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Author Knight, Comdr A.M. U.S.N. 1854

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Ordnance

Lectures delivered by

Commander Austin M. Knight, U.S.N.

at

Naval War College, Newport, R.I.

August 29. 1906.
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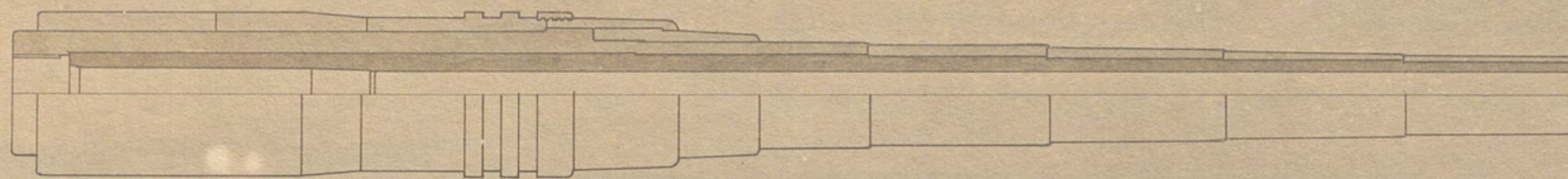
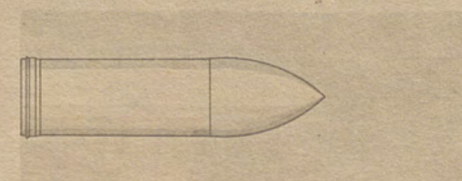
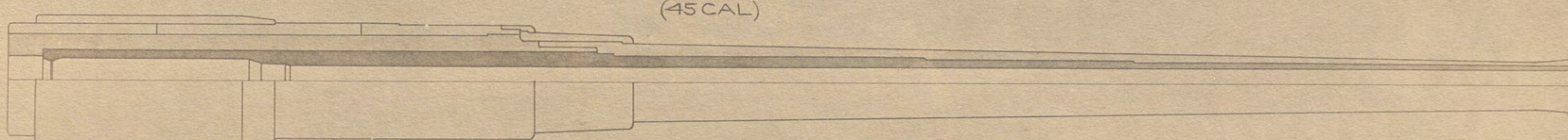
12 INCH B.L.R. MARK I.
(35 CAL)

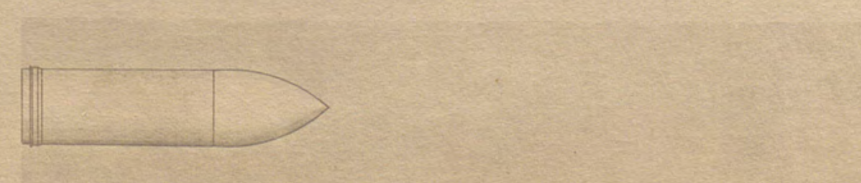




26000 FT. TONS.

12 INCH GUN. MARK V.
(45 CAL)





49368 FT. TONS.

The developments in Ordnance during the last ten years may be classified broadly, as follows:

1st. Increase in the size of guns and very marked increase in their power.

2nd. Improvements in powder and in our knowledge of the action of powder in the gun.

3rd. Improvements in armor.

4th. Improvements in projectiles, including explosives for bursting charges.

5th. Improvements in mechanical details of Ordnance material, such as mounts, sights, fuzes, &c.

In the development of guns, the advance has been very notable, as is indicated by a comparison of our own 12-inch guns of 1896 and 1906, shown in the accompanying sketches. (Plate I)
The power of this calibre has increased, as will be seen, from about 26,000 to something over 49,000 foot-tons. This increase has been gained by a considerable increase in the size and weight of the gun; by improvements in the quality of the steel and in methods of manufacture; and, finally, by improvements in powder.

As regards the size of the gun, it would seem that we have now nearly or quite reached the limit. The 12-inch gun of to-day weighs practically the same as the 13-inch gun which was given up ten years ago as being too large for advantageous use on shipboard; and while it is true that the increase in the displacement of battleships allows a great increase in the weight of the battery, the tendency is to put this additional weight into more guns, rather than larger ones. As regards the length of the gun, this is limited not only by the additional weight which comes with an increase of length, but by the danger of drooping toward the muzzle in the case of a very long gun, and by the greater diameter of the turrets which such a gun demands. It may not at first thought be clear why a few calibres added to the muzzle should necessitate a larger turret. The explanation is that the weight added to the muzzle throws the center of gravity forward, and with it, the pivotting-point; and as the pivotting-point must be near the port hole, if the port hole is not to be unduly large, the change throws a greater length of the breech inside the turret.

The most important improvement in the quality of the steel for guns is connected with the introduction of nickel steel. The quality of what is technically known as "gun steel", - by which is meant the simple carbon steel which has until quite recently been used exclusively for guns, - has not materially improved in the last few years, except in the size and general trustworthiness of the forgings which can be produced; but nickel steel, which was for a time considered too unreliable a product for use in guns, has now been so far perfected that it will probably be exclusively used in future. This gives us an elastic strength of from 60,000 to 70,000 lbs. and a tensile strength of fully 100,000, as against 40,000 and 60,000 lbs. for carbon steel. So far as the tube of the gun is concerned, a new factor has recently entered into the question of the most suitable material. This is the power of the various grades of steel to resist erosion; - that is to say, the wearing away of the bore, and especially of the lands, by the wash of the powder-gases. I shall discuss this subject a little later at considerable length, and describe some interesting experiments which have been made with various grades of steel in the hope of finding some material offering exceptional resistance to erosion. It has been hoped that such a material might be found among the many new grades of steel which have been developed within the last few years, of which the so-called "high-speed tool-steel" is the best example. Personally, I am not very hopeful as to the results of this search, but I am hopeful, - indeed I am convinced, - that from the development of these new grades of steel we are likely to get a material for use in the construction of guns which will be enormously <u>stronger</u> than any that we have now. It has long been known that the characteristics of ordinary carbon steel could be greatly modified by the addition to it of small quantities of other substances; but only within the last few years has any systematic study been made of the possibilities of such alloys.

