = \frac{V}{V_0}$

The general expression for the burning surface of any grain at time t, and when a layer of thickness l has been burned, is

$$s = s_0 + a\,l + b\,l^2 \tag{1}$$

and for s',

$$s' = s_0 + a\,l_0 + b\,l_0^2 \tag{2}$$

in which a and b are constants for the same form of grain, and may be either positive, negative or zero.

The general expression for the volume burned is

$$V = \int_0^l s\,dl;$$

whence substituting for s its value from (1) and integrating we have

$$V = s_0 l + \frac{a}{2} l^2 + \frac{b}{3} l^3 \tag{3}$$

The initial volume V_0 is what V becomes when the grain is completely consumed, that is when $l = l_0$. Therefore

$$V_0 = s_0 l_0 + \frac{a}{2} l_0^2 + \frac{b}{3} l_0^3 \tag{4}$$

If in (4) we substitute for s_0 its value from (2), namely,

$$s_0 = s' - a\,l_0 - b\,l_0^2$$

it becomes

$$V_0 = s' l_0 - \frac{a}{2} l_0^2 - \frac{2b}{3} l_0^3 \tag{5}$$

Fraction of grain burned. We have by definition

$$F = \frac{V}{V_0} = \frac{s_0 l + \frac{a}{2} l^2 + \frac{b}{3} l^3}{V_0}$$

$$= \frac{s_0 l_0}{V_0} \cdot \frac{l}{l_0} \left\{ 1 + \frac{a l_0}{2s_0} \cdot \frac{l}{l_0} + \frac{b l_0^2}{3s_0} \cdot \frac{l^2}{l_0^2} \right\}$$

Let

$$\frac{s_0 l_0}{V_0} = \alpha; \quad \frac{a l_0}{2s_0} = \lambda; \quad \frac{b l_0^2}{3 s_0} = \mu.$$

Then

$$F = \alpha \frac{l}{l_0} \left\{ 1 + \lambda \frac{l}{l_0} + \mu \frac{l^2}{l_0^2} \right\} \tag{6}$$

In this last equation F increases with l and becomes unity when $l = l_0$. When this occurs the grain is consumed and (6) reduces to

$$1 = \alpha \{ 1 + \lambda + \mu \} \tag{7}$$

This relation always subsists between these numerical constants and serves to test the correctness of their derivation in any case.

Expressions for a and b. By means of equations (2) and (5) we readily find

$$a = -\frac{2}{l_0} (2s_0 + s') + \frac{6 V_0}{l_0^2} \tag{8}$$

and

$$b = \frac{3}{l_0^2} (s_0 + s') - \frac{6 V_0}{l_0^3} \tag{9}$$

It will be observed from these last two equations, as well as from (1) and (2), that a is a linear quantity while b is of zero order of magnitude. These properties can be used as tests, so far as they go, as to whether the work of deducing a and b in any particular case has been correctly performed.

If we substitute the values of a and b from (8) and (9) in in the expressions for λ and μ they become

$$\lambda = \frac{3V_0}{l_0 s_0} - 2 - \frac{s'}{s_0} \text{ and } \mu = 1 + \frac{s'}{s} - \frac{2V_0}{l_0 s^0}$$

Therefore

$$1 + \lambda + \mu = \frac{V_0}{l_0 s_0} = \frac{1}{\alpha}, \text{ as in equation (7).}$$

We also have the relation

$$\alpha(\lambda + 2\mu) = \frac{s' l_0}{V_0} - 1$$

an equation which will be of use further on.

Applications. We will now apply these formulas to a discussion of various forms of grain now in use or which may come into use.

1. Sphere. For a spherical grain we evidently have $l_0 = R$, or radius of grain. Also by mensuration, $s_0 = 4\pi l_0^2$, $s' = 0$ and $V_0 = \frac{4}{3}\pi l_0^3$. Substituting these in the expressions for a and b we find

$$a = -8\pi l_0 \text{ and } b = 4\pi$$

and, therefore,

$$\alpha = 3,\ \lambda = -1 \text{ and } \mu = \tfrac{1}{3}.$$

It is unnecessary to compute a and b; and it will be shorter in many cases to use the expressions for λ and μ in terms directly of s_0, s' and V_0, as these must all be computed to determine a and b. Therefore for spherical grains

$$F = 3\frac{l}{l_0}\left\{1 - \frac{l}{l_0} + \frac{1}{3}\frac{l^2}{l_0^2}\right\} = 1 - \left(1 - \frac{l}{l_0}\right)^3$$

It is evident without the aid of analysis that this form of grain burns with a diminishing surface, and therefore that the volume of gas given off as successive layers of equal thickness are burned, also diminshes. This may be shown analytically as follows: Substituting the values of a and b in equation (1) it becomes

$$s = s_0 - 8\pi l l_0 + 4\pi l^2$$

or

$$s = s_0\left(1 - \frac{8\pi l l_0}{s_0} + \frac{4\pi l^2}{s_0}\right) = s_0\left(1 - \frac{l}{l_0}\right)^2$$

If we divide the least dimension of the grain, or what is the same thing, the thickness of web, into five equal parts, the following table may be computed, which will be useful for comparing this form of grain with others to be given.

$\frac{l}{l_0}$	F	First differences	Second differences
0.0	0.000		
		0.488	
0.2	0.488		−0.192
		0.296	
0.4	0.784		0.144
		0.152	
0.6	0.936		0.096
		0.056	
0.8	0.992		0.048
		0.008	
1.0	1.000	1.000	

The second column gives the entire fraction of grain burned and the third column the fraction of grain burned for each layer. It will be seen that nearly one-half the volume of the grain is in the first layer.

2. *Parallelopipedon.* Let $2l_0$ be the least dimension of the parallelopipedon and m and n the other two dimensions. We have by the rules of mensuration

$$s_0 = 4l_0m + 4l_0n + 2mn$$
$$s' = 2(m-2l_0)(n-2l_0) = 2mn - 4l_0m - 4l_0n + 8l_0^2$$
$$V_0 = 2l_0mn$$

Substituting these in (8) and (9) they readily reduce to

$$a = -8(m + n + 2l_0) \text{ and } b = 24.$$

By making the following substitutions, viz.:—

$\frac{2l_0}{m} = x$ and $\frac{2l_0}{n} = y$ (in which x and y are each less than unity) we have finally,

$$\alpha = 1 + x + y; \quad \lambda = -\frac{x + y + xy}{1 + x + y}; \quad \mu = \frac{xy}{1 + x + y}$$

We therefore have for grains in the form of a parallelopipedon,

$$F = (1 + x + y)\frac{l}{l_0}\left\{1 - \frac{x + y + xy}{1 + x + y}\frac{l}{l_0} + \frac{xy}{1 + x + y}\frac{l^2}{l_0^2}\right\}$$

It may be noticed here that these values of α, λ, μ satisfy equation (7).

There are three special parallelopipedons worthy of separate notice:

(*a*) *Cube.* The cubical form has been adopted for ballistite and also for some of the French government powders. For this form we evidently have

$$x = y = 1.$$

These values give

$$\alpha = 3; \quad \lambda = -1; \quad \mu = \tfrac{1}{3}$$

and are the same as those already found for spherical grains, as might have been inferred. These values of α, λ, μ also apply approximately to sphero-hexagonal, mammoth, cannon and rifle powders.

(*b*) *Square, flat grains.* For these grains, (still used in rapid-firing ammunition) m and n are equal and greater than $2\,l_0$. Therefore x and y are equal and less than unity, and we have

$$\alpha = 1 + 2x\,; \quad \lambda = -\frac{x(2+x)}{1+2x}\,; \quad \mu = \frac{x^2}{1+2x}$$

If these grains are very thin, x becomes a very small fraction and may be omitted in comparison with unity. In this case λ and μ become zero and α unity. This gives

$$F = \frac{l}{l_0}$$

or, a constant emission of gas during the burning; but the grain is consumed in a very short interval of time.

(*c*) *Grains made into long slender ribbons with rectangular cross-section.* These grains are approximately those of the new English powder called "axite." If we suppose the width of the ribbon to be five times, and the length twenty times, their thickness we shall have $x = 0.2$ and $y = 0.05$. Therefore $\alpha = 1.25$, $\lambda = -0.208$ and $\mu = 0.008$. The expression for F becomes

$$F = 1.25\,\frac{l}{l_0}\left\{1 - 0.208\,\frac{l}{l_0} + 0.008\,\frac{l^2}{l_0^2}\right\}$$

The following table illustrates the progressiveness of this particular grain:

$\frac{l}{l_0}$	F	First differences	Second differences
0.0	0.00000		
		0.23968	
0.2	0.23968		−0.02032
		0.21936	
0.4	0.45904		0.01984
		0.19952	
0.6	0.65856		0.01936
		0.18016	
0.8	0.83872		0.01888
		0.16128	
1.0	1.00000	1.00000	

In the following table the length of the ribbon is taken at forty times its thickness:

$\frac{l}{l_0}$	F	First differences	Second differences
0.0	0.00000		
		0.23584	
0.2	0.23584		0.01816
		0.21768	
0.4	0.45352		0.01792
		0.19976	
0.6	0.65328		0.01768
		0.18208	
0.8	0.83536		0.01744
		0.16464	
1.0	1.00000		

It will be seen that doubling the length of ribbon makes but very little difference in the manner of burning of a grain.

If we suppose the cross-section of the ribbon, or strip, to be square, then will

$$m = 2\,l_0 \text{ and } x = 1.$$

Therefore in this case

$$\alpha = 2 + y\,; \quad \lambda = -\frac{1+2y}{2+y}\,; \quad \mu = \frac{y}{2+y}$$

If the strips be very long in comparison with the linear dimension of cross-section, y may be considered zero, and we have

$$\alpha = 2\,; \qquad \lambda = -\tfrac{1}{2}\,; \qquad \mu = 0.$$

Therefore

$$F = 2\,\frac{l}{l_0}\left\{1 - \frac{1}{2}\,\frac{l}{l_0}\right\} = 1 - \left(1 - \frac{l}{l_0}\right)^2$$

3. Solid cylinder. For this form of grain there are two cases to be considered:—(*a*) When the diameter of cross-section of the cylinder is the least dimension. (*b*) When the length of cylinder is the least dimension. That is, a cylinder proper and a circular disc.

(*a*) *Cylinder proper.* In accordance with the notation adopted, l_0 will be the radius and m the length of the grain. We have by mensuration

$$s_0 = 2\pi\,(l_0 m + l_0^2)\,; \qquad s' = 0\,; \qquad V_0 = \pi\,l_0^2\,m.$$

whence

$$a = -\,2\pi\,(4\,l_0 + m) \text{ and } b = 6\pi.$$

Putting, as before, $\frac{2\,l_0}{m} = x$, there results

$$\alpha = 2 + x; \qquad \lambda = -\frac{1 + 2x}{2 + x}; \qquad \mu = \frac{x}{2 + x}.$$

These are the same expressions for α, λ, μ as were found for a strip with square cross-section, as might readily be inferred.

If x be small in comparison with unity, that is, if the grains are long slender cylinders (thread-like) as is the case with English cordite, we have approximately

$$\alpha = 2; \qquad \lambda = -\tfrac{1}{2}; \qquad \mu = 0.$$

$$\therefore \quad F = 2\frac{l}{l_0}\left\{1 - \frac{1}{2}\frac{l}{l_0}\right\} = 1 - \left(1 - \frac{l}{l_0}\right)^2$$

The following table was computed by this last formula:

$\frac{l}{l_0}$	F	First differences
0.0	0.00	
		0.36
0.2	0.36	
		0.28
0.4	0.64	
		0.20
0.6	0.84	
		0.12
0.8	0.96	
		0.04
1.0	1.00	1.00

Comparing this table with that on page 190, we see that axite is much more progressive than cordite.

If the length of the solid cylindrical grain be the same as its diameter, then $x = 1$; and we have

$$\alpha = 3, \qquad \lambda = -1 \text{ and } \mu = \tfrac{1}{3}$$

as for spherical and cubical grains.

(*b*) *Circular disc.* With this form of grain the *thickness* becomes the least dimension, instead of the diameter.

Let $2l_0$ be the thickness of the disc and R its radius. Then $s_0 = 2\pi R(2l_0 + R)$; $s' = 2\pi(R - l_0)^2$; $V_0 = 2\pi l_0 R^2$. Whence $a = -4\pi(2R + l_0)$ and $b = 6\pi$. And as has already been found in case of square flat grain,

$$\alpha = 1 + 2x; \quad \lambda = -\frac{x(2 + x)}{1 + 2x}; \quad \mu = \frac{x^2}{1 + 2x}.$$

If the disc is very thin in comparison with its diameter, x may be neglected and we shall have

$$\alpha = 1; \quad \lambda = 0; \quad \mu = 0.$$

In this case the velocity of burning is practically uniform. This is exemplified in the disc powder invented by Mr. Quick of the English Navy,—which however never came into general use, probably because of its liability to break up into small fragments in the gun.

4. Cylinder with axial perforation. Let R = radius of grain; r = radius of perforation and m = its length.

We then have

$$2 l_0 = R - r$$

and

$$R + r = 2(R - l_0)$$

By the rules of mensuration we find

$$s_0 = 2\pi(m(R + r) + R^2 - r^2) = 4\pi(m + 2 l_0)(R - l_0)$$

$$s' = 4\pi(m - 2 l_0)(r + l_0) = 4\pi(m - 2 l_0)(R - l_0)$$

$$V_0 = \pi(R^2 - r^2)m = 4\pi l_0 m (R - l_0)$$

Therefore

$$a = -16\pi(R l_0) \text{ and } b = 0.$$

Making, as before, $x = \frac{2 l_0}{m}$, we have finally

$$\alpha = 1 + x; \quad \lambda = -\frac{x}{1 + x}; \quad \mu = 0.$$

If the length of grain is the same as the thickness of web, then $x = 1$, and we have

$$\alpha = 2; \quad \lambda = \tfrac{1}{2}; \quad \mu = 0.$$

As an example of this form of grain suppose the length to be ten times the thickness of web. Then

$$x = \tfrac{1}{10}, \quad \alpha = \tfrac{11}{10} \text{ and } \lambda = -\tfrac{1}{11}$$

Therefore

$$F = \frac{11}{10}\,\frac{1}{l_0}\left\{1 - \frac{1}{11}\,\frac{1}{l_0}\right\} = \frac{1}{l_0}\left\{\frac{11}{10} - \frac{1}{10}\,\frac{1}{l_0}\right\}$$

The following table was computed by this formula:

$\frac{l}{l_0}$	F	First differences	Second differences
0.0	0.000		
		0.216	
0.2	0.216		—0.008
		0.208	
0.4	0.424		0.008
		0.200	
0.6	0.624		0.008
		0.192	
0.8	0.816		0.008
		0.184	
1.0	1.000		

This form of grain is very progressive,— much more so than cordite or even axite; and seems well adapted for gunnery purposes. A grain burning in accordance with the above table might have the following dimensions:

Diameter of grain	0″.48
Diameter of perforation	0″.08
Length of grain	2″.0
Thickness of web	0″.2

This grain would answer well for the heaviest seacoast guns; while for the 6-inch R.F. guns grains of the following dimensions would give good results:

Diameter of grain	0″.26
Diameter of perforation	0″.06
Length of grain	1″.0
Thickness of web	0″.1

Both these grains have the same expression for F; namely,

$$F = \frac{11}{10}\,\frac{l}{l_0}\left\{1 - \frac{1}{11}\,\frac{l}{l_0}\right\} = \frac{1}{10}\,\frac{l}{l_0}\left\{11 - \frac{l}{l_0}\right\}$$

and their manner of burning is illustrated in the preceeding table. It will be seen that that the volume of the last layer burned is but fifteen per cent. less than the first; while for cordite it is 89 per cent. less, and for axite 30 per cent. less.

Multi-perforated grains. The formulas which have been deduced cannot be employed for the service multi-perforated grains, because the law of burning for these grains changes abruptly when the grain is but partially consumed. For these grains we will proceed as follows: Let R be the radius of the grain, r the radius of each of the seven equal perforations and m the length. Of these seven perforations one is axial and the other six are symmetrically disposed about the axis, their centers joined forming a regular hexagon.

The original volume of the grain is

$$\pi m (R^2 - 7 r^2).$$

After a thickness l has been burned from all the surfaces, R becomes R − l, r becomes r + l and m changes to m − 2l. The volume remaining is then

$$\pi \{ (R-l)^2 - 7(r+l)^2 \} (m-2l)$$

Subtracting this from the original we have the volume burned. Thus we have for the volume burned,

$$\pi \{ (R^2 - 7r^2) m - ((R-l)^2 - 7(r+l)^2)(m-2l) \}$$

If we divide this last expression by the original volume the quotient will be the fraction burned, or F. Therefore

$$F = 1 - \frac{(R-l)^2 - 7(r+l)^2}{R^2 - 7r^2}\left(1 - \frac{2l}{m}\right)$$

Expanding, reducing and arranging terms according to the powers of l we have

$$F = \frac{2(R^2 - 7r^2) + 2m(R + 7r)}{m(R^2 - 7r^2)} l + \frac{6m - 4(R + 7r)}{m(R^2 - 7r^2)} l^2 - \frac{12}{m(R^2 - 7r^2)} l^3$$

Finally factoring and introducing l_0 we have

$$F = \frac{2l_0 \{ R^2 - 7r^2 + m(R + 7r) \}}{m(R^2 - 7r^2)} \frac{l}{l_0} \times \left\{ 1 + \frac{l_0 \{ 3m - 2(R + 7r) \}}{R^2 - 7r^2 + m(R + 7r)} \cdot \frac{l}{l_0} - \frac{6l_0^2}{R^2 - 7r^2 + m(R + 7r)} \frac{l^2}{l_0^2} \right\} \quad (10)$$

Therefore for multi-perforated grains we have

$$\alpha = \frac{2l_0 \{ R^2 - 7r^2 + m(R + 7r) \}}{m(R^2 - 7r^2)};$$

$$\lambda = \frac{l_0 \{ 3m - 2(R + 7r) \}}{R^2 - 7r^2 + m(R + 7r)};$$

$$\mu = -\frac{6l_0^2}{R^2 - 7r^2 + m(R + 7r)}.$$

Before proceeding further we will illustrate these formulas with some numerical examples.

The grains of the nitrocellulose powder used in a portion of the experimental firings of the 16-inch B.L. rifle, at Sandy Hook, had the following dimensions:

$$R = 0''.485$$
$$r = 0''.0385$$
$$m = 2''.64$$

The thickness of web ($2\,l_0$) bears the following relation to R and r, in our service grains, viz.:—

$$2\,l_0 = \frac{R - 3r}{2}$$

From this we find

$$2\,l_0 = 0''.18475 \qquad \therefore \qquad l_0 = 0''.092375$$

Substituting these numbers in the expressions for α, λ and μ we find

$$\alpha = 0.68992\,; \quad \lambda = 0.26716\,; \quad \mu = -\,0.023097$$

The expression for F is therefore

$$F = 0.68992\,\frac{l}{l_0}\left\{1 + 0.26716\,\frac{l}{l_0} - 0.023097\,\frac{l^2}{l_0^2}\right\} \qquad (11)$$

This equation gives the law of burning, or the fraction of grain burned, from the beginning where l is zero to

$$l = l_0 = 0''.092375$$

When this occurs the grain is not all consumed; but its original form disappears and there remain twelve relatively small, three-cornered pieces with curved sides, technically called "slivers." To determine their volume we have only to make in (11)

$$\frac{l}{l_0} = 1$$

and we find

$$F = 0.68992(1 + 0.26716 - 0.023097) = 0.85833.$$

That is, about 86 per cent. of these grains is consumed when they break up into slivers; and therefore the total volume of the twelve slivers is about 14 per cent. of the original grain. We may avoid the analytical difficulties arising from considering the slivers apart from the burning of the body of the grain by slightly increasing the value of l_0 so as to make

$$\alpha\,(1 + \lambda - \mu) = 1$$

If in (11) we make $F = 1$ and solve the cubic equation we find

$$\frac{l}{l_0} = 1.137668\,;$$

from which we find for the new values of l_0, α, λ, μ,

$$l_0 = 0.105092\,;\ \alpha = 0.78490\,;\ \lambda = 0.30393\,;\ \mu = -0.02989.$$

Therefore for the hypothetical grain we have

$$F = 0.78490 \frac{l}{l_0} \left\{ 1 + 0.30393 \frac{l}{l_0} - 0.02989 \frac{l^2}{l_0^2} \right\} \qquad (12)$$

which becomes unity when $l = l_0$. By employing (12) we have the same law of burning from $l = 0$ to $l = 0.092375$ (which is half the real thickness of web), as though (11) were used. The following table gives the values of F, with first differences, for the values of l/l_0 in the first column. Also corresponding values of l, or thickness of layer burned.

$\frac{l}{l_0}$	F	First differences	l	Remarks
0.0	0.00000		0.00000	Grain in its original form.
		0.16633		
0.2	0.16633		0.02102	
		0.18429		
0.4	0.35062		0.04204	
		0.20113		
0.6	0.55175		0.06305	
		0.21684		
0.8	0.76859		0.08417	
		0.08974		
0.878991	0.85833		0.092375	Grain reduced to slivers.
		0.14167		
1.0	1.00000		0.105092	
		1.00000		

The column of first differences shows that this grain burns with an increasing surface; but this is due to its length. If it were made short enough it would burn with a decreasing surface. By referring to (10) it will be seen that when

$$m = \tfrac{2}{8}(R + 7r),$$

that is, for the present example, when the length of grain is a little more than half an inch (0″.503) the second term within the brackets disappears, and the expression for F becomes

$$F = 0.98724 \frac{l}{l_0} \left\{ 1 - 0.0847154 \frac{l^2}{l_0^2} \right\}$$

This grain burns with a decreasing surface as is illustrated by the following table:

$\frac{l}{l_0}$	F	First differences	Second differences	l
0.0	0.00000			0.000000
		0.19678		
0.2	0.19678		−0.00402	0.018475
		0.19276		
0.4	0.38954		0.00802	0.036950
		0.18474		
0.6	0.57428		0.01205	0.055425
		0.17269		
0.8	0.74697		0.01605	0.073900
		0.15664		
1.0	0.90361	0.90361		0.092375

The third column shows that more than 90 per cent. of the grain is burned when reduced to slivers.

If $m = 0''.65$ the grain will begin to burn with an increasing surface, but will soon change to a decreasing surface. The expression for F for this length of grain is

$$F = 0.904174 \frac{l}{l_0} \left\{ 1 + 0.056954 \frac{l}{l_0} - 0.071579 \frac{l^2}{l_0^2} \right\}$$

The following table was computed by this formula :

$\frac{l}{l_0}$	F	First differences	Second differences
0.0	0.00000		
		0.18238	
0.2	0.18238		+0.00100
		0.18338	
0.4	0.36576		−0.00208
		0.18130	
0.6	0.54706		−0.00520
		0.17610	
0.8	0.72316		−0.00831
		0.16779	
1.0	0.89095	0.89095	

This table shows that the emission of gas is very nearly constant for this grain.

As a second example of the burning of multi-perforated grains take the Laflin and Rand powder designed for the 8-inch B.L.R. The data were furnished by the President of the Company in a letter dated December 10, 1904 :

$$R = 0''.256 ; \qquad r = 0''.0255 ; \qquad m = 1''.029.$$

Therefore

$$l_0 = 0''.044875$$

From these data, proceeding as before, we find

$$F = 0.72667 \frac{l}{l_0}\left\{1 + 0.19590\frac{l}{l_0} - 0.02378\frac{l^2}{l_0^2}\right\} \qquad (13)$$

This equation corresponds to (11). When

$$l = l_0 = 0.044875,$$

that is, when the grain is reduced to slivers, we find

$$F = 0.85174$$

which is very nearly the same as was found for the larger grain. The half thickness of web (l_0) required to make F unity is found to be $0''.051713$. With this the expression for F becomes

$$F = 0.83740\frac{l}{l_0}\left\{1 + 0.22575\frac{l}{l_0} - 0.03158\frac{l^2}{l_0^2}\right\} \qquad (14)$$

which makes F unity when $l = l_0$. The following table was computed by (14) :

$\frac{l}{l_0}$	F	First differences	Thickness of web burned
0.0	0.00000		0.00000
		0.17483	
0.2	0.17483		0.01034
		0.18869	
0.4	0.36352		0.02069
		0.20126	
0.6	0.56478		0.03104
		0.21258	
0.8	0.77736		0.04137
		0.07438	
0.868	0.85174		0.044875
		0.13826	
1.0	1.00000	1.00000	0.05171

Expression for weight of charge burned. If we assume that the entire charge is ignited at the same instant, which is practically the case with an igniter at both ends of the cartridge, the combustion of the charge will be expressed by the same function that applies to a single grain. Therefore if y is the weight of the charge burned at any period of the combustion, and $\tilde{\omega}$ the weight of the entire charge we may assume the equality (since the weights are proportional to the volumes)

$$F = \frac{y}{\omega} = \alpha \frac{l}{l_0} \left\{ 1 + \lambda \frac{l}{l_0} + \mu \frac{l^2}{l_0^2} \right\} \qquad (15)$$

In this equation α is always positive from its definition, while λ or μ may be positive, negative or zero, according to the form or dimensions of the grain under consideration.

Expressions for volume and surface of charge. Let N be the number of grains in a pound of powder and δ the specific gravity (density) of the grain. Then since a pound of water fills a volume of 27.68 cubic inches (nearly) we have the equation

$$N \delta V_0 = 27.68 \qquad (16)$$

Therefore

$$N = \frac{27.68}{\delta V_0}$$

or

$$\delta = \frac{27.68}{N V_0} \qquad (17)$$

The last equation is the more useful, since the number of grains in a pound can be counted; and with the carefully moulded grains now in use, V_0 can be determined with great accuracy. Thus (17) can be employed for determining the specific gravity of powder when it is not given by the maker, as is usually the case.

Let S be the entire surface of the grains of one pound of powder of any form. Then since s_0 is the surface of one grain we have

$$S = N s_0 = \frac{27.68 s_0}{\delta V_0}$$

But

$$s_0 = \frac{\alpha V_0}{l_0} \qquad \text{(page 187)}$$

Therefore

$$S = \frac{27.68 \alpha}{\delta l_0} \quad \text{square inches.} \qquad (18)$$

From (18) it follows that for two charges of equal weight, and made up of grains of the same density and thickness of web, but of different forms, the entire surfaces of all the grains in the two charges are to each other as the value of α for each form of grain.

EXAMPLE 1. What is the entire burning surface of a charge of 70 pounds of m. p. powder designed for the 8-inch B.L.R? For this powder we have $\delta = 1.58$, $l_0 = 0''.044875$, and $\alpha = 0.72667$.

$$\begin{aligned} \log 27.68 &= 1.44217 \\ \log \alpha &= 9.86134 \\ c \log \delta &= 9.80134 \\ c \log l_0 &= 1.34801 \\ \hline \text{Sq. in. of surface of one pound, } \log 283.69 &= 2.45286 \\ \log 70 &= 1.84510 \\ \hline \log 19859 &= 4.29796 \end{aligned}$$

The initial burning surface is therefore 19859 square inches.

Continuing the calculations we find

$$\begin{aligned} V_0 &= 0.19715 \text{ cubic inches} \\ s_0 &= 3.192 \text{ square inches} \\ N &= 88.363 \end{aligned}$$

These calculations are based upon an assumed value of δ which may not be exactly true.

EXAMPLE 2. Suppose the powder of example 1 were made into spheres (or cubes) having the same thickness of web. Compare the initial surfaces of the two charges, or of any two charges of equal weight.

For a sphere (or cube) we have

$$\alpha = 3.$$

Therefore the initial surface for these last would be 3/0.72667 = 4.1284 times the former.

Let C′ be the volume of the entire charge exclusive of interstices. Then from (16) we have

$$C' = \frac{27.68\,\bar{\omega}}{\delta} \tag{19}$$

Density of loading. The density of loading is defined to be the "ratio of the weight of the charge to the weight of a volume of water just sufficient to fill the powder chamber." Let Δ be the density of loading and C the volume of the powder chamber,—by which is meant all the vacant space in rear of the base of the projectile when in its firing seat. In our service this volume is always given in cubic inches. Then since a pound of water occupies a volume of 27.68 cubic inches (nearly), it follows from the above definition that

$$\Delta = \frac{27.68\,\bar{\omega}}{C} \tag{20}$$

Reduced length of the initial air space. The initial air space is that portion of the chamber not occupied by the powder; and the reduced length of the initial air space is the length of a cylinder whose diameter is the same as the bore and whose volume is equal to the air space. Denote this length by z_0. Then since C is the volume of the chamber and C′ that of the powder, both in cubic inches, we have by the above definition

$$z_0 \omega = C - C'$$

where ω is the area of cross-section of the bore, in square inches, while z_0 must be in inches. From (19) and (20) we easily get

$$C - C' = 27.68\,\tilde{\omega} \left(\frac{1}{\Delta} - \frac{1}{\delta}\right)$$

Put

$$a^2 = \frac{1}{\Delta} - \frac{1}{\delta} = \frac{\delta - \Delta}{\Delta\,\delta}$$

Then, in inches,

$$z_0 = \frac{27.68\,a^2\,\tilde{\omega}}{\omega} \tag{21}$$

It will be convenient in deducing the formulas of Chapter 2 to keep all linear dimensions in feet. For this purpose ω must be in square feet and 27.68 must be divided by 1728. We then have in feet

$$z_0 = \frac{0.016\,a^2\,\tilde{\omega}}{\omega} \tag{21'}$$

[To be continued.]