Since then, the developments along this line have been little less than marvellous, and the possibilities of the future seem almost unlimited. We are all familiar with the great step in advance which came with the introduction of nickel steel. Even earlier than this, manganese steel had been found effective in projectiles, and both Holzer and Firminy were getting wonderful results, also in projectiles, from alloys of which the full secrets have never been made public. The essential feature of the Krupp armor plate is the use of chromium.

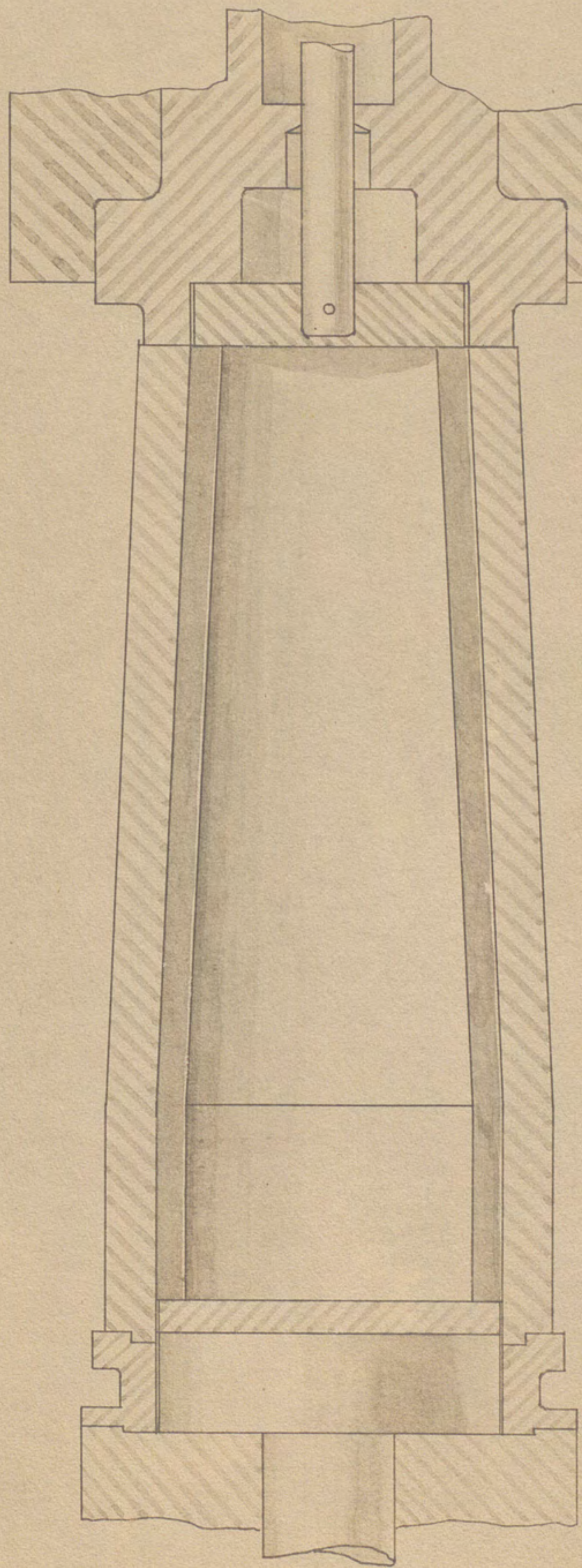
But the most striking results of all have been obtained in tool-steel, by a combination of carbon, chrome and tungsten. This alloy, when appropriately tempered, gives an edge which cannot be turned, and which, in a tool, holds its temper no matter at what speed it may be worked; whereas in the case of a tool made of ordinary steel, the temper is drawn and the tool ruined, by the heat generated by even a very slight excess of speed. The remarkable results obtained with tools have led to experiments in other directions and with other alloys, and steel can now be had commercially in forgings of considerable size with an elastic strength of nearly 150,000 lbs.

Two experimental 6" guns are now building of a material known as "Amorphous" steel, the elastic strength of which exceeds 100,000 lbs. It is probable that this or some similar material will sooner or later be adopted for general use in guns, but for the present we shall doubtless continue to rely upon nickel steel. While this is reliable in the main, it occasionally develops flaws for which no satisfactory explanation has yet been found.

(Remarks upon streaks, blow-holes, &c., their probable cause, and their effect).