EMPLOYMENT OF RAPID-FIRE ARTILLERY IN THE FIELD

By M. WALLUT, Major of Artillery

From the "*Revue d'Artillerie*", November, 1905.

OBJECT OF THIS STUDY

ON the field of battle artillery cannot act alone; it opens the way for the infantry or protects it from the fire of hostile batteries; it facilitates for infantry the capture of ground which, by its own means alone, it is incapable of maintaining and the possession of which, nevertheless, insures victory. It is the indispensable auxiliary of the other arms.

It is proposed to study the employment of the 75 mm. gun in combination with the other arms, particularly with infantry, and to compare, as the cases occur, the prescribed methods of the French and German regulations.

Before beginning this study, we shall briefly review the properties of the 75 mm. gun and the consequences that result therefrom.

Properties of the 75 mm. gun.—In time-fuze fire, with the normal height of burst, a round from this gun covers with deadly bullets a front of 20 meters and a depth varying with the range (about 150 meters at 2500 meters). In percussion fire with the Robin shell, the accuracy of the gun is such that once the fire is regulated (fork of 25 m.), 10 to 20 rounds, according to the range (between 2 and 3 km.), are needed to put out of action a hostile piece very plainly visible on the terrain. With explosive shell, the effect is sensibly greater.

In fire for effect, it is very easy to fire 10 to 12 rounds per gun per minute whatever may be the range.* The rate of fire of the German gun model 96 (77 mm.) is much less; it does not exceed one round per gun per minute, except in rapid fire executed at a range less than 1500 meters, in which case it can attain 8 rounds.

*General Rohne places the figure at 17, when the conditions are altogether favorable, which is not at all exaggerated.

Occupation of positions.—One of the first results of the power of the 75 mm. gun is that an unmasked battery (plainly visible) risks being nailed in its tracks by the fire of the enemy's artillery: either by a fire for effect, with time fuze, which after having reduced it to silence, will prevent every movement of limbers (or resupply caissons) and put *hors de combat* the personnel and the teams; or preferably a demolition fire, with percussion fuze, which will put out of action the majority of its carriages in less than a quarter of an hour (ranging included).

Artillery should, then, mask itself from sight on all occasions when the tactical situation or the configuration of the ground offers no objection thereto, or a *complete* concealment can be realized without inconvenience as regards the laying and firing when there is a fixed objective or one slightly mobile (infantry). The German regulations also provide for the defilade of batteries, or rather for masked fire, but in exceptional cases; direct fire constitutes the rule.

Control of fire.—The former French regulations of July 18, 1898, prescribed concentration of fire and obtained it by the convergence of fire of batteries that might be separated from one another but operating under a single head; it was action in mass. The German artillery still fights according to that principle. The regulations recommend deploying at the beginning of the battle a number of guns greater than that of the enemy and acting at once by mass.

Given the low rate of fire of the German 77 mm. gun these provisions are wise and logical. In order to be able to throw a desired number of projectiles on the enemy's position in a given time, all available batteries must generally be brought into action. This is unnecessary with the 75 mm. gun on account of its great rapidity of fire; therefore the new French regulations proceed upon a principle altogether different, only that number of batteries must fire that is deemed sufficient to obtain the desired result in the minimum amount of time.

As the weights of the projectiles of the 75 mm. and 77 mm. guns differ but little (75, 7.240 kg.; 77, 6.850 kg.), the ratio of the efficiencies of the two weapons as regards the quantity of iron and lead thrown upon a hostile position in a given time, is practically that of the two rates of fire; or, as we have already seen, page 203, 1 to 10 at ordinary battle ranges (2 to 3 km.) and 4 to 5 at very short ranges.

Distribution of batteries.—There is need of reserving as often as possible some batteries available for opposing the enemy's artillery as it appears. In fact, every battery when firing is in a poor situation to respond promptly to a new adversary. The cessation of fire on the former objective has as a result a new distribution of the batteries, from which cause results a momentary slackening of fire.

The mode of employment of batteries as prescribed by the French regulations possesses every advantage in this respect: the available batteries are either in a *position of observation*, that is to say, hidden from view, ready to open fire at the simple indication of the angular deflection with respect to an aiming point; or in a *waiting position*, that is, limbered, hidden from view, in the near vicinity of known and selected emplacements which will probably be occupied, and in any case, ready to take up immediately any desired position. It is the principle of economy of force applied to the artillery; where a single battery suffices for the task, why, as General Rohne asks, have two or three firing, when they would probably only inconvenience one another in ranging.

In order to calculate "the number of batteries sufficient to obtain the desired result in the minimum of time", it does not suffice to consider solely the breadth of the front to be fired upon; other elements also enter: its nature, its visibility. As a battery can cover a front of 200 m., with sweeping, at 2500 meters' range, it would be sufficient to engage a number of batteries equal to (or slightly greater than) half of the enemy's front expressed in hectometers, if only the front of his line is taken into consideration. This rule, which has the advantage of simplicity, excludes the eventuality of demolition fire which must be resorted to, however, every time the objective (artillery) is clearly visible; it is the surest way of rapidly and completely overwhelming the hostile batteries, with a relatively small expenditure of ammunition.

In demolition fire the front generally does not exceed 50 meters, or one quarter of the figure given above. Finally, operating in this manner neither the nature of the objective nor its visibility is taken into consideration.

The rule to be followed can be formulated as follows: Against visible artillery execute demolition fire, opposing piece against piece; this will often be a fight to the finish; front 50 meters. Against artillery that cannot be seen, to take a front of 200 m. appears excessive; an unequal distribution of fire may be feared and consequently a part of the enemy's line may be left untouched by projectiles; a front of 150 meters seems to be a maximum, 100 to 120 m. the general rule, which reduces to opposing one 4-gun battery of 75 mm. pieces to one battery (or one battery and a half) of six 77 mm. guns. Against infantry, take the maximum front, or 200 m.; perhaps some parts of the line may be slightly, or not at all, covered, but this is less to be feared than in the case of artillery, because generally the range will be shorter, and therefore fire will be more easily observed; moreover these gaps are of less importance. In no case go below a front of 50 meters. This, in order to avoid the confusion of shots of two batteries having neighboring objectives and consequent difficulties in ranging that are sometimes insurmountable. In no case have two batteries fire on the same objective. The smoke of the shortest shots prevents observation of those nearer the target and of the overs and often renders ranging impossible.

With regard to firing against infantry, the German regulations recommendudirecting the fire on the most advanced line, unless supports and other fractions in close order present a particularly favorable target in rear. This procedure seems logical. The French regulations prescribe choosing clearly defined objectives and preferably those that most efficaciously oppose the infantry's advance. This will lead, in the majority of cases, to adopting the rule given by the German regulations.

Conduct of fire.—Every battery silenced should not by that fact alone be considered as out of action. Unless demolition fire has been executed against it, there is always the chance of seeing it either re-opening fire, or bringing up its limbers for the purpose of getting in shape again under cover. Therefore there should be left pointed upon it the number of guns that would be deemed strictly necessary to prevent any such attempts rapidly and effectively. Generally, a half battery (2 pieces) will suffice to take care of a battery of six pieces. This half battery will endeavor to close its fork to 50 m. (if it has not already obtained this result) and to verify the limits of it; it will then hold itself ready to execute a fire for effect the moment that it notices any signs of activity in the enemy.

The nature of the combat will be, then, like this: repeated fire for effect of extreme violence and very short duration, preceded or not by ranging fire, and between whiles long silences interrupted only by some rounds from single guns intended for registering the terrain and giving the infantry troops a moral support during the crises of the battle.

Marches.—Generally the batteries of the advance guard are too near the head of the column, as often as they can they should be separated from it by at least 3 km. As a concrete case let us suppose an enemy occupying a defensive position with his artillery concealed from view. The head of the advance guard comes into contact with him and the artillery will be called upon to lend its aid to the infantry, which can no longer advance. Mixed in the column the batteries often would be able only to deploy to the right and left of the road and would have to fire on the obstacles preventing the advance of the infantry without having in most cases any choice of positions to be occupied. At this moment they will find themselves under the fire of the enemy's artillery, which is on the watch for them, and misfortune awaits them if they have made any mistake in their preparations; they will have ample time to be overwhelmed before the arrival of the batteries of the main column, even if they may have taken the wise precaution of extending their formation.

In order to avoid this danger the procedure to be adopted consists in having the artillery march at the rear of the advance guard. When the zone is entered in which the enemy has been signalled the artillery halts behind each cover, at the top of each ascent and deploys, if this be necessary, ready to go into battery without showing itself. As soon as the artillery commander sees the head of the advance guard reach the crest or the next cover and, in every case, at the latest when he is about to be joined by the head of the main body, he takes up the march and regains at the trot the rear of the advance guard.

If, on the contrary, the infantry happens to come into contact with the enemy he goes into battery in positions that have been reconnoitered and is all ready to come to its aid under very good conditions. He could, in most cases, occupy a masked position, which would enable him to sustain the fight even against artillery much greater in numbers; but if the batteries had been in the column, he would not, in general, have had the chance of doing so. The maneuver zone of the artillery is the distance of the advance guard.

These marching tactics, by successive advances, had already received recognition by several officers at a time when the 75 mm. gun was not yet in existence; to-day they are imperative. In addition, they are the application of a relatively recent official document (June 7, 1902) which calls attention to the danger of pushing the artillery to near the head of the advance guard.

The caution not to allow oneself to be seen during marches of approach to emplacements is found in both regulations, likewise in the case of reconnaissances; but while the German regulations prescribed making them *on foot*, leaving all escort in rear, which leads necessarily to great slowness in their execution, the French regulations simply advise making them hidden from view of the enemy, leaving to the commanding officer the choice of means of execution. The latter is correct.

Both regulations recommend defilading batteries of the advance guard*, but while in France they are distributed over the terrain, in Germany they are to remain united. The first method renders command less easy, especially if on account of lack of space new batteries come up and take position in the intervals, but it has undeniable advantages. It forces the enemy to reveal more artillery than very often he would wish to show; for example, one battery can, when necessity demands, cover and engage a group at normal intervals, which occupies a front of only 200 m. (batteries of four pieces), three would be needed if the front exceeds 400 m. It deceives the enemy more readily as to its strength and leads him to deploy greater numbers, which is the object of the advance guard.

Opening of fire.—Generally, there is a tendency to open fire prematurely. The German regulations rightly attach great importance to the first shot, especially on the defensive; the commanding officer of the troops, it says, will generally give the order to fire it. The French regulations are less precise on this point except in the case of the defensive. Perhaps this is to be regretted, for often a hasty, ill-timed shot will prevent surprise or diminish its effects. It is a signal, "*garde a vous*," given to the enemy. In a general manner in the course of the battle, artillery fire is begun too soon. An enemy appears from cover (crest, woods, etc.), quickly he is fired at; more quicky still, he disappears, often before having been seriously hit. One should wait until he is sufficiently distant from his shelter so as to have time to hit him before he may have executed a sudden change of direction and have disappeared.

The artillery duel.—The duel between the two artilleries, with its different phases, will begin immediately after the first shot. As we have previously seen, the mode of action of the two adversaries will not be the same. On the one hand, we have a number of batteries engaged proportionate to the front

*Also General Rohne, *L'Artillerie de campagne francaise.*

of the enemy, its nature and the visibility of objectives ; on the other, the greatest possible number of batteries brought into action and, from the beginning, action in mass. On the one side, fire for effect, intermittent, sudden, rapid, and of extreme violence, separated by silences hardly broken by some few single shots ; on the other, a converging cannonade, and progressive increase in the rapidity of fire.

What will be the final result ? It seems difficult to say exactly. However, as the effect produced on a body of troops and the disorganization of command and control depend not only on the losses suffered but also on the rapidity with which they are produced, it is very likely that rafales, intermittent but of extreme violence, will win success over the German cannonade. Thanks to the marked superiority of the 75 mm. gun over the 77 mm., the tactics employed by the French artillery, for equal consumption of projectiles, result in a better proportion between the end in view and the results accomplished.

Decisive attack.—However that may be, at a certain moment, one of the adversaries having gained a marked advantage in the artillery duel, or believing it to have been obtained, will seek to drive the enemy from his position, and for this purpose will proceed to the decisive attack.

The French regulations indicate two phases in the decisive attack : 1, the special preparation ; 2, the execution. This manner of carrying it out is, perhaps, not free from all criticism. Formerly with smoothbore, muzzle-loading guns, firing at short ranges, and having a low muzzle velocity and a very mediocre efficiency, it had to be done as indicated above ; but with rapid-fire guns, with long range, a very efficient death-dealing projectile, the question is altogether different.

Take the case of a battery having for its objective a shelter trench of a 100 m. front along the position to be carried, with orders to render it untenable.* At the beginning it will have registered the ground, calculated and verified all its elements of fire. At a designated signal it begins at once its fire for effect.

Ten shots per piece per minute can be assumed as the rate of fire, or a round every six seconds ; with the 75 mm. gun,

*By arguing on the supposition of a single battery and the attack on a trench of 100 m. front, the author does not seem to consider the subject from the same point of view as the French regulations. The scene of action is reduced to too small a part of the whole. What is true for a 100 meters may cease to hold good for the total extent of a position covering several kilometers, consisting of open spaces, woods, villages, etc.—*Ed. Rev. d'Art.*

this rapidity, as we have already seen, can be very readily obtained. Now let us endeavor to estimate the effectiveness of such a fire. A projectile of this gun contains about 300 bullets, 12 grams each. Hence, more than 11,000 bullets, or nearly 140 kg. of lead, are fired per battery per minute. All these bullets are not death-dealing, that is to say, capable of putting *hors de combat* any foot soldier that may be hit by them on a part of the body protected by clothing; their velocity is small relatively to that of the rifle bullet. Experience shows that the total number should be reduced by about one-third, hence we shall have ⅔ x 11,000 = 7,000 effective bullets. The depth of the dangerous sheaf of the shell is about 150 m. at mean battle ranges, therefore these 7,000 bullets will be distributed over an area of 100 x 450 = 45,000 square meters, (assuming that fire is executed on four elevations varying by 100 m.); or one bullet for every 7 square meter of horizontal surface.

At the end of 10 minutes of such firing, 110,000 bullets will have been discharged, or 70,000 effective ones over 45,000 square meters, which gives, on an average, nearly one bullet and a half per square meter. Experience as well as theory shows that the distribution of these bullets over the ground is not uniform but varies from once to twice as many. Hence we have a minimum of one bullet per square meter. These results appear to be fully sufficient for the preparation of the attack.

At this precise moment, according to the regulations, the attack should open; preparation is complete, execution begins. But already each piece has fired 100 projectiles, the contents of a caisson, one-third the total supply of a battery.* During the twenty, thirty or more minutes that the attack will consume in reaching the enemy's line, the artillery that remains in position will have to continue its fire, but it will be prevented very soon from firing at this rate, on account of lack of ammunition and in consequence also of the physical exhaustion of the personnel. At the most decisive moment, fire will necessarily slacken.

And what will the enemy's infantry be doing during this time? As long as it is not threatened by the attacking infantry, this storm of lead will pass over its head without its stirring. The smallest furrow in the ground will protect the head and shoulders of the soldier lying down and his haversack the rest of his body. It will remain motionless, crouched to the earth,

*Each caisson carries 72 rounds, each limber 24; 4 guns and 12 caissons would then have 1248 rounds, or 312 per piece.

without suffering losses, but also without firing. On the other hand, as soon as it is menaced by the attacking infantry it will expose itself in order to reply, and then it will become vulnerable. Precisely at this moment the artillery fire of the attack weakens. What purpose will the "special preparation", otherwise known as the preparatory fire, have served? Of warning the enemy that the attack was about to begin; of giving him time to concentrate his troops, to draw closer his reserves. In 1870, during the siege of Paris, the Germans were always warned of sorties that the besieged were about to make, by the cannonade from the forts and detached works. This prevented them from being surprised.

General Langlois, as long ago as 1890, arrayed himself, in his writings, against this manner of conducting the attack. The German regulation is of the same opinion and says as follows: "It is only a waste of ammunition to fire on entrenchments that are occupied by a few troops or none at all. This is particularly to be feared if there is a separation of the battle into two phases: one, the preparation by the artillery; the following one, the infantry attack. The action of artillery against points of support will be most efficacious if at the same time our infantry hurls upon the enemy the force to man his lines and make him reveal his troops". The German regulations appear to be absolutely correct. It is the main duty of the commanding officer to ensure the close connection of the two arms and to regulate the infantry advance according to the progress of the artillery, whose fire assists the former's forward movement.

The duration of the march of the attacking troops over open ground will always be more than sufficient to give time to the artillery to sweep the ground in front of the infantry; therefore the artillery fire probably will not have the violence that we have assumed. After some rafales for effect, executed under the form of progressive fire over one or several zones (which will permit utilizing the maximum rapidity of the material), the hostile position will have already received a considerable number of bullets; moreover it will be covered, generally, by a thick cloud of smoke, which will interfere with the fire of the defense (principally infantry). This result having been secured, the battery commanders will continue their fire under the form of salvos at their command, which will enable them to remain constantly in control of their fire and to conduct it according to their personal observations at the moment.

At a given signal, then, the infantry, with its accompanying batteries, leaves its cover, executes its attack and simultaneously the artillery that remains in position opens the way for it by a suddenly opened fire. The effect of surprise, the unison of the two arms, all should conspire to success, if sufficient means are at hand.*

Of course, it is understood that if some material obstacle (walls, etc., for example) oppose the advance of the attack, the artillery will have had to proceed to its destruction previously.

The registering of the terrain, done by shots fired beforehand, enables the batteries to determine exactly the moment when their fire will become dangerous to the attacking infantry (500 m. from the objective); they will then raise their elevation in order to avoid hitting it and to prevent the enemy's reserves from coming up in line.

This fire for effect will last fifteen, or twenty minutes or more, and will entail an enormous consumption of ammunition. It can be conducted surely and methodically only when the supply for the guns is plentifully assured in advance. It will not do to interrupt the fire to enable the caissons to come up and replenish the pieces or even to have recourse to the first re-supply caissons. On the side of each piece (at the right and left) there will have to be placed beforehand two or three caisson bodies, the personnel of which will be ready to relieve the detachment of the piece. This is a measure that the German regulations prescribe; ours is silent on the subject. This is an omission.

Horse batteries.—The cavalry combat is generally one of quick action, therefore it is proper that the artillery should fire almost exclusively on the cavalry only, without considering the hostile batteries.† These conditions are hardly compatible with defilade of the batteries, for if a defiladed 75 mm. battery executes its ranging fire as well and almost as quickly as if it were in the open firing on a fixed target or one slightly mobile, like infantry, it is by no means the same when it is a question of very mobile objectives or those often moving across the field of fire. Coming into battery in view will be, then, the rule generally in battle and at the galop. The conditions of rapidity of conception, of decision, and above all of execution, are more

*Exception is made of the batteries which are held available (in observation, or in waiting positions) ready to engage hostile batteries re-opening fire, or watching the terrain in the immediate vicinity of the position to be carried.

†The first line of the enemy's cavalry constitutes at the beginning the principal objective.

important than others. What is the exception for field batteries becomes the general rule for horse batteries attached to cavalry divisions.

Both the German and French regulations leave to the cavalry divisions their groups of artillery during the battle; this is logical, for the addition of these batteries to the others would be indeed of small moment and the service that they are capable of rendering in co-operation with their cavalry are very much more important.

So long as these batteries have to attend only to the enemy's horse artillery or to field batteries surprised or taken in the flank, their role is simple and their losses very small. But if, located in the open, they attack batteries that are well concealed and in good tactical positions, or allow themselves to be attacked by the latter, they will be rapidly annihilated; their six limbers, their platoons of horses, without mentioning caissons, constitute a superb objective for a 75 mm. field battery, a front of 80 meters by a depth of 60 meters.

Remarks.—There still exist some few artillerymen of the old school for whom the height of the art consists, in the majority of cases, of coming into position at an increased galop and firing the first shot immediately, in the air, or in the dust. They do not admit masked fire. To hide oneself is to show lack of courage.* They do not take into account the fact that the mode of combat for the artilleryman as well as for the foot soldier, must be modified with the progress of armament. The infantryman is taught to advance hidden from the enemy's view, to make use of the smallest obstacles for the purpose of concealing himself, to lie down in open ground in order to be less visible and less vulnerable; is the artilleryman to be reproached for imitating him? Even making exception of the facts that artillery defiladed from view leaves the enemy uncertain as to the forces he has before him, renders his ranging more difficult, diminishes consequently the effectiveness of his fire, and, finally, preserves its own freedom of action, it should not be forgotten that a battery in action constitutes a fixed objective, more easy to define and hit than a line of skirmishers. Once the enemy's fire is regulated on a field battery the artilleryman has to submit to it without having the

*This manner of acting seems to have been somewhat that of the Russian artillery *at the beginning* of the Manchurian campaign. It had to give it up very quickly and even seems to have gone to the other extreme of using nothing but indirect fire, with the batteries directed by means of signals or by telephone.

advantage, as the infantry soldier has, of being able to move away, of running to the nearest depression or fold of the ground to conceal himself. If the personnel is protected neither by the material nor by the terrain, it will be annihilated in a few minutes and the guns will be silenced due to lack of cannoneers to serve them.

The German regulations are on the same lines as ours in this respect. They recommend having the personnel kneel, when under fire, and, if there is time for it, having gun-pits constructed, even in offensive battle.

As General Rohne says, the spirit of the offensive has not been destroyed by the adoption of the shield, it is in the personnel and not in the material. Opinion has advanced since the time when a German paper published the remark that the adoption of the shield would be a disgrace to the arm. All the Powers have adopted a shield in their new field material. The Russians were the last to adopt it, but the experience of the Russo-Japanese war have modified their ideas on the subject.

In the same manner as the infantryman, under certain circumstances (as in the decisive attack for example), should boldly advance straight on his objective, without seeking either cover or defilement of any kind, so should the batteries take up a position in the open whenever it is necessary. If their duty is to attach themselves to the infantry, to accompany the attack, so much the better will it be if they draw upon themselves some of the enemy's fire; the losses that they will suffer are largely compensated for by the increase of force that they will have brought to bear upon him. In decisive moments, the German regulations say, artillery must not fear facing infantry fire, even the most intense.

Conclusions.—We can sum up as follows the conclusions to be drawn from the foregoing study:—

On the march, the artillery of the advance guard should not be mixed in with the infantry; it should march at the tail of the advance guard and advance by successive rushes from cover to cover. Its maneuver zone is the advance-guard distance.

The moment of opening fire by artillery has often a great importance especially on the defensive. It is the duty of the commanding officer to give precise orders on this point.

Opening fire prematurely, during the course of the battle, on every objective that appears must be avoided. Generally it is better to wait until the target is a sufficient distance from its cover such that one may surely have time to hit it before it may have regained shelter.

During the infantry combat the batteries should occupy positions concealed from the enemy's view; however, they should not hesitate to take up positions in the open when that is the only means of efficaciously assisting their infantry.

On the other hand, in cavalry combat horse batteries should in general establish themselves in the open on account of the essentially mobile nature of their objectives. Horse batteries have two distinct modes of employment according to whether they risk having to engage field batteries or not.

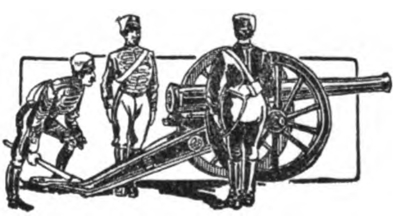
The artillery commander determines the number of batteries to be engaged, according to the extent of the front to be covered, the nature and visibility of the objective. The rest remain available nearby (in observation or in waiting positions).

The maximum front to be assigned each battery is 200 meters, the minimum, 50 meters. Two batteries should never have a common objective.

Endeavor should be made to have in hand at all times the maximum number of batteries available for engaging every new objective, without being forced to make a new distribution of fire.

Batteries charged with the preparation of the decisive attack should have about two or three caisson bodies near each gun; they register in advance the terrain of the attack; determine exactly their elements of fire, but begin their fire for effect only at the moment when the attack debouches from its final cover.

One of the essential duties of the commander of the troops is to assure the combined action of the attacking troops and the batteries charged with opening the way for them.



RANGE CORRECTIONS FOR WIND

By Captain ALSTON HAMILTON, Artillery Corps

IN table V. of the September-October number of the JOURNAL are given the values of f_w, a corrective for wind in the ballistic coefficient.

As shown in that article Maitland's method of treatment was followed as it deals directly with the ballistic coefficient.

Upon careful reflection as to whether the density alone, apart from the dynamic effect, was all that it was necessary to consider, the writer very naturally turned to the cardinal equation of ballistics: that of the retardation,

$$r = \frac{A_0 v^n}{C}$$

What effect would a wind produce here on the velocity of the projectile relatively to the earth?

The mean velocity of a projectile covering a trajectory of length S in time T is $\frac{S}{T}$; and the retardation corresponding to this velocity is

$$r_m = \frac{A_0 \left(\frac{S}{T}\right)^n}{C}$$

The average velocity in the trajectory in either high- or low-power guns is in general such that it falls under the upper or lower quadratic laws and accordingly, in general n may be taken as 2 in each case and we have

$$r_m = \frac{A_c \left\{\frac{S}{T}\right\}^2}{C}$$

This is the mean retardation in a calm.

Let us suppose a wind component W_x, + if a head wind, — if a rear wind. Then we should have, for the mean retardation of the projectile,

$$r_w = \frac{A_0 \left\{ \frac{S}{T} + W_x \cos \theta_m \right\}^2}{C}$$

If now we assume such a value C_w of the ballistic coefficient as would, in a calm, produce the measured range we would have

$$r_w = \frac{A_0 \left\{ \frac{S}{T} + W_x \cos \theta_m \right\}^2}{C} = \frac{A_0 \left\{ \frac{S}{T} \right\}^2}{C_w}$$

Hence

$$f_w = \frac{C_w}{C} = \frac{\left(\frac{S}{T}\right)^2}{\left\{ \frac{S}{T} + W_x \cos \theta_m \right\}^2}$$

$$= \frac{1}{\left\{ 1 + \frac{W_x T \cos^2 \theta_m}{X} \right\}^2}$$

or

$$f_w = \frac{1}{\left\{ 1 + .489 \frac{W_x T}{X} \cdot \frac{\tan^2 \varphi_m}{\{ (\varphi_m) \}^2} \right\}^2}$$

This value is tabulated as Table V., herewith, and is to replace that in the Supplement to the September-October JOURNAL, before referred to.

This method was completely developed just as the September-October JOURNAL was in the press, for which reason the former Table V. was not replaced by it.

That the wind velocity at the ground is merely a guide to the mean velocity in the trajectory is an established fact. Professor Greenhill states that as a rule about double the wind at the surface should be allowed for. This is of course traceable to friction experienced by the air near the ground and is dependent on the conformation of the terrain. This rule would probably obtain for a flat sea-coast, or as the guns occupy in general a high point, it would probably obtain generally, where the maximum ordinate was 1000 feet or more.

A recent article in "Harper's Weekly" bears interestingly on the subject.

We are there informed that a high flying kite reached 21,100 ft. altitude carrying a minimum thermometer, giving a minimum temperature of − 13° F., corresponding to a ground temperature of 41° F. (Humidity not stated, nor possibl eof determination).

The kite showed that corresponding to a surface velocity of 18 m. per hr., the velocity at 21,100 ft. was 54 m. per hr., (direction not stated). As the means of measuring must have been by pressures, I presume that the wind pressure was such as to give the same effect in the rare air as three times the surface wind in the surface air. This would mean a much greater wind velocity at this height.

For direct fire, the elevation reached by the projectile is, in general, not sufficient to make a supposition of the constancy of wind direction a risky one. Hence the increased velocity may be presumed to be in the same direction.

TABLE V.

Values of f_w. W_x is wind component in miles per hour. R, range in yards.

$$\varphi_m = \frac{\varphi + \omega}{2}.$$

$\frac{W_x T}{R}$	φ_m							
	0°	10°	20°	30°	40°	50°	60°	70°
−.10	1.109	1.107	1.103	1.096	1.086	1.073	1.055	1.032
−.09	1.098	1.096	1.092	1.086	1.077	1.065	1.049	1.029
−.08	1.086	1.085	1.082	1.077	1.068	1.057	1.043	1.026
−.07	1.075	1.074	1.072	1.067	1.059	1.050	1.037	1.022
−.06	1.064	1.063	1.061	1.057	1.051	1.043	1.032	1.019
−.05	1.053	1.052	1.050	1.047	1.042	1.036	1.027	1.015
−.04	1.042	1.041	1.040	1.038	1.034	1.029	1.022	1.012
−.03	1.032	1.031	1.030	1.028	1.026	1.022	1.016	1.010
−.02	1.021	1.021	1.020	1.019	1.017	1.014	1.011	1.006
−.01	1.011	1.010	1.010	1.009	1.008	1.007	1.005	1.003
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
+.01	.990	.991	.991	.991	.992	.993	.995	.997
+.02	.981	.981	.982	.983	.984	.987	.990	.994
+.03	.971	.972	.973	.974	.977	.980	.984	.990
+.04	.962	.962	.964	.966	.969	.974	.979	.987
+.05	.953	.953	.955	.957	.961	.967	.974	.984
+.06	.943	.944	.946	.949	.954	.961	.969	.980
+.07	.934	.935	.937	.941	.947	.955	.964	.977
+.08	.925	.926	.928	.933	.940	.948	.959	.974
+.09	.916	.917	.920	.925	.932	.941	.954	.971
+.10	.906	.908	.912	.916	.924	.935	.949	.968

PROFESSIONAL NOTES

ARTILLERY MATERIAL, U. S. SERVICE

Seacoast carriages.—The 6-inch disappearing carriage, L. F., model of 1905, differs radically in some respects from the model of 1903, in that the energy of recoil of the gun is principally absorbed by a single hydraulic recoil cylinder, placed vertically in the center of the counterweight, which is cored out for that purpose, instead of by two horizontal cylinders heretofore formed in the top carriage. The counter recoil is controlled by separate cylinders located on the exterior of the chassis acting on the top carriage. The gun is retracted by hand power into loading position through a train of spur gearing acting directly on the counterweight, instead of by ropes attached to the upper ends of the gun levers. The sighting platforms are located near the front end of the chassis to afford greater protection to gunners and the sighting mechanism.