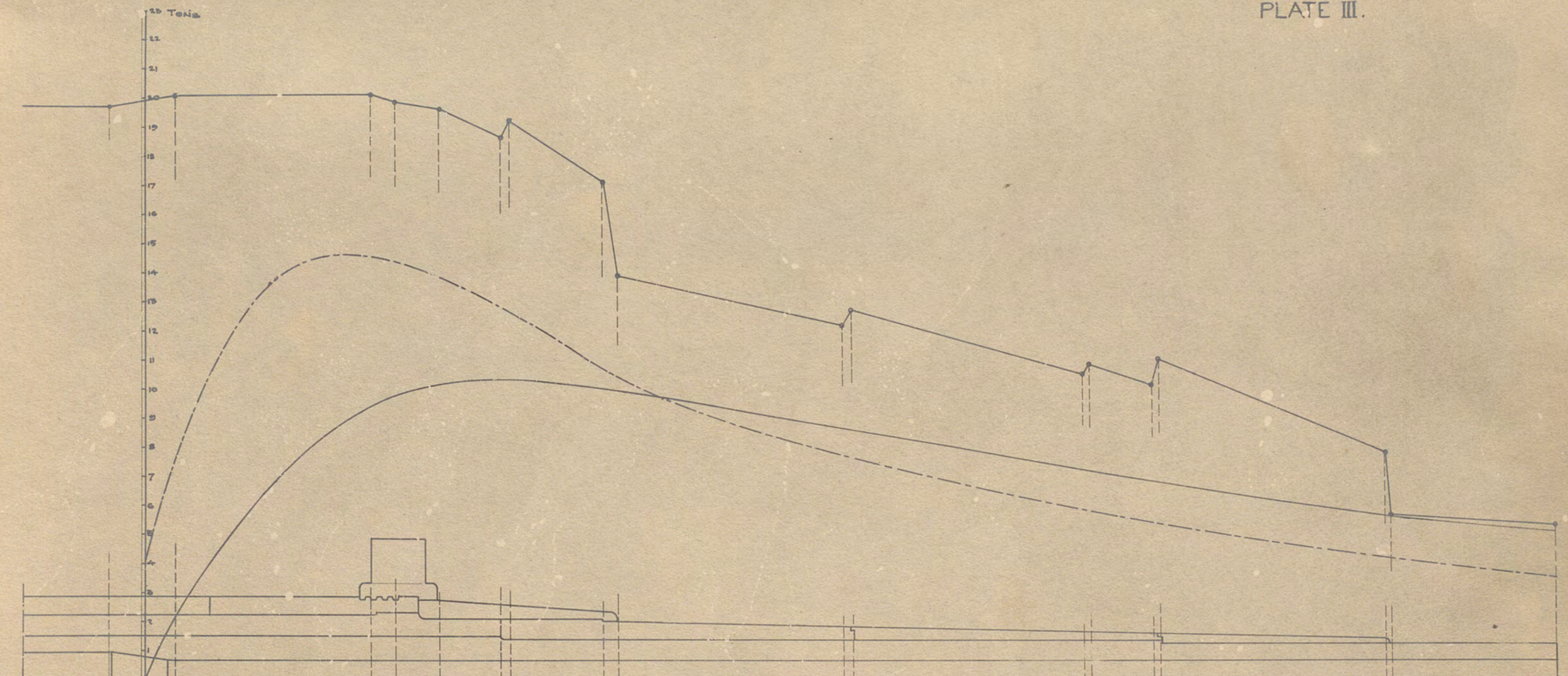
As a means of eliminating these, and of perfecting large forgings, there has recently been devised in France a new and very interesting process of fluid compression, known as the Harmet process, in which the liquid metal is poured in a conical mould placed with its small end up, and is then forced <u>upward</u> by power applied to the moveable base. By this process, the metal is continually compressed inward upon its center, with the effect of eliminating the defects

HARMET PROCESS.



which with other processes develop in the mass of the ingot, especially toward the center and top. The process is, in fact, one of wire drawing, and is said to produce more perfect ingots than can be made in any other way. (Plate II)

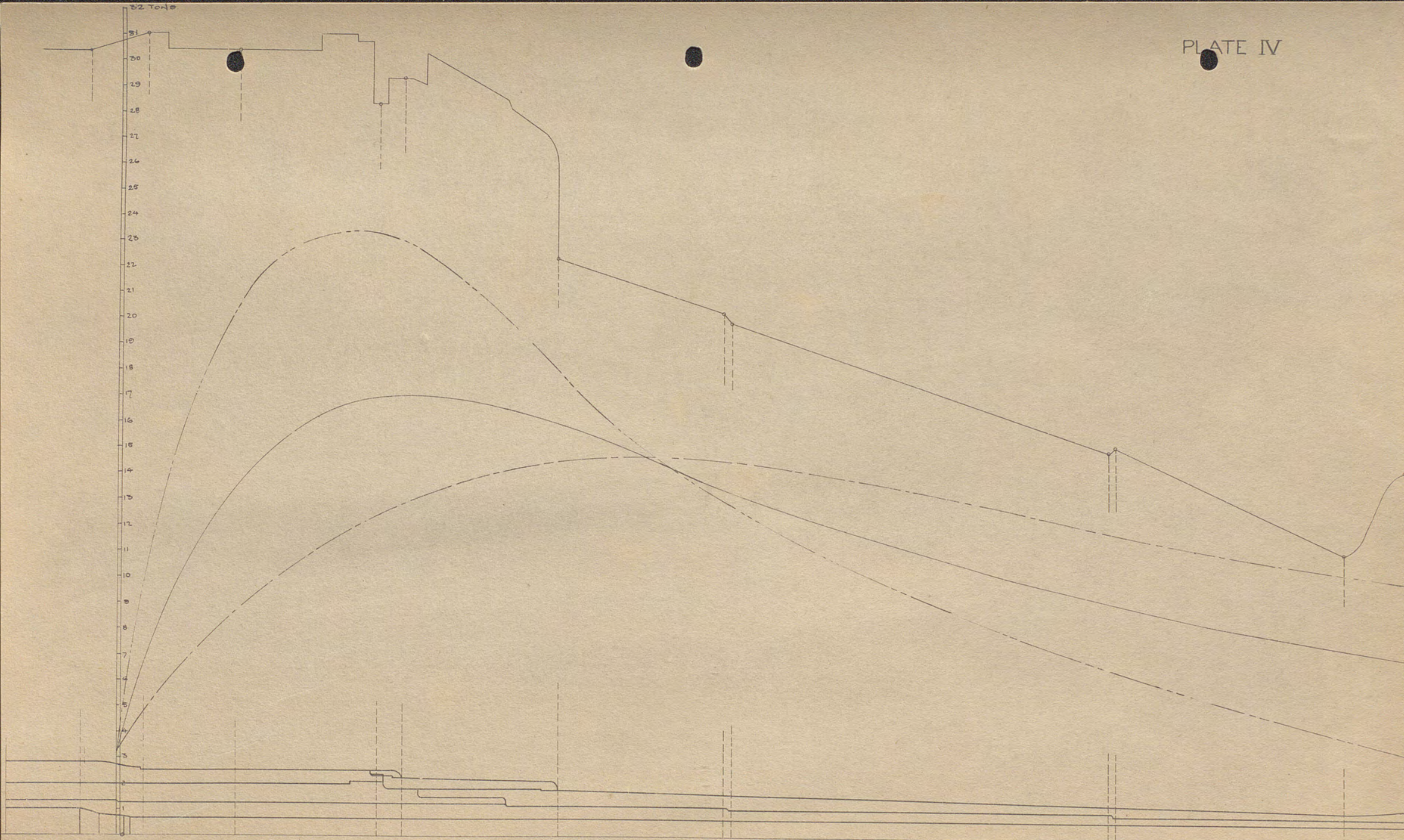
Coming now to the designs of our own and foreign guns, a marked change is to be noted in the strength given to the walls at and near the muzzle. The earlier designs were not, in most cases, hooped to the muzzle, the idea being that the pressures here would necessarily be low. Comparatively little was known, when these guns were designed, about the mode of combustion of smokeless powder. Experiments which have been carried on at the Proving Ground at Indian Head within the last two years have furnished data by which we have been able to plot the pressure curves of this powder in all of our service guns, with what is probably a fair approach to accuracy. These curves indicate that with our present composition of powder and with the granulations which have heretofore been used, the curve of pressure is flatter than had been supposed, and the muzzle pressures considerably higher. This accounts for the accidents to the 8-inch guns of the "IOWA", in which the muzzles of the guns were blown off. English guns of the same period were of similar design and have in many cases given trouble through the enlargement of the muzzle. It is not known that any of them have actually exploded, but this is not because they were stronger than our guns but because the English Cordite is essentially much quicker than our own nitro-cellulose powder, and therefore gives, for a given muzzle energy, a