.*Carriage for the type 16-inch breech-loading rifle.*—A disappearing carriage of the service type is being designed upon which this gun is to be mounted. It is anticipated that the drawings will be completed this winter.

12-inch mortar carriage.—The increased appreciation of the defensive value of mortars has warranted the preparation of a design of an improved carriage for 12-inch mortar. The mortar will be mounted and will recoil in a cradle similar to that of barbette carriages for rapid-fire guns, and will be capable of being fired at from 45° to 70° elevation. The azimuth circle will be more fully protected, and the method of bringing the mortar to the angle required for loading and returning it to the desired elevation for firing will be improved.

4.5-inch shields for barbette carriages.—Comparative tests of two different designs of shields for 5 and 6 inch barbette carriages made by firing 5 and 6 inch projectiles at shields of each type mounted on a carriage showed the design prepared and being produced by the Department to be superior.

Seacoast guns.—Continued exercise with the armament has indicated that breech-blocks, when the threads are made very smooth and are well lubricated, have a tendency to rotate, notwithstanding that the pitch angle of the threads of the blocks is very small. No accidents from this cause have occurred in service, but as a matter of precaution automatic locking devices have been designed and are being applied to all guns of models of 1895 and 1900, the ones with which the tendency exists. The important improvements which have been made in rapid-fire guns of small caliber since 1898 have made it necessary to design changes in a large number of 15-pounder guns and mounts purchased during that year in order to increase their efficiency and to remove a certain lack of satisfaction which has existed in service, since a comparison has been made with those of more recent type. The principal change in the guns will be in improved firing mechanisms which will be applied simultaneously with changes in the mounts, and as rapidly as funds will permit.

Since the beginning of gun construction the art has at various times encountered elements which for the time being have placed a limit upon its advance. For a long time the element was the strength of the gun to resist bursting, the powders in use being capable of developing higher pressures than the guns could be made to withstand, and the charges therefore being necessarily kept within small limits and giving correspondingly low velocities to comparatively light projectiles. There was gradual improvement in the methods of construction by the use of better materials, by improved methods of casting iron guns, by reinforcement with wrought-iron jackets, and finally by the introduction of the present high class of steel forgings and the system of building up of concentric cylinders under shrinkage. These advances were accompanied by improvements in the powder whereby its rate of burning was better controlled and larger charges were employed, which, giving off their gases more gradually, would sustain for a longer period the pressures which the guns would endure, and would thus continue the accelerating action upon the projectile. The improvement in powders naturally brought about both the carrying forward toward the muzzle of the strong section of the gun and the lengthening of it so as to hold the projectile longer subject to the accelerating force. These advances brought about a temporary check in regard to the projectiles, perhaps more feared than realized, these being apparently unable to withstand the impact produced by their high velocities against first-class armor. But such improvement of them was speedily made as to remove this limit upon the power of guns.

Accompanying the use of the larger charges of powder there was introduced a new element limiting the life of guns, namely, that of erosion of the bore. This was very great in the neighborhood of the seat of the projectile, and very decided in its action, scoring and guttering the surface in a manner which required its renewal after a certain number of rounds. The life fixed by this process, however, was not unreasonably short, a 10-inch gun being capable of enduring from 250 to 300 rounds before requiring relining, so that the question of limiting the power because of this difficulty was scarcely considered. With the general use of smokeless powder, however, with its still better control of the rate of burning, and the great increase in the powder charges and in the velocity, the subject of the wear of the bore has greatly increased in importance. This wear is of a different kind from that described above, being unaccompanied by the deep guttering of the surface which was experienced with the powder immediately preceeding, but the smooth and even wearing away of the surface proceeds with such rapidity that after some 50 or 60 rounds from large guns the rifling is so worn away that the projectiles are no longer given the motion of rotation necessary to steadiness of flight, and inadmissible loss of accuracy results. There has, therefore, been brought about a serious consideration of the question whether the guns should not be used at a power less than that which their strength enables the realization of in order to diminish the erosion and increase the life.

It must be remembered that in thus using the guns at less power the energy of the projectile is reduced by a sacrifice of that quality which it loses soonest in flight in any event, namely, the velocity; and it must also be remembered that it is quite possible to retain the superiority of the gun over anything which it is called upon to attack by using larger calibers for given work and by building guns of larger size than is now customary, experimental constructions, as well as theory and natural foresight, having shown that the present conventional maximum need by no means be accepted as a limit. These questions are receiving serious consideration in order to make wise selection among courses which are open. Satisfaction can be felt that we have thus far escaped serious accident and annoying and disturbing fissures of the tubes of our large guns which have been reported elsewhere, whether because of better and more careful manufacture or of fortunate chance it is difficult to say.

Automatic machine guns.—One hundred and twenty automatic machine guns, caliber .30 (Vickers, Sons & Maxim), with tripod mounts, spare parts, and pack outfits, are under manufacture for issue to cavalry and infantry; 55 of these guns, with wheeled mounts, are being made for use in and around seacoast forts. The wheeled mount was especially designed for man draft on sandy beaches, and has been made as light as consistent with requisite strength.

TELESCOPIC SIGHTS

3-inch objective telescopic sights.—The graduated reticule is being removed, and a system of direct illumination of the cross wires substituted for the field-of-view illumination to improve its qualities as a night sight. The deflection scale will be transferred to the rear end of the cradle, where it can be more easily read. The experience so far had in service with these sights has been very satisfactory.

2-inch objective telescopic sight.—Tests having demonstrated that a good telescope of low power and large field of view is the best known form of night sight, a design of a telescopic sight having a 2-inch objective, a power of 6 diameters, and a field of view of 5° is being prepared and will be applied as fast as funds permit to all carriages in service on which are monnted rapid-fire guns of caliber less than 6 inches.

IMPROVEMENTS IN INSTALLED SEACOAST CARRIAGES

Electric firing of seacoast guns.—The electric firing from a distant station of seacoast guns having been disapproved, a firing circuit for each individual mount for guns is being prepared. On account of the very small amount of current required to fire a primer and the danger apprehended from the use of a current of high voltage, the current for the firing circuit will be supplied by a battery of six dry cells.

Electric firing of mortars.—The firing of mortars in salvo requires an electric-firing system, by which the mortars in any pit can be simultaneously fired from a point outside thereof. A 360°-contact, safety-firing switch, cables, and conduits have been designed for installation as rapidly as funds will permit.

Electric traversing and elevating and depressing mechanisms.—The experience had in service with carriages on which guns of the larger calibers are mounted and the proficiency attained in their use indicate that the only electrical power equipment necessary for their efficient service is that for retracting the gun to the loading position for drill purposes. The reduced intervals at which the data required for laying a gun are now sent would seem to justify the providing on the sighting platforms of even the largest mounts a slow-motion traversing handwheel and near the elevation scale a slow-motion elevating handwheel. A study of such designs is being made.

12-inch mortar carriage, model 1896.—The excellent results obtained in service with the 12-inch mortar renders it highly desirable to strengthen sufficiently the carriage to permit the power and range of the mortar to be more fully utilized. One carriage, modified accordingly, has been tested with satisfactory results. It is therefore proposed to alter similarly all 12-inch mortar carriages, model of 1896, in service as rapidly as funds will permit. These changes consist principally of the interposition of cast-steel beams between the racer and hydraulic recoil cylinders; of the substitution of continuous grooves for the five throttling holes in these cylinders; of the addition of a brake to prevent accidental rotation of the racer, and of the addition of improved counter-recoil buffers.

Loading platform for subcaliber practice.—To enable subcaliber practice to be conveniently had with disappearing carriages, a platform, to be attached to ths gun and extend rearward from the breech, upon which the cannoneers can stand in loading the gun, has been designed and its manufacture undertaken.

Counter-recoil throttling valve.—The increase in the velocity of counter recoil of the top carriage resulting from the increase in the weight of the counterweight in later models of disappearing carriages, made to increase their quickness of return to battery and the rate of fire, and the changes in the viscosity of the oil in the cylinders, caused by variations in its temperature, have increased the difficulty of shaping the counter-recoil buffers so as to insure their satisfactory action under all conditions. To remedy this difficulty, a valve similar to the throttling valve has been designed, which, upon trial, has been found to accomplish its purpose satisfactorily. The addition of this valve obviates the necessity of providing small hand weights.

GAS-CHECK PADS

The experimental gas-check pads now being tested to determine their their fitness for service in seacoast guns embody new features in dimensions, in the material of the pad composition, and in the covering. Several pads prepared for 10-inch B. L. rifle, model of 1900, are a modified form of the service pattern, with the body reduced about 30 per cent in thickness and the exposed surface (between the split rings) proportionately more reduced in width to obviate the bulging due to melting and softening of the pad material under the influence of heat in sustained rapid fire. These pads include, besides the ordinary material (abestos-tallow mixture), several in which the tallow is replaced by grease or oil having a higher melting point and slight acidity. A considerable per cent of oleic acid is found to be always present in tallow and produces rust, which combined with the low melting point, about 116° F., makes tallow a relatively poor substance to use. The thinning of the pad will permit a greatly improved service with the tallow composition, but a further improvement will be obtained by using other material.

A special pad material has also been submitted which is claimed to have no melting point and to retain a requisite degree of plasticity and hardness under the the heat due to all service conditions, to be a chemical compound instead of a mechanical mixture and not subject to decomposition, to be nonabsorbent of moisture, and a preservative of the canvas cover. Two pads of this material, one 12-inch and one 6-inch, will shortly be tested. The qualities described are most desirable.

Several samples of the Gerdom pad, patent No. 732541, June 30, 1903, have been tried. The composition comprises glycerin and starch mixed with tallow or oil and a covering of wire netting. Fault was found with an earlier sample for lack of consistency in the material. A sample for 12-inch rifle, model of 1900, recently received and now under firing test promises more satisfactory results.

The present continued investigations for improvement of gas-check pads were at first directed to providing a protection or support for the exposed surface of the thick abestos-tallow pad to obviate its deformation under heat and cutting of the covers. The device tried included among others a complete covering of sheet copper and steel or copper cups supporting the edges. One form with light copper cups at front and rear of the exposed surface proved so efficient in ordinary firing that it was subjected to firing in 10-inch rifle, which included 30 rounds fired within 30 minutes. The fault inherent to all devices of this nature was developed in that the metal of the cups was forced outward in the repeated firing pressures and caused binding of the pad in its seat in the gun. The test showed, however, that with an equal exposed surface of a width of about three-eighths inch only in the 10-inch pad, the bulging due to heat was not objectionable, and advantage has been taken of this development in producing the latest design of relatively thin pads. Asbestos wire cloth of commercial quality for steam packing was also tried as a substitute for the canvas covering. The simple asbestos wire cloth without rubber coating has given very favorable results, with absence of the cutting, scorching, or rotting to which the canvas is subject, and will be continued on trial for further observation.

POWDER

Changes have been made in the specifications for powder for the purpose of improving ballistic results, and contracts for a large amount of powder to be made under these specifications have been entered into with various powder makers. Effort has been particularly made to decrease the variations in results by increasing uniformity in manufacture and to eliminate, at the time of the test of the ballistic sample, powders having a critical point in their pressure curves.

In the last four or five years the requirements in regard to stability have been made somewhat more rigid, and more complete purification of the nitrocellulose is required. This has led to having frequent tests made of those powders of manufacture prior to 1900 and 1901 which have been issued to the service, and which were tested by potassium-iodide test only. Some of these are now found not to meet the requirements of the more recent tests, but it is not believed that many of them are any more unstable than they were at the time of acceptance.

Attention has been given to the absorption of moisture by nitrocellulose smokeless powder for the purpose of ascertaining the amount of moisture absorbed and the rate of absorption. For this purpose weighed samples of powder were immersed in water, being removed at intervals and weighed. Other samples were exposed to an atmosphere saturated with water vapor and also weighed to determine the per cent of increase by weight. The assumption was made in both of these cases that the gain in weight was due entirely to the addition of water, although there was undoubtedly some loss of volatile solvents at the same time. It was found that there was little difference in the rate of absorption between the powders actually immersed in water and those exposed to saturated atmosphere. It has often been assumed that all absorption of moisture by smokeless powder has been surface condensation, and the moisture does not penetrate the interior of the grains. If this were true, the absorption of water would be proportional to the surface; but these investigations indicated that this was not the case. If powders are exposed to moisture for a short period, the absorption appears to be proportional to the surface. This is explained by the fact that although the moisture enters into the powder its movement is very slow, but that it eventually penetrates and saturates the entire mass is evidenced by the tendency of the figures to approach a limit in the neighborhood of 2½ per cent. One 15-pounder powder reached its maximum absorption of 2.52 per cent of moisture in 25 days, and another lot of 10-inch powder absorbed 2.21 per cent in 38 days and had not reached its limit. Nitroglycerin powders show much less absorptive power than the nitrocellulose powders, due probably to the oily nature of the nitroglycerin. After all of the powders had reached their limits of saturation they were exposed to the air of the laboratory and the loss of weight noted from day to day until the weight of the powder was what it was at the beginning of the experiment. It appears that if a powder has become wet by storage in a damp magazine it would be impossible effectually to dry it out at posts by exposure to air for a short time.

From these experiments it may be concluded that nitrocellulose powders when exposed to saturated atmosphere will absorb moisture to the extent of 2 to 2½ per cent of their total weight. This absorption takes place slowly, and the time required for complete saturation is proportional to the web thickness. If a powder is not completely saturated, the time of drying will depend on the length of exposure to moist atmosphere. If completely saturated, it will vary with the web thickness of the powder and the degree of humidity of the surrounding air.

CLOTH FOR POWDER BAGS

Tests have been made of chemically treated material for powder bags to render it noncombustible. These showed that there is slightly more residue left in the chamber by the treated than by the untreated bag. The difference is slight, however, and it can be stated that this residue does not constitute a serious objection to the use of the treated material. While no reason can be seen at this time for any bad effect of this cloth on smokeless powder during storage, it is not considered safe to assume this to be a fact without actual trial.

While in land service the danger of premature ignition of service cartridges is considered remote, it is still true that the use of a noncombustible cloth for cartridge bags would give additional safety, and it is intended to continue the investigation by submitting to storage test powder bags treated with all substances now available to render them fireproof. One bag of each kind will be filled with powder, placed in a hermetically

4ᴵᴺ A.P. SHELL

172 fragments, including shell, cap and copper band, were recovered from a Bethlehem Steel Company 4" capped A.P. ribbed cavity shell, loaded with black powder, which penetrated a 4" hard-faced Harveyized plate and burst about eight feet to the rear of it.