8 INCH GUN MARK III.

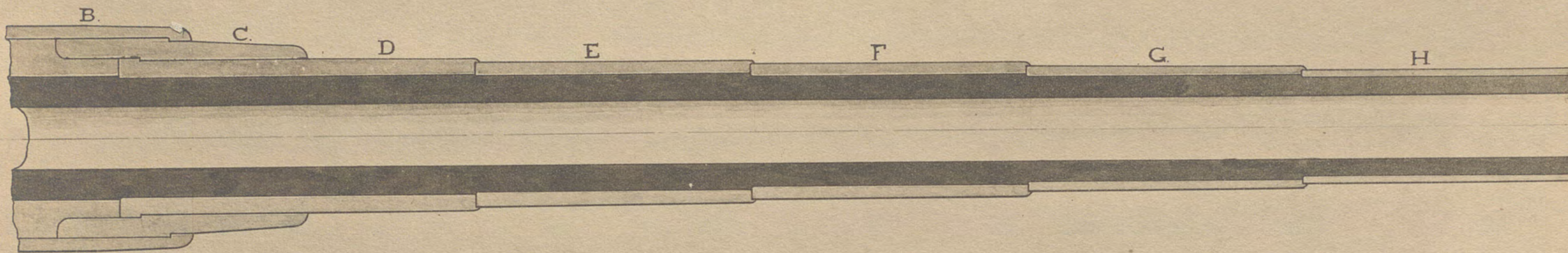
(35 CAL.)

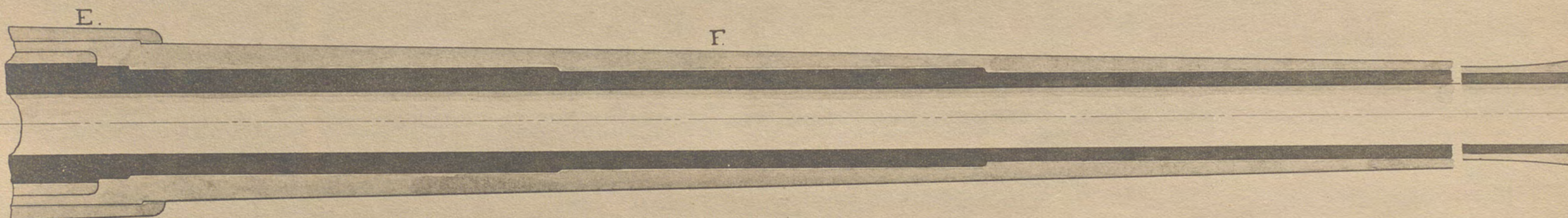
PLATE III.



8 INCH GUN. MARK VI.

12 INCH B.L.R. MARK I.
(35 CAL)





12 INCH GUN MARK V.
(45 CAL)

PLATE V.

pressure curve which is considerably higher at the breech, and correspondingly lower at the muzzle.

The drawings herewith show the advance in design of our 8-inch guns from the Mark III of 1896 to the Mark VI of 1904. (Plates III & IV). It will be seen that the latest design has abundant strength at all points, even for a powder much slower than any that we have thus far had occasion to use. With such a gun we might even approach rather closely to that old ideal of the artillerist, "a low maximum pressure maintained uniformly throughout the length of the bore".

Explain objections to this view - lack of economy, large charges to carry and handle, very severe blast, bad effect of blast on accuracy of fire, irregularity resulting from variable quantity of powder blown out unburned, awkwardness of gun, large turret required.

Illustrate by three pressure curves.
(a) high maximum pressure, low muzzle.
(b) moderate " " , higher "
(c) flat

(Explain these curves, - discuss) (Plate IV)

A very important advance in design is illustrated in the sketches of plate V, which shows two types of 12-inch guns both of which are hooped to the muzzle. In the Mark I, five short hoops are used along the chase. In the Mark V, these are replaced by a single long hoop, giving great longitudinal strength and stiffness. It would have been impossible to make such a hoop as this ten years ago. The steel-makers could not have produced the forging and the shops could not have machined it. (Explain why.)