Original weight of shell empty, with fuze - 31 lbs.
Total weight of recovered fragments ------- 26½ lbs.
Weight of largest fragment recovered ------ 2¼ lbs.
Average weight of fragments recovered ----- 2.4 ozs.

Tested at B.S.Co's. Proving Grounds, Redington, Pa., Oct.12,1905.

6^IN^ A.P. SHELL

About 650 fragments, including shell, cap, copper band and fuze, were recovered from a Bethlehem Steel Company 6" capped A.P. ribbed cavity shell, loaded with black powder, which penetrated a 6" hard-faced Krupp plate and burst about eight feet to the rear of it.

Original weight of shell empty ----- 102½ lbs.
Total weight of recovered fragments- 94-3/16 lbs.
Weight of largest fragment recovered 10¼ lbs.
Average weight of fragments recovered 2-5/16 ozs.

Tested at B.S.Co's. Proving Grounds, Redington, Pa., Oct.26,1905.

sealed case and stored for at least one year. Should such bags be adopted it is proposed to depend upon the primer to make a hole through the treated cloth in order to reach the igniter, which will be inside the bag. The primer is strong enough to do this, and it is thought that the full protection of the treated cloth can only be obtained by covering the igniter as well as the smokeless-powder charge.—*Report, Chief Ordnance, 1905.*

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TESTS OF BETHLEHEM 6-INCH AND 4-INCH A. P. SHELLS

Through the courtesy of Mr. John F. Meigs of the Bethlehem Steel Company, we are enabled to reproduce the accompanying interesting photographs showing the bursts of capped 6-inch and 4-inch armor-piercing shells tested at the Bethlehem Company's proving grounds, October 12, and 26, 1905.

The projectiles were the ribbed cavity armor-piercing shells manufactured by the Bethlehem Steel Co., and black powder was used as the bursting charge. The first plate shows the results obtained with the 4-inch A. P. shell. After penetrating a 4-inch hard-faced Harveyized plate, it burst about 8 feet in rear of the plate and 172 fragments were recovered. The 6-inch shell, Plate II., after penetrating a 6-inch hard-faced Krupp plate burst about 8 feet in rear, and about 650 fragments were recovered. The legends give the following data:

4-inch capped A. P. Shell.

Original weight of shell, empty, with fuze	31 lbs.
Total number of fragments	172
Total weight of recovered fragments	26½ lbs.
Weight of largest fragment recovered	2¼ lbs.
Average weight of fragments recovered	2.4 ozs.

6-inch capped A. P. Shell.

Original weight of shell, empty	102½ lbs.
Total number of fragments	about 650
Total weight of recovered fragments	94 3/16 lbs.
Weight of largest fragment recovered	10¼ lbs.
Average weight of fragments recovered	2 5/16 ozs.

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HIGH EXPLOSIVES

New classification of explosives.—In a paper before the Liége Mining Congress, Herr Bichel, Director of the Sprengstoff Actien Gesellschaft Carbonit, Hamburg, classifies explosive substances according to their liability to be detonated by shock. He used for his experiments small drop hammers, the blocks of which are raised in a graduated tube, being allowed to fall from the height desired, the various high explosives being prevented from moving laterally on receiving the impact. The following is the order thus obtained:—

1. Pure nitroglycerine, which regularly exploded on receiving the impact of 100 grammes (3½ oz.) falling from height of 15 cm. (6 in.).
2. Nitroglycerine and its derivatives.

3. Explosives composed of nitroglycerine and ammonium sulphate, such as gelatine-carbonite.

4. Kohlen-carbonite and other explosives with slight nitroglycerine contents.

5[a]. Ammonium sulphate explosives with a slight quantity of nitroglycerine, such as ammon-carbonite and donarite.

5[b]. Explosives composed entirely of ammonium sulphate, such as Grisoutite-Couche and Roburite II.

6. Trinitrotoluol, which is the most insensible to shock, picric acids and guncotton.

The practical use of these comparative experiments is to show that the strength of the detonator must be in inverse proportion to the sensibility of the explosive to shock.

How are high explosives detonated?—As a reply to this question Herr Bichel's experiments have shown that the shock necessary to cause an explosion varies considerably with the nature of the explosive and that, the greater the shock required, the greater also must be the charge of mercury fulminate. In endeavoring to determine the detonation speed of the fulminate, he has found 3,920 meters (12,850 ft.) per second, for a diameter of 6.45 mm. (¼ in.); and as the usual diameter of the cartridges for high explosives is 30 mm. (1.2 in.), it may be admitted that the detonation speed of mercury fulminate is much greater than that of high explosives. Heat alone merely exerts a secondary influence as regards the firing of explosives; but, as the detonation temperature of mercury fulminate is 4,382 degrees centigrade, it may be admitted that the fulminate acts chiefly by the great speed of its detonation and also, though subsidiarily, by the high temperature it produces.—*Arms and Explosives.*

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HIGH VELOCITIES AND GUN EROSION

The biggest problem, in the development of war material at the present time, is to overcome the terrific erosion which burns out the inner tube of our modern high-velocity guns. The success of Admiral Togo in defeating the enemy by long-range rifle fire has directed attention more than ever before to the advantage of high velocity and big guns. There are two ways in which the punishing range of the gun can be extended; one is by increasing the velocity of the projectile, and the other is by increasing its weight. The disadvantages of increasing the weight are that less ammunition can be carried per gun, and that the loading of the gun is somewhat slower and its rapidity of fire is reduced. On the other hand, if the muzzle velocity be increased, the same striking energy can be developed at the same range without any increase in the weight of the projectile, and if a powder containing a high percentage of nitroglycerine be employed, there need be no serious increase in the weight of the charge. The United States government prefers to use a powder with less nitroglycerine than is present in the English cordite; but although it has succeeded in obtaining as high, and a little higher velocities at the proving grounds, this result is gained at the cost of using a powder charge that is over twice as heavy, the cordite charge for a 12-inch gun weighing 141 pounds, and our nitrocellulose charge weighing for the same gun, 350 pounds.

Nature, however, demands a heavy toll from those artillerists who seek to secure greater range by higher velocity; for in order to secure high velocity, the powder pressures within the gun must be raised to such a degree that the corresponding temperature plays the Old Harry with the inner tube, the white-hot gases melting it away, just as a block of ice is melted by a stream of boiling water. Up to a certain limit, pressures and temperatures may be raised and velocities increased without serious injury to the lining of the gun; but above that point the inner tube begins to deteriorate, the rifling is burnt out, and the projectile fails to rotate on its axis, with resulting loss of accuracy.

We do not hesitate to say that to-day the greatest problem in the development of artillery is the prevention of gun erosion.

There are no great mechanical difficulties to be encountered in getting high velocities. There are to-day at Sandy Hook under test by the Board of Ordnance of the army, two 6-inch wire-wound guns, each of which has shown muzzle velocities far in excess of anything that is used either ashore or afloat to-day. One of these is a design by General Crozier, the present head of the Bureau of Ordnance, and the other is the well-known Brown wire-wound gun, the distinguishing feature of which is its inner core of laminated steel plates. We have before us some of the results that have been obtained during the tests of the latter gun at Sandy Hook. These include sixty-five rounds fired with powder charges of from 32 to 72 pounds, with corresponding muzzle velocities of from 1913 feet per second to 3380 feet per second, and with powder pressures ranging from 12,274 pounds per square inch to 53,370 pounds to the square inch. The high velocity of 3123 feet per second was reached in the fourth round, and in the rounds from that up to the sixty-fifth round the velocities have ranged from 3200 feet per second up to 3380 feet per second, and most of them have been over 3300 feet per second. We understand that structurally the gun has shown no signs of weakness whatever, and the indications are that, were it not for the erosion troubles, the velocities could be carried up to 3500 feet per second, and the gun would prove to be perfectly well able to carry these velocities in service. Unfortunately, in both this gun and the Crozier gun, which has been tested simultaneously with it, that universal enemy of the artillerist, erosion, is getting in its destructive work. Thus we are once more reminded that the question of the ultimate practicable velocities of our guns is a question for the chemist, the metallurgist, and the powder expert to determine. We are squarely up against the fact that our steel makers cannot provide an inner tube that will endure the terrific heat engendered by modern smokeless powders. Furthermore, our artillerists admit that they do not know what is the exact explanation of erosion, whether the action is mechanical or chemical, or both. This is a field that will well repay investigation. The remedy may be found in the projectile, or in the tube or liner, or in the powder; but probably a careful study of the question of proper obturation will give the quickest solution of the difficulty.

—*Scientific American.*

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NEW SWISS FIELD GUN

Now that the artillery of the I. and II. army corps is equipped with the new long recoil gun and the III. and IV. army corps will be supplied with the same in the course of the year 1906, the Swiss War Department has sanctioned the publication of the following data concerning this material:—

Gun and breechblock. Caliber, 75 mm. (2.95 in.)
Metal, nickel steel.
Construction, jacketed tube.
Length, 30 calibers, (L/30.)
Number of grooves, 28.
Rifling, increasing twist, right-handed.
Obturator, metallic cartridge case.
Breechblock, horizontal wedge, guide-shaft-block.
Weight of gun, 330 kg. (727.5 lbs.)

Carriage. Construction, long recoil, trough-shaped trail.
Limits of elevation, + 16°, — 8°.
Traverse in azimuth, ± 2°.
Brake, glycerine.
Recuperator, springs.
Maximum recoil, 1350 mm. (53.15 in.)
Height of line of fire, 1000 mm. (39.37 in.)
Diameter of wheels, 1300 mm. (51.18 in.)
Track, 1400 mm. (55.12 in.)
Weight of carriage, stripped, 525 kg. (1157.4 lbs.)
Shield, sheet steel.
Height of shield, 1550 mm. (61.03 in.)
Carriage has road brakes and fixed spade at end of trail.

Weight of gun in firing position, about 1000 kg. (2204.6 lbs.) (without 2 men.)

Limber. Number of rounds, 40.
Weight packed, 757 kg. (1669 lbs.)

Piece limbered. Weight in draft, 1750 kg. (3858.2 lbs.)
Number and weight seated cannoneers, 5 x 75 kg.
Weight including cannoneers, 2125 kg. (4685. lbs.)
Pull (per horse) 354 kg.
Horizontal turning angle, 70°.
Vertical turning angle, 40°.

Caisson. Number of rounds, 96.
Weight packed, 1750 kg. (3858.2 lbs.)
Number and weight seated cannoneers, 6 x 75 kg.
Weight including cannoneers, 2200 kg. (4850. lbs.)

In the battery. 4 guns.
10 caissons.
1120 rounds.
280 rounds per piece.

Ammunition. Shrapnel. Weight, 6.35 kg. (13.9 lbs.)
Number of bullets, 210, 12.5 grams each.
Bursting charge, 100 grams black powder.

Explosive shell. Weight 6.35 kg.
Bursting charge, 215 grams, white powder.

Cartridge. Charge, 0.515 kg. smokeless powder.
Metallic case, fixed ammunition.

Muzzle velocity. 485 m. (1592 f. s.)
Muzzle energy. 76.1 m. tons, (246 foot-tons.)
Maximum range, with shrapnel, about 6000 meters, (6560 yds.)
—*Schweizerische Zeitschrift fuer Artillerie und Genie.*

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FIELD ARTILLERY TACTICS

It may be assumed that the old academic system of having three positions for the varying stages of the fight is no longer needed. Artillery must of course advance, but they will no longer be able to change their positions as frequently as they did. The idea of constant movement has been fostered both in practice camps and on maneuvers—on maneuvers because, instead of having one great battle, we generally have had a series of field-days; and at practice camps because the batteries remain so short a time on the range that they have to be hurried through their practice. Service conditions, however, show that guns may often remain for days in the same position. During this time they intrench themselves, register ranges, etc., and make other observations. In peace training, however, they have no time for this. Thus the preparation for war is not complete. It is not proposed that the mobility of the artillery should be destroyed; it is, however, suggested that they should be given more training during peace in the work which they may be asked to do on service.

The publication of the French Drill Regulations created a sensation in artillery circles. It would, however, be well to inquire whether the optimism displayed by these regulations in regard to the fire effect likely to be obtained has been justified by recent events. An increase in the fire effect produces a greater desire for concealment. Will this more general use of cover, then, counteract the greater power of the gun? Success in battle must of course depend on the correct co-operation of all arms. There are, however, many general principles bearing on the employment of the artillery in the earlier stages of the fight to which some attention may be paid. For instance, to begin with, the value of concealment may be briefly summarised thus. The events of the Russo-Japanese war seem to prove that—

(1.) Artillery firing from behind cover will annihilate artillery in the open, provided the effect of the fire can be observed.

(2.) When both sides are concealed, the side with the best observing station will obtain the upper hand first.

(3.) The enemy's position may frequently be located by spies.

(4.) Any indication of the presence of the enemy may justify the opening of a searching and sweeping fire.

(5.) A surprise can only be effected through the use of concealed positions.

It would of course be impossible to lay down definite rules when everything depends on the nature of the ground. The first duty of the artillery is, however, the support of its infantry, and on occasions the guns will have to move into the open to effect this. What, however, must be borne in mind, is the fact that the incurring of rash losses will not tend to produce the desired result. In the recent war the Japanese appear to have made extensive use of concealed positions. In addition to this they made every effort to get good observing stations, and it has been stated that their observing parties were on occasion placed beyond the danger zone. On the other hand, they appear to have detached special batteries to harass the enemy's observers. This all points to the fact that an effective fire cannot be opened without the use of an observing party. Searching and sweeping may be necessary on occasions, but must always tend to produce a waste of ammunition. For instance, the Russian position was located by spies in one of the earlier battles of the war; it was then swept with some effect by a searching fire. The Russians, however, moved during the night, so that when the Japanese continued the bombardment on the following day, they wasted a large amount of ammunition in firing at nothing. Another instance of the same class occurred at Liao Yang, where a thousand rounds were expended in firing at a position on which there was no enemy. Where there is a definite object in view, such an expenditure of ammunition would of course be justified. In the earlier stages of the action it would, however, seem to be a waste. In regard to the last point referred to, it is evident that a great effect might be produced by opening a rapid fire from a concealed position. The moral effect of such a surprise would be very great, and the French justly attach great importance to it.