A comparison of our guns with English guns of corresponding periods reveals no important difference in power. Their latest 12-inch design, - that for the "DREADNOUGHT" - is a wire-wound gun of 45-calibres, weighing 58 tons and firing a projectile of 850 lbs. with a velocity of 2900 f.s. These figures are identical with those of our 12-inch, Mark V. In smaller calibres, they have still the 9.2 inch, to which they are now proposing to give a length of 50 calibres. Regarding this as an intermediate battery gun, English writers compare it with out 8-inch, to which it is, of course, much superior. It is not clear, however, that there would be any advantage to us in putting in this calibre between the 8 and 10-inch.

As regards quick-firing guns, the "DREADNOUGHT" was designed to carry a 50-calibre 3-inch gun exactly like our 3-inch, but there has been some talk of substituting a heavier gun for this, recent developments in the automobile torpedo having indicated the necessity of standing off torpedo-boats by a gun which will be effective against them up to 5,000 yards. Anticipating this development and assuming that torpedo-boats will in future have better protection than they have had in the past, our own Bureau of Ordnance has developed a 50-calibre 4-inch gun, having a penetration of nearly 3-inches of steel at 5,000 yards. (Discuss this at some length).

The information available with regard to French and German Ordnance is not very full.

The Germans have for many years been content with an 11-inch gun of low power for their turret ships. For the new ships which they are planning, to meet the "DREADNOUGHT" design, it is known that they expect to adopt a 45-calibre 12-inch, which will probably correspond rather closely with our own and the English guns. It is not easy to see how they can make it any more powerful without exceeding the limit of length, which seems to be established for guns to be carried in turrets.

The French are reported as contemplating a 12-inch gun of 50 calibres, to give a muzzle velocity of 3,000 f.s. As this velocity is to be obtained with a projectile much lighter than our own, the power of the gun is really less than that of our Mark V. The French have always preferred to get their energy with light projectiles and high velocities - a policy to which there are several objections. Apart from the fact that a light projectile loses its energy much more rapidly than a heavy one, there is a serious disadvantage in attacking hard-faced armor with a light projectile, the racking and smashing effect of a heavy projectile being very helpful in breaking through the hard face of a Krupp or Harvey plate. For the attack of homogeneous and relatively soft plates, like the Schneider plate of ten years ago, the use of a light projectile with a high velocity was logical enough, and it may have been their belief in this type of plate - a belief to which they clung after the rest of the world had abandoned it - which committed the French artillerists to the policy in this matter to which they still adhere.

In adopting a 50 calibre 12-inch gun, they are going beyond the limit which seems to be fixed for naval guns by considerations which have already been explained; - the danger, that is to say, of drooping toward the muzzle, and the necessity for using turrets which are unduly large. On the other hand, they are gaining certain advantages in reducing the blast, and in carrying it well clear of the ship. (Explain).

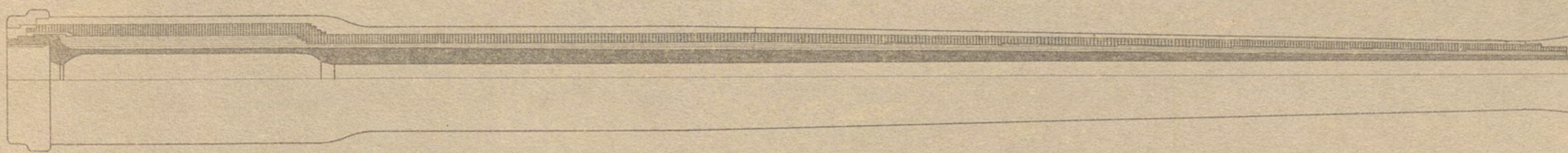
The conditions which limit the size of naval guns have no application to guns for use on land. The Ordnance Department of the Army designed, some years ago, a 16-inch gun, firing a projectile of 2300 lbs. with a velocity of 2150 f.s. Only one gun of this type was actually constructed, and this one has never been provided with a service mount, although it has fired a good many rounds. It is by far the most powerful gun in the world to-day. Believing that this gun is unnecessarily powerful, and that the 12-inch is not powerful enough, the Army has designed a 14-inch, which will fire a projectile of 1600 lbs., with a velocity of 2150 f.s. Apart from the increase of power which this gun gives as compared with the 12-inch, it is believed that the low velocity and pressure used will greatly reduce erosion and that the life of these guns will be much greater than that of a smaller gun giving the same energy by means of a lighter projectile fired with higher velocity. If this view proves to be correct, it will furnish another argument against the new French 12-inch gun. This matter is to be taken up experimentally at Indian Head.

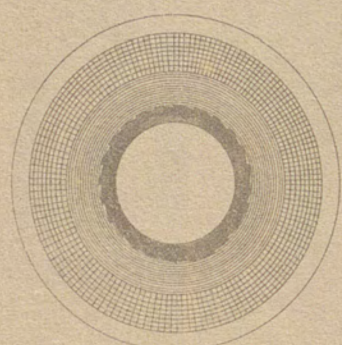
Assuming that, so far as guns for use on shipboard are concerned, the limit of size has been reached in our 12-inch Mark V, it is clear that any further increase in power must come from improvements in the design of the gun, the material of which it is made, and the powder which it burns.

One of the most promising advances in construction is the use of wire - winding, which has been adopted in nearly all recent English designs. The advantages claimed for wire - winding are two-fold. 1st, the material used is in such shape that no flaw in its manufacture can possibly escape detection, and secondly, it can be made so strong that when properly used it will give us a gun whose <u>ultimate</u> strength is far beyond that of a gun built up from forgings. It must be clearly understood that this is not at all the same thing as the <u>working</u> strength. The working strength is the strength within the elastic limits of the tube. If we go beyond this the tube will take a permanent set, and the accuracy of the gun will be destroyed, whether the tube is supported by a forged hoop or by layers of wire. But a pressure which would actually explode the forged gun would only deform the wire one, - so that not only do we get a safer gun by this process, but we can afford to use a lighter one, because we do not need so great a margin of safety. It is only fair to state that many advocates of the wire-winding system do not accept the view that the working pressure must not exceed the elastic strength of the tube. By winding the wire at very high tension - in some cases as high as 140,000 lbs. to the square inch, - they put the tube into a state of compression beyond its elastic limit for compression, thus very much extending the range through which it can be worked under internal pressures. This practice is condemned by the best authorities on gun construction, who insist that no part of the gun should at any time be strained beyond its elastic limit. Recent reports of failures in English guns constructed with over-compression of the tubes are to the effect that the tubes have stretched unduly - longitudinally - and that the bore has closed in, reducing the diameter so much as to necessitate condemning the gun. It seems at least possible that this trouble comes from a breaking down of the metal of the tube from over-compression.

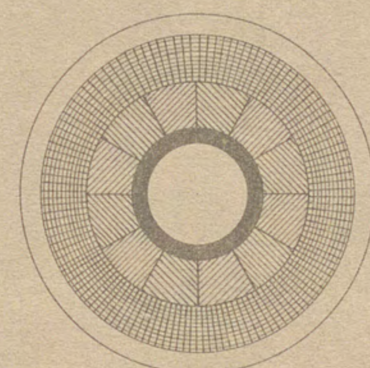
I have here a small piece of wire which was used in building the Army 6-inch wire wound gun at the Watervliet Arsenal. It includes a brazed joint, the strength of which is in excess of that of the wire.

There has been a good deal published within the last few years about the Brown segmental wire-wound guns, and several guns of this type have been tested by the Army at the Sandy Hook Proving Ground, with good results. In so far as the advantages of the wire-wound system depend upon the fact that better material is secured by manufacturing the gun in small parts, it may fairly be said that the original Brown gun carried the system to its logical conclusion. In this gun, the longitudinal construction was subdivided into staves arranged segmentally around the bore and bound tightly together by the layers of wire outside them. At first, no liner was used, but later a liner was

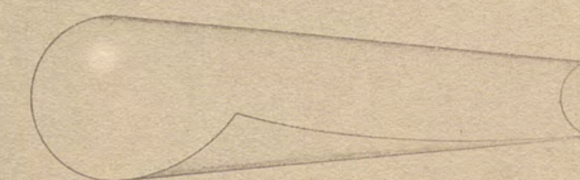




1905



1894



INVOLUTE SHEET.

BROWN SEGMENTAL WIRE WOUND GUN.

introduced merely to carry the rifling. Over the outside of the wire, hoops were shrunk, but only to protect the wire; - not to strengthen the gun. This arrangement, although theoretically excellent, was found to have mechanical disadvantages, and has now been given up. In his latest gun, which is now undergoing test at Sandy Hook, Mr. Brown uses a tube for his longitudinal strength, and over this wrapes thin "involute" sheets of steel which are bound tightly upon each other and upon the tube by the layers of wire outside. In this gun the wire is carried all the way to the muzzle, instead of being confined, as in some other types, to the breech of the gun. As a matter of fact, it is at and near the muzzle that the wire is capable of being most useful.

(Plate VI).

There is no doubt that the Brown system makes a very strong gun, but not necessarily a stronger one than can be made by other and less complicated processes. Moreover, it is doubtful whether we shall ever be able to use with this or any other gun, the very high pressures which this construction is designed to permit. It is found that erosion increases rapidly with pressure, and the 6-inch Brown gun at the Sandy Hook Proving Ground is practically worn out after about 60 rounds. The pressures used have exceeded twenty-two and the velocities have been well above 3,000 f.s.

EROSION.

Exhibit casts from guns, worn and unworn.
" " " re-lined guns.
" bands old, new, worn, &c.

The very great increase of the last few years in the power of ordnance has been purchased by a great reduction in the lifetime of the guns. The 12" guns of the TEXAS and IOWA show little or no wear after more than 150 rounds, while the corresponding guns of the MAINE and MISSOURI were so badly worn after 50 rounds that the projectiles fired from them, in many cases, tumbled end over end.

Erosion is not a new phenomenon, but the acute form in which it has manifested itself of late is not only new but surprising and very disquieting. It was forseen, of course, that the wear on the bore of a gun would increase materially with an increase in power from 26,000 to 49,000 foot-tons, but nobody could have anticipated that the increase would be as great as it has proved.

There have been many theories put forward to account for this trouble; one of them attributing the wear to gases escaping past the band of the projectile during the brief interval which elapses after a pressure is set up in the chamber and before the projectile begins to move; others attributing the trouble to the friction of the band. It seems now, however, to be pretty well established that while both of these causes just mentioned may, and probably do, contribute more or less to erosion, the greater part of the trouble is due to a softening of the inner layers of the bore by the very high temperature to which they are exposed, and to the wearing away of the bore thus softened by the friction of the rapidly moving gases which follow up the projectile. It is clear that if this is the explanation, the lands should be affected more than the grooves, since they project downward into the bore and feel the heat of the gases on three sides. Moreover, in the motion of of the gases as they rush down the bore, there is undoubtedly something of a vortex-action, which carries the mass of the gas around the bore, as well as along its axis, causing it to cut across the projecting lands. It is found that, as a matter of fact, the lands are actually worn away about twice as much as the grooves. The wear increases with the temperature, which in turn increases with the pressure. It increases also with the amount of gas which passes over a unit surface of the bore; and this explains why a large gun wears so much more rapidly than a small one, the amount of gas per unit surface being greater in the larger gun. The wear also increases with the temperature of combustion of the particular powder in use. (Nitro-glycerine vs Nitro-cellulose powders. Discuss).