This, then, leads up to the question of how the enemy's fire is to be drawn. Will both sides remain silent, until the infantry of one is launched to the attack? It has been suggested that special batteries should be detached to draw the enemy's fire. This was was tried before the engagement at Colenso without success. If batteries were so detached they would be used by the defense as a means of making the enemy deploy, and by the attack for the purpose of ascertaining the position of the enemy's guns. In the first case the desired end might be obtained from concealed positions without betraying the main line of defense. In the second it would be necessary to expose the batteries, and the question then arises as to how they could be withdrawn. Once committed, their withdrawal would seem impossible if the enemy chose to annihilate them. It, however, seems likely that the defense would ignore the stratagem and remain silent, as the Boers did in the second attack on Colenso, on the 1st January, 1900. The development of an action will, however, probably be gradual. The point of attack cannot be decided on until the position has been reconnoitered. The enemy's advance troops will first be driven back. Favorable positions will then be seized in front of the main line, and from these the attack will begin. The time taken to carry out this preliminary procedure will of course depend on the amount of opposition offered by the defense. Once the advanced posts have been seized, the attacking force will be assembled behind them during the night. The final advance will then partake of the nature of a surprise. During this time the part played by the artillery will depend largely on what the enemy does. If he opens fire, the attacking artillery can open fire from concealed positions. If he refrains, the artillery must be divided up, a portion to occupy the main position and engage in the artillery duel, and another to accompany the advancing infantry. The first portion should occupy what the French call a position "en surveillance." In this connection it is interesting to note that the French lay down the principle that where one battery is sufficient for a given task, two should not be used. This is somewhat contrary to the principles generally accepted after the war of 1870. The change is, however, really one of detail, and is counteracted by the fact that though only a portion of the artillery fires, all is ready. From this it will be seen that the main object to be achieved is concealment, secrecy, and surprise, carried out with a view to co-operating with the other arms.

The aggressive tendencies of the French drill-book are exemplified by the fact that the defense is almost entirely ignored. The old theory of the attack and counter-attack is dead, or if it still lives, it applies to army corps and divisions, and not to batteries and brigades. Such counter-attacks will form battles in themselves, as was the case in China. Therefore there seems to be no need, in considering the defense, to allot batteries to the counter-attack, when this attack will be made by a complete unit adopting offensive tactics! If, however, a portion of the line has to act on the defensive, how is the artillery to be used? Should the guns be intrenched on or near the crest, or in concealed positions behind it? With a rapid-firing gun the greatest effect against moving objects will be obtained by firing over the sights. This, however, involves placing the guns on the crest. Though a few guns may be concealed on the crest, as the Boers concealed theirs, it is very unlikely that the ground will generally admit of a large number being similarly placed. With strong telescopes, portions of the position would be located. The attack could then concentrate all their fire on these, and crush them in detail. In addition to this, the damage done to the earthworks by the Japanese artillery is said to have been very great. Consequently a position on the crest should be occupied only when there is ample time to prepare it. This preparation may involve the use of covered ways to the rear, as the chief difficulty in all exposed positions is that of bringing up supplies, as was proved at Colenso. The war has, however, proved that it is impossible to place guns behind the crest and then pull them up at the decisive moment. In addition to this, some of the guns now in use are too heavy to be man-handled. Consequently the choice lies between the crest and a concealed position below it. If the latter is used, the only way to deal with advancing troops would seem to be to register areas and ranges before hand, and then when the enemy appears, sweep the registered district with a fire something similar to the French "rafale." Every line of approach might thus be dealt with. A compromise could of course be effected through the use of both systems. That is, the guns detailed for the duel or general action could be placed in concealed positions, whilst the remainder were strongly fortified on the crest with a view to repelling the decisive attack. The guns on the crest would, however, run the risk already referred to, namely, that of being located and destroyed before they opened fire. In any case, they would probaly be subjected to a very severe fire when the final advance arrived. The points referred to may be regarded as the general principles involved. The method of their use will depend primarily on the objective and the nature of the ground. It is unlikely that the pure defensive will ever be thought of, therefore the principles of the defense must be combined with those of the attack and every effort made to co-operate with the other arms. Uuder such conditions alone can success be obtained.

—*United Service Magazine.*

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ATTACK OF SHIELDED FIELD ARTILLERY.

The best method of attacking modern shielded artillery is still a problem which has not been properly solved. This, at least, is the opinion of Gen. H. von Rohne, when writing recently in the *Militaer-Wochenblatt.* Though all who think on artillery questions do not always agree with von Rohne, his opinion is certainly worth consideration. He treats this subject with his usual care and thoroughness, and there is no reason to doubt that from the artillery point of view he is correct in his assumptions. No one can contradict the fact that the shielded gun is a very difficult target to destroy or even to silence, and this is more especially the case when these guns are situated out of sight of the man who is attacking them.

He treats the attack of the shielded guns from four different standpoints, and discusses each in turn: —

(1) The destruction of the unprotected portions of the detachments.

(2) The destruction of the protected detachments by the penetration of the shields.

(3) The destruction of the guns or caissons by direct hits with whole shell.

(4) The destruction of both personnel and material by the bursting of common or high explosive shell in the battery.

In considering these headings he points out that, under the first, the exposed unprotected surface of men has become very small, and that, therefore, there is a great waste of ammunition in attacking with ordinary shrapnel to produce any considerable effect.

Under the second heading he argues rather round the subject. He shows that in this nature of attack the shell must be burst very close to the target to obtain any effect, which has, of course, many disadvantages on account of the necessary irregularities in the shooting of guns and the inherent defects of all fuzes, while, as a form of attack against a hidden artillery target, it is practically hopeless, since a large majority of the shells would necessarily fall in the intervals, causing further useless expenditure of very valuable ammunition. He discusses the question of special shell, and appears to anticipate that in this direction there is a chance for a solution of the problem. He, however, acknowledges that shell for the attack of guns must in all probability be inferior as a man-killing projectile to shrapnel.

The third method of attack, that is by the direct hit, he dismisses as wasteful of ammunition; and he considers that any system of having small bore cannon, especially for this purpose, to be fundamentally wrong on general principles, maintaining that any success which was obtained by such cannon in the Boer War was in spite of their small caliber, and not on account of it.

As regards the fourth heading, he sees here considerable chances of success, as he holds that shell falling both short and long would do some damage, while those which got the correct range, or actually hit, would be most destructive. The chief disadvantage he appears to consider to be the danger in bringing caissons with high explosive shell into the battery, as a lucky hit on the part of the hostile artillery might cause the annihilation of the whole battery.

The above is, of course, only a resumé of a very good article. There, however, appears to be more in this question than what may still be called the unsolved portion, viz., how any particular battery is to fight any other particular shielded battery. The problem is bound up more in the tactical handling of the artillery as a whole, and in the control of fire and its concentration and direction on particular points or areas than on any question of the ammunition *per se*.

The German author has not thought it necessary to consider this, nor was it necessary, for he belongs to an organized army, and he knows that with them the machinery exists for all the details of fire control and fire tactics. The necessity of linking by command the artillery brigades in a division, or the divisions in an army corps are as great or greater now than they ever were. This can only be done by a superior artillery organization running right through our army organization. The shield is a well-nigh indestructible defense when attacked from in front, but it cannot well have two or three fronts without becoming inconveniently heavy. It, therefore, follows that any battery of shielded guns attacked from two or three points a considerable distance apart must have a very large portion of its personnel exposed to one of the attackers. Quick-firing artillery can take most wonderful advantage of such situations if it is under superior control. This control, however, can only exist and be judicious when the tactical handling of the artillery is treated as part of the tactical handling of the whole army, and when the concentration and direction of its fire is as much a subject of the concern of the general in chief command as is the launching of an infantry attack or the envelopment of some exposed flank by a cavalry maneuver.

Every battery and brigade commander will of necessity fight the targets immediately opposed to him, unless his fire is directed to some other point by some superior commander. These superior commanders should be specialists on the staff of the general. Every division requires an artillery leader in peace and war; every army corps wants one; every army wants one. This is no new necessity; it is a permanent necessity; but now its importance is brought into prominence by the fact, that unless we meet it, we shall find in the next war that our shielded batteries are destroyed by the concentration of hostile fire, whilst we are without the machinery necessary to produce such concentration of fire for the destruction of our foes. These things cannot be righted on the outbreak of war. War is merely the test of the military education of a nation during peace; if that education be neglected, the result in war must be failure.

—*Army and Navy Gazette.*

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SEMI-PERMANENT WORKS IN THE WAR

Since the days of Todleben, Russia has been strong in Engineers. The defenses of Port Arthur were of vast strength, and the temporary works thrown up around them of scarcely less importance than the scarped castles on the limestone rock behind them.

During the battle of Liaoyang, Kuropatkin caused a huge *tete du pont* of semi-permanent works to be constructed on the west or left of the position. *La France Militaire* holds that this combination of works was of great strategical value as it enabled the Russian Generalissimo to use two army corps only, protected by these works, to watch Generals Nodzu and Oku whilst he concentrated the rest of his forces on the north-east of the town to face the enveloping movement of Kuroki. The works erected to the south of Liaoyang, deserve more than passing mention. The credit of their construction belongs to the East Siberian Sapper battalions. Of these the 2nd were taken prisoners at Port Arthur, and the 1st elsewhere employed, so the 3rd and 4th are the units that probably did most of the work. The profiles were strong, and constructed so as to give the greatest possible development to front, or direct, rifle fire. In the interior slopes were placed barrels, sunk in the earth, constantly filled with rifle ammunition. This idea, borrowed from the Turks at Plevna, enabled the infantry lining the parapets to pour a continuous and intense rifle fire on the glacis and all the ground in front of the works, without having to trouble itself about the difficulties of supply of ammunition under fire. This matter, as all infantry officers know only too well, is a difficult one, and its successful arrangement by the Turks and Russians is to be noted. In the angles, or *pans coupés*, of the works, which resembled blunt lunettes, were placed quick-firing guns mounted *en barbette*, so as to command an all-round fire. These guns could be easily run down under cover by the ramps of approach. Under these ramps and the whole parapets, with twelve to eighteen feet of earth cover, were the shelters, in which the garrisons of the works slept, fed, and passed their few leisure hours. These retreats were approached by steps; the width of the entrance being small the danger from shell-bursts was reduced to a minimum. Outside and all round the works was a complete barrier of wire entanglemenes and *trous de loup*, or pits provided with sharp stakes. These obstacles were directly under the fire, not only of the infantry, whose rifles lay on the superior slope, but of the quick firing guns in the angles of the works before described. Owing to the configuration of the ground it was not possible to give these works all the necessary advantages of site. Many of them were commanded by hills to the south, and from 4,000 to 6,000 yards from them. As these were in the occupation of the Japanese they mounted heavy guns there that they had used at Port Arthur. But the results of the bombardment from this heavy artillery were but meagre. Brought up at such labor it failed either to breach the works, to subdue their fire, or to cause serious casualties in the ranks of the defenders. The Japanese found it necessary to call in the aid of the field artillery. The direct defensive rifle fire and the mutual flanking fire of the works rendered nugatory all the Japanese efforts to take them by infantry assult. The attackers lost enormously, whilst the garrisons of the forts suffered little, their total casualty list amounting to only 300. Not one of these semi-permanent works was taken. When the retreat commenced, and the ground between them was vacated, the fire of the forts still denied it to the enemy. The works themselves were only vacated on the 3rd September at 6 a. m., by order of the General Commander-in-Chief.

It will appear from this description, drawn it is true from Russian sources, that it is almost impossible to dislodge good troops from strong semi-permament works. All the attacks on Bilderling's army on the Shaho position, near Mukden, were repulsed, as well as those above described. Yet these attacks were made by excellent troops, supported by a powerful artillery, including guns of 28-centimeters, say 11-in., caliber. The effects of the bombardment were not sufficient to force the infantry out of its underground shelters, and at the moment of assault its fire, like that of the Turks at Plevna, recovered its full intensity, when the fire of the attacking guns was suspended for fear of killing their own infantry. Whilst full belief may be given to the assurances of the *Russki Invalid* as to the tactical supremacy conferred by semi-permanent works, there is another, the strategical, aspect to be considered. The general result of the occupation of these strong works on the Shaho was to give a false confidence the the Russian Commander-in-Chief. He was, in a measure, justified in the belief that he could hold any force in check. But the works, like permanent fortresses, had their defects. They could be, and were turned. The two army corps that should have been placed more or less in reserve between Mukden and Tieling were not there when they were wanted. Or, if on the spot, they had been so harried and worn out by marches and counter-marches as to be too exhausted to make an effort. These troops had been sent away from the real post of danger, on the west, to assist Linievitch to the east, in the mountains forty miles away. It is true that the Japanese on this flank attacked with a desperation and courage that we have not been accustomed to read of in late years. Hecatombs of dead and dying did not prevent them from renewing their attack day after day. But 90,000 solid Russian troops, with so much artillery as Linievitch had at his command, should, one would have thought, have been able to contain both Kawamura and Kuroki under the circumstances. Not so; or at all events Linievitch did not think so. There can be no doubt that Linievitch's constant calls for help uterly misled the Commander-in-Chief, and indeed the world, as to the real situation. For days it was thought that the Russian left, and not the right, was in danger of being overwhelmed by the Japanese.

The point to insist on is the danger of relying too much on powerful semi-permanent works and of denuding their neighborhood of the mobile troops in reserve, who should always be ready to meet the development of a flank attack. It has come to pass that flanks must be turned. Central attacks will always be more or less of a containing kind. It would seem then better in some cases to strengthen the center rather than the flanks by immobile works, holding the reserves always ready to repel the final efforts that the attacking enemy is certain to make on the extremities of the position. It was the want of mobile troops that forced the French to retire from the stone walls at St. Privat. Possibly semi-permanent works, if they have been erected, would have delayed for another day the victory of Gravelotte. It is rather the combination of semi-permanent defenses and mobile troops that will insure success in battle, than too absolute a confidence in the power of either to fulfil the part that should be assigned to both.

—*Royal Engineers Journal.*

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THE BLISS-LEAVITT TORPEDO

The E. W. Bliss Company, Brooklyn, N. Y., is now at work on a large order for its Bliss-Leavitt torpedoes from the United States Government. These embody the latest improvements in torpedo design and construction and also embrace many features peculiarly their own. The new weapon conforms, in its external appearance and in the leading features of its internal subdivision and method of control, to the Whitehead, but in size, power, speed, range, and accuracy it far surpasses it. The 18-inch torpedoes have a length of 16 feet 6 inches. The charged weight, ready for ejection, is 1300 pounds. They have an effective range of 2000 yards, as against 1500 yards for the Whitehead torpedo. Their speed is 36 knots, as against 28. The 21-inch torpedoes, the largest size, have a guaranteed range of 3600 yards, and will probably reach 4000 yards.

The shell of these torpedoes is composed essentially of three parts, namely, a central flask, a head, and an after body which contains the turbine for operating the propellers, the immersion chamber for regulatiug the depth of the torpedo beneath the surface of the water, and the gyroscope gear by which the torpedo is automatically steered and maintained on its proper line of flight. The flask, which is a little over one-half the total length, is made of a special steel having an elastic limit of 90,000 pounds and a tensile strength of 128,000 pounds. It is delivered to the works as a cylinder having a thickness of over 1 inch and is turned down to a thickness of $\frac{3}{8}$ inch. This is done as a precaution in order to reveal any defects in the metal. The great strength is required by the use to which the flask is to be put. It serves as a reservoir for the air operating the engine, and is charged at a pressure of 2250 pounds to the square inch. The ends of the flask are closed by a dished plate resembling the manhole plate of a boiler. This plate rests against a ring secured within the flask.

The after portion of the torpedo, or the tail, contains in its forward end the engine which drives the propeller. The torpedo is operated by a turbine engine of the Curtis compound type, having two wheels 11 inches in diameter and each having 84 buckets. The wheels make 1200 revolutions per minute. The engine develops 110 horsepower as against 35 to 40 in the 3-cylinder engines heretofore employed.

It should be mentioned here that the remarkably high efficiency in speed and range of the new torpedo is due to the use of a superheating process applied to the compressed air. This consists of a flame which is automatically ignited, the instant the torpedo is launched from the tube, and which burns during the entire run. The compressed-air flask contains a burner or pot, the flame of which is fed automatically with alcohol. The flow is so regulated that an even and steady temperature is maintained in the air flask.

The propeller shaft is driven directly from the engine. The rear propeller is rigidly mounted on the shaft, while the forward one is carried by a sleeve. The latter propeller is moved in the opposite direction by means of the usual system of three beveled gears. This insures an even keel. With the introduction of the cigar-shaped torpedo came the double driving propellers—two sets of blades carred on the same shaft, but turning in opposite directions. Rigid vertical fins were tried for the purpose of keeping the torpedo on an even keel, but not with much satisfaction.

Immediately astern of the compartment containing the turbine is the apparatus for maintaining the proper depth of immersion and for steering. The regulation of the depth is effected by means of a vertical diaphragm, on one side of which is the water, which is allowed to enter by holes provided in the shell for that purpose, and on the other side a series of coiled springs, the water pressing against the diaphragm on one side, and the springs pressing the diaphragm in the opposite direction on the other side. The springs are adjusted so that their pressure shall exactly equal the pressure of the water at the given depth at which the torpedo is to travel. If the torpedo descends below that depth, the water pressure, overcoming the spring pressure, pushes the diaphragm inwardly. If the torpedo is above the desired depth, the springs overcome the water pressure, and push the diaphragm outwardly. The center of the diaphragm is attached to levers and rods which pass through the tail of the torpedo and act on a pair of horizontal rudders, throwing them up or down, according as the diaphragm is pressed inward or outward, and thus correcting the deviation of the torpedo from the horizontal plane at which it is designed to travel.

Astern of the immersion chamber is located the steering geer. The direction of flight is preserved by a modified Obry gear. This consists of a small gyroscope wheel so connected that any deflection of the main body of the torpedo from the true course is corrected by the action of two small rudders. The action is quick and positive. The gyroscope wheel is a sphere of steel about as large as a baseball and weighing less than two and a half pounds. It is driven in a most effective and ingenious way. One-half of the wheel spindle is hollow to receive air from the flask. The wheel proper is formed with a series of channels arranged in a central plane vertical to the spindle. The channels are placed tangentially so that the escaping air acts on the principle of the Barker mill. By this means a speed of 18,000 revolutions per minute is obtained. If the torpedo tends to deflect to the right or to the left, this gyroscope turbine maintains its original position, and its angular motion with regard to the torpedo (or to speak more accurately, the angular motion of the torpedo about the gyroscope) serves to actuate a mechanism, which turns the vertical rudders to the right or left, and corrects the deviation.

Each torpedo is provided with two heads—a practice and a war head. When fired with serious intention the war head contains a charge of 125 pounds of wet guncotton. This head is formed of two halves, cut longitudinally and brazed together, the joint being made after a saw-tooth pattern. So accurately is this job performed that it is impossible to detect the joint being made after the piece has been finished.

The Bliss Company has perfected a very perfect machine for cutting the buckets of the turbine wheels. These buckets are made integral with the body of the wheel. The machine resembles a double spindle lathe, the work being held on the tail stock. There are two cutters which alternately recede and advance toward the rim of the wheel, which is held in a horizontal position. At the same time the cutters revolve about a common center. One cutter operates on one wall of the bucket and the other on the opposite wall. The result is a bucket perfect in contour and having highly finished surfaces.—*Iron Age*; *Scientific American.*

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JAPAN'S INCREASING SEA POWER

It is now possible to calculate with some degree of accuracy and completeness the net results of the late war upon the maritime strength of Japan and to estimate the place of that empire among the naval powers of the world in the near future. Authoritative details are now at hand of the success of the Japanese in raising and repairing the Russian ships which were sunk at Port Arthur and elsewhere, and the showing is most impressive. From June 12, when the mighty Bayan was raised, to October 28, when the merchant ship Kirin was rescued from the depths of the sea, the Japanese raised at Port Arthur alone no fewer than four great battleships (the Peresviet, the Poltava, the Retvizan and the Pobieda), two cruisers (the Bayan and the Pallada), two gunboats and one destroyer, a total of nine war vessels, of 64,669 tons, and seven merchant ships, of 14,982 tons. At Chemulpo, also they raised the cruiser Variag, 6,500 tons, and the merchant steamer Sungari, 1,415 tons. At Dalny they raised the steamer Nagatan, 802 tons. They are now at work on the Novik and four gunboats, but the result is still problematic.

They also captured, without sinking, the two battleships Orel and Nicolas I., two coast defense ships and two destroyers, with a total of 32,786 tons. They captured sixty-four merchant steamers and released fourteen of them, leaving a net capture of fifty, of 121,239 tons. Thus they gained by capture and salvage a gross total of 16 warships of 103,955 tons and fifty-nine merchant steamers of 138,438 tons. Against these must be set their losses of twelve warships of 46,025 tons and thirty-five merchant steamers of 55,652 tons. Thus the net gain to Japan in shipping as a result of the war was four warships of 57,930 tons and twenty-four merchant steamers of 82,786 tons. This alone would be a considerable increase of Japanese naval power.

But the island empire is by no means content with that, nor is it waiting to see what other powers are going to do, nor slackening its naval construction because some others appear to be so doing. We have hitherto spoken of two large battleships of 16,500 tons each now being finished for Japan in England, which will rank among the most formidable vessels in the world. But they are not all. Japan is doing better than that at home. In one of her own yards she is building two more, of 18,000 tons each, which will decidedly outclass the English-built monsters, and perhaps be the most formidable battleships in the world. She is also building at home four of those heavily armed and armored cruisers for which her navy has been noted—vessels of 14,000 tons each, carrying 10-inch or 12-inch guns and able to hurl themselves through the water at twenty-four knots an hour. She is likewise building two smaller cruisers and twenty-eight destroyers, a total under construction of thirty-eight vessels of 140,520 tons. Thus by end of the next year the Japanese navy will comprise—not counting almost innumerable torpedo boats and submarines,—no fewer than 118 ships of 472,634 tons. These will mostly be strictly modern vessels, of the highest grade of efficiency. Such an array will make her a strong competitor for the third place among the naval powers of the world.

Short Notes

The most powerful gun in the world has just been completed at Essen. It is a 16-inch breech-loader of the built-up type, and the forgings for the tube and jacket are reported to weigh 184 tons. The tube is 49¼ feet long.

—*London Engineer.*

The War Office has decided to re-arm all the coast defense forts from the Thames to Plymouth with 6-inch and 9-inch guns, the present armament, 4.7-inch guns, being considered inadequate.

A new 11-inch gun is being adopted for the S class of German battleships, and, unlike previous German service pieces, it will be of fifty calibers in length. The muzzle velocity is reported to be 3000 foot-seconds, but this, perhaps, is an optimistic view, as German service velocities are usually well under the highest possible, and there is much conservatism in the matter. In any case, however, it will be a very powerful piece.—*Engineer* (*London*).

On September 1st, a further series of experiments in night firing with live shell was carried out by the guns' crews in the Spithead forts. A target representing a torpedo boat was towed at fifteen knots, and at an unknown range, pass the forts and was subjected to a heavy bombardment. The men seemed to find the range very accurately, and the number of hits registered was very considerable, the target being practically blown to pieces. Also tests of the defenses of Devonport have been carried out, a network of wire entanglements being suspended between the two old screw sloops Mariner and Reindeer, moored at either side of the narrow entrance to the harbor to prevent the ingress of torpedo craft. The defense is not really of the boom type, the only booms employed being those used for the protection of the two sloops. A number of attacks on the defense were delivered by destroyers and torpedo boats of the Devonport reserve division.

—*Army & Navy Gazette.*

A Japanese correspondent favors us with some details about the Iwami, formerly the Russian Orel. It appears that though the upper works were blown to pieces, the ship, when she surrendered, was substantially unhurt and the story of the 150 thrown overboard is pure fiction. About 32 men were wounded all told, and about half that number killed. One 12-inch gun had been broken off short, also one 6-inch, and the sum of real damage ended there.

It is now definitely established that no Russian ships were sunk by gunfire in Port Arthur harbor, but that all were scuttled by the Russians. All machinery was carefully greased, the Kingston valves were then opened and the ships settled down. The object of this was to reduce the target offered. It appears that the Russians expected Rodjestvensky to reach Port Arthur in a crippled condition after a partial victory. The submerged ships were then to have been raised, comparatively little the worse for the land bombardment. This, at least, was the apparent plan. The surrender, of course, upset it. It further appears that the Russian Baltic fleet was amply supplied with all stores and ammunition, and an examination of the Orel shows that the story about defective armor will not bear examination. The armor was quite good. There is now no doubt that the lost vessels got into difficulties through water invading their lower decks, and finally sank in most cases from torpedoes, which seem to have been fired literally by the score.—*Engineer* (*London*).

Russian Submarines.—Simon Lake, the inventor and builder of submarine boats, is now in St. Petersburg to submit to the Admiralty for its approval the final plans for four big Lake "cruiser" submarines, which he is to build for Russia. It is said that these boats will be of the largest tonnage of any of that type of construction. With the incorporation of these craft and others which are being built in Russia, as well as several which are in course of construction in Germany, Russia probably will take rank as second in the navies of the world with vessels of this type. In addition to those in the Baltic division there will be at least fifteen, including the five Lake boats which are now at Vladivostok.

On account of the nature of Russia's naval problem it is probable that the defense of the coasts and narrow seas of the country must devolve for several years on small vessels. The Admiralty is greatly interested in submarine boats, and is experimenting with German, French and American types, as well as with Russian modifications of these.

BOOK REVIEWS

The Times History of the War in South Africa, 1899-1902. Edited by L. S. Amery, Formerly Fellow of all Souls. Vol. III. London: Sampson Low, Marston and Company, Ltd. 1905.

The third volume of this magnificent work has been very slow in making its appearance, the second volume having preceded it some three years ago, but the improvement over the preceding volume, effected by this long delay (so necessary to collect all needed data), has justified the deliberate procedure of the publishers.

The period covered by the present volume was the critical period of the war, and in many respects the most important as well as the most instructive in a military sense.

Volume II. ended with the "Black Week" of defeats, marking the definite failure of the expeditionary force originally thought sufficient for the conquest of the Boer republics. The present volume comprises the events of the second three months of the war, the period in which defeat was turned into victory. The operations include the siege of Ladysmith, the attacks on the centre of the Boer line at Colesberg, the various attempts — Spion Kop, Vaal Krantz, Pieter's — to relieve Ladysmith, and finally Lord Roberts' campaign, which resulted in the relief of Kimberly, the capture of Cronje's army, and the occupation of Bloemfontein.

The volume opens, however, with a series of chapters in which is analysed the effect of the previous failures on the people of England, on South Africa and on the outside world.

Home feeling, the attitude of the British colonies, that of European Powers, and of the United States, are very clearly presented:

"If actions are any test, then certainly American effective sympathy may fairly be described as having been with England. Not only did President McKinley firmly decline to lend himself to the suggestions for intervention made by irresponsible senators and still more irresponsible journals, but the attitude of the whole administration was one of decided friendliness. This was especially apparent in the foreign and diplomatic service of the United States, at the head of which stood a remarkably able and broad-minded statesman, Mr. Hay. The friendship of the United States' representatives at the European capitals, often expressed with most undiplomatic bluntness, contributed most usefully to dispel the idea of the possibility of a general intervention of all the great Powers."

The work then takes up the military operations, beginning with the actions around Colesburg and ending with the occupation of Bloemfontein.

The same fearless spirit of criticism pervades this volume as marked the preceding ones. As an historical work, therefore, it constitutes a most valuable contribution, and as a military study it stands unrivalled. No pains have been spared to make the accounts of actions as accurate as possible, and the maps and plans of battles are remarkable for the correctness of detail as well as general accuracy.

The defects of Buller's plan of operations on the Upper Tugela are set forth in strong words. All the blundering, confusion and misunderstanding that make up the story and the general causes of failure stand out clearly.

It is here that the severest criticisms are passed in this volume, but there are many others interspersed among the accounts of the various operations. On the other hand unstinted praise is given to French's operations around Colesberg and to Lord Robert's brilliant campaign.

The entire work has been a great undertaking, and the three volumes thus far issued mark it as one of the most important historical works of our day, particularly to the military student. The lessons of the Boer War are valuable to-day, and the more recent war in Manchuria has but illuminated them with a clearer light.

We can confidently recommend the work to all military men as an excellent study, not only on account of the grander features of organization and strategy involved, but also because of the attention bestowed on the domain of tactics, and particularly the scrupulous accuracy of the descriptions even to the smallest details.

The editor has had the assistance and co-operation of the best military commanders in the army, and the work as it is presented in these volumes represents, therefore, the best military opinion in the service.

The Gunner's Examiner. Prepared by Harold E. Cloke, Captain Artillery Corps, U. S. A. Ed. 2. 6+174 p. 92 il. O. New York. John Wiley & Sons. 1906. $1.50.

We welcome a new edition of this excellent and useful book. In this edition the same general arrangement and form has been followed as in the first but the author has thoroughly revised the work making it accord with the requirements of G. O. 93, W. D. 1905, and has enlarged its scope considerably. The present book includes descriptions of the range board, deflection board and other devices of the new position finding service; several later types of guns are illustrated and described, and the examination of gunners of torpedo companies has been added, including questions and answers on storage batteries, searchlights and the telephone, etc. Such corrections in the first edition as came to notice have also been incorporated. The book has thus been made very complete, covering all the course of instruction for gunners in a very practical and satisfactory manner. The illustrations are numerous and most excellent.

The book can be warmly recommended both as a manual for the enlisted man and guide for officers and instructors in the important work of indoor instruction.

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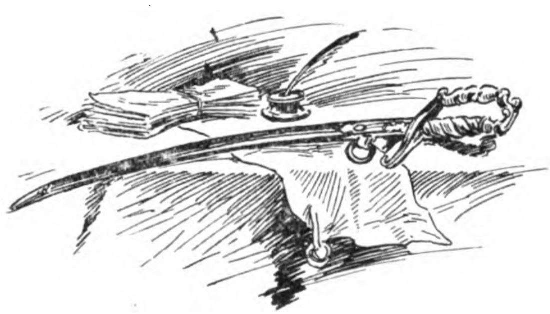

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