The highest temperature to which the bore of the gun is subjected is felt only in the chamber and for a short distance forward of the origin of rifling; and it is here that erosion appears in the most pronounced form. As the projectile moves forward from its seat, the powder is still burning rapidly, and both temperature and pressure are rising; but this continues for a short time only.

The maximum pressure is presently reached and the gases begin to expand, absorbing heat and lowering the temperature, with the result that the rifling forward of this point is not heated and softened sufficiently to be worn away. Thus the effects of erosion are confined to the first few calibres forward of the origin of rifling, and here the lands are so nearly worn away, after something like 50 rounds, that they do not at first grip the band or start the projectile to rotating. The projectile thus gathers way in what is practically a smooth bore, and drives down the bore without turning, striking the lands, when it finally begins to engage them, with a velocity of translation such that the soft metal of the band is more or less completely <u>sheared</u> before the lands get sufficient hold to start the projectile to rotating. If the band is sheared completely through in this process, as in some cases it is, the shell takes up no rotation at all, and of course tumbles end over end in flight. Bands have been recovered at the Proving Ground which have been thrown off from 12-inch shells fired from badly worn guns, on which the marks of the rifling were entirely obliterated.

(Show bands.)

This difficulty has been met, for the present, by a change in the size of the rotating bands, the new band being considerably wider than the one heretofore in use and having a lip at its after end, which serves the double purpose of arresting the projectile at a fixed point in loading, and also of checking the escape of gas forward of the band at the first instant of ignition of the charge and before the band has been jammed into the rifling so as to give complete gas sealing. Another change, designed to help the band in its resistance to sheering, has been made, in changing the material from the soft copper which has been used for so many years, to cupro-nickel. As a result, we have a band of harder metal and with much more metal to be sheered. With this band, the 12" guns have been fired up to 90 rounds, and the projectiles are still steady. There is no doubt, however, that the trouble will recur, necessitating a further increase in width of the band; and that, sooner or later, a point will be reached where no increase in width nor any other change thus far suggested will give steady flight from our high power guns. When this time arrives, and with some of the guns it cannot be far distant, the only remedy is to re-line the guns, and preparations have already been made to undertake this work at the Washington Navy Yard.

It is something of a consolation to recognize the fact that in this difficulty, as in many others which from time to time arise in ordnance, other nations are quite as much embarrassed as we ourselves, although we know much less about their troubles than about our own. Cordite, which has been the English service powder for many years past, gives 50% higher temperature in the bore than is given by our powder, and the erosion of English guns, when fired as they are now being fired, - as rapidly as possible and with full service charges, will unquestionably be much more pronounced than with us. So far as France and Germany are concerned, it is difficult to learn just how they stand, but it is well known that the French, although very conservative in the matter of target practice, have been greatly concerned about the wear of their guns. The Germans state, in an official note which recently came under my notice, that the principal measure resorted to for the avoidance of erosion is to "Refrain from wearing out the guns in time of peace". It has been stated, on what seems good authority, that a number of the Japanese turret guns had to be replaced during the recent war because of erosion, and that the end of the war found the fleet seriously crippled because of the inaccuracy of many other turret guns resulting from this cause.

It has been suggested that a partial remedy for erosion might be found in the use of a harder steel than that which is now used, the suggestion being based upon the theory that the wear was connected with the friction of the band. As a matter of fact, there is more hope in the use of a softer material, approaching wrought iron. What is needed is evidently a material whose melting point is the highest possible; and the melting point of high steel is lower than that of mild steel, and much lower than that of wrought iron. A series of tests have recently been made in which smokeless powder was exploded in a bomb, and the gases were allowed to escape by vents bored through plugs made of different grades of steel. It was hoped that among the various alloys to which reference has been made in the discussion of gun steel, some material would be found with greater resistance to erosion than is afforded by carbon or nickel steel. The results were not encouraging, and it is probable that a mild soft steel, without nickel, will be used for the tubes of guns, no matter what improvements may be made in the steel for hoops and jackets, unless the plan should be addpted of building guns originally with liners which can be replaced from time to time as may be found necessary, in which case the tube would be made of the material giving the highest possible elastic strength, and the liner of wrought iron or very low carbon steel. There is much to be said in favor of this construction.

It has been stated that the 12-inch guns in our service which have been worn out would be re-lined as soon as practicable. This may be done either by a liner running the whole length of the bore, or by one inserted from the rear and extending only far enough forward to cover the eroded part. In the case of the Mark III guns of the MISSOURI class and the monitors, it has been decided to extend the liner to the muzzle and to make it of nickel steel rather than of soft steel, with a view to increasing the strength of the guns at the same time that the erosion is corrected. There is a 13-inch gun at Indian Head which was relined in this way some years ago and which has since fired a large number of rounds and is still in efficient condition.

In other cases, where there is no reason for seeking to gain any increase in strength, the plan will probably be adopted of inserting a partial liner, of mild steel. This method has been used and successfully with one of our own 6-inch guns and with a 10-inch Army gun, both of which have fired a large number of rounds without developing any difficulties due to the joint between the two parts of the bore. Either one of these plans for relining will require from four to six months for each gun.

It has been explained that the excessive erosion of high-power guns is due to two factors, the high pressure and temperature developed by large charges of powder and the very great mass of gas which results from the use of such charges. Evidently, both of these factors would be reduced by the use of smaller charges. The gain which can be effected in this way is, in fact, rather surprising. Experiments made with English guns and powder indicate that the erosion from one full charge equals that of four 3/4 charges or sixteen 1/2 charges. In most foreign services, advantage is taken of this fact to spare the guns in time of peace by using reduced charges for much of the target practice, full rounds being used occasionally, to test the material and to familiarize the gun crews with the effect of full charges. This was the custom of the English service until a few years ago, but their practice is now the same as ours; that is to say, they use full charges at all times, without reference to the probability that their guns will wear out more rapidly than they can be relined or replaced.

It must not be supposed that erosion in a serious form is confined to guns of large caliber. It is far more rapid with such guns, all conditions being equal, that with smaller ones, because the amount of gas per unit surface of the bore is greater in the larger guns; but any gun when used with large charges and high pressures wears away very rapidly. There are at present two 6-inch guns at Sandy Hook which have fired about 60 rounds each with velocities in the neighborhood of 3,000 foot seconds and pressures of 18 tons or more. Both of these guns are practically worn out.

If our latest guns, most of which have abundant strength for any demand that can be made upon them, are worked up to their maximum capacity, with velocities from 2800 to 3000 f.s., their endurance may be estimated roughly as follows:

6-inch guns,............ 150 rounds.
8-inch " ,............ 100 "
12-inch " ,............ 60 "

The subject of erosion is now being very carefully studied experimentally, with a view to determining all the elements which enter into it, and the comparative importance of each.

Having a prescribed velocity for a given gun, we can get this in two ways - by a large charge of slow-burning powder giving a low maximum pressure, or by a small charge of quick burning powder. Only experiment can determine which of these methods is the better, so far as erosion is concerned.

Investigations along another line have already demonstrated that powders made from cotton of a high degree of nitration produce more erosion than those to which the cotton used is less highly nitrated. These and other lines will be followed up and may result in prolonging somewhat the life of our guns. But at the best the gain will not be great.

ARMOR.

In the character of armor there have been no important developments since the displacement of the Harvey by the Krupp process about ten years ago. There have, of course, been improvements in the details of manufacture and a gradual perfection of the product, but no pronounced step has been taken in advance like that from the compound plate to the Harvey or from the Harvey to the Krupp. New processes have been introduced by various makers in this country and abroad, for which originality is claimed, but all consist essentially of the cementation of the face of the plate by burning in carbon to the depth of an inch or more, and the subsequent hardening of this cemented face,- the back in the meantime being toughened by such processes of "heat treatment" as experience shows to be appropriate to the particular grade of steel in use. The essential difference between the Krupp and Harvey processes is one of composition, the result of which is to make the back of the Krupp plate much tougher than that of the Harvey; and this difference in composition results in important differences of treatment.

The Harvey plate is of nickel-steel, the treatment of which is comparatively simple. The Krupp plate contains from 1% to 2% of chromium, the effect of which is to increase very greatly the possibilities of the plate, and to increase very greatly also the difficulty of bringing out these possibilities. Chromium makes for toughness, and, generally speaking, for nearly all the desirable qualities of steel; but just because it does make for so many and such widely differing qualities, it renders the plate extremely sensitive. The difference of only a few degrees in the temperature to which it is subjected, whether in tempering or in annealing, will entirely change the resulting structure of the steel. This explains why the Krupp process has not been found practicable for thin plates. To obtain the hard face of either a Krupp or a Harvey plate, we must raise the cemented face to a tempering heat; and with a thin plate it is next to impossible to do this without raising the back of the plate to somewhere near the same point. With a Harvey plate this does not matter. The nickel-steel of which it is made up is not especially sensitive to changes of temperature - provided they are not too sudden - and we may therefore heat the whole mass of the plate and then chill and harden the cemented face, without in the least affecting the toughness of the back. But with the sensitive chrome steel of the Krupp plate, this will not do. We must keep the tough back at a uniform temperature while heating and chilling the face. Otherwise we shall destroy the fibrous structure upon which the toughness of the back depends. With a thick plate we can protect the back by loam or ashes, while treating the face; but with a thin plate the back will feel the heat and the chill in spite of all precautions, and will become more or less hard and brittle. The result is that for the present the Harvey process still holds its own for plates up to 5-inches, although plates as thin as 3-inches have been treated by processes allied to the Krupp, with very good results. The trouble is that these results cannot be duplicated at will. Several foreign manufacturers have recently attempted to develop thin plates which shall give as good comparative results as the Krupp process gives for thick plates. What is needed here is not a new method of treatment, but a new composition for the steel; - a composition, that is to say, which shall give as tough a back as the chrome steel of the Krupp plate, without the sensitiveness which makes the Krupp process unsuitable for thin plates.

It is claimed that a steel having these characteristices has been developed in England, but if this steel has been tested, the results have not been published. Very good results seem to have been obtained in France with what is called the Charpy process, - the invention of the Director of the St. Jacques Steel Works. It is stated of that this composition that it is primarily a nickel steel, but with a very much larger percentage of nickel than is used in the Harvey process.

All of these efforts to develop a satisfactory face-hardening process for thin plates are based, of course, upon the assumption that face-hardening is favorable to the efficiency of thin plates.

It is by no means certain that this is the case. It certainly is not invariably so. A face-hardened plate is most efficient when the attack which it is called upon to resist does not greatly overmatch it. Suppose, for example, that we have two 3-inch plates, one of them Harveyized, the other of homogeneous tough steel, - say Krupp steel non-cemented - not face hardened. If, now, these plates are attacked by 3-inch projectiles, at, say, 2200 f.s. velocity, the hard faced plate will probably keep out the projectile, while the soft plate will be pierced. But suppose that the attacking gun is a 4-inch, with 1600 f.s. velocity. The hard-faced plate will almost certainly be pierced, while the soft plate will have a chance of resisting successfully. If for the 3-inch or 4-inch gun we substitute a 6-inch and let the striking velocity be what we please, both plates will be pierced, but the hole in the hard-faced plate will be larger than that in the other. If we could be sure that the thin plating of our casemates, our armored decks and our gun shields would be attacked only by light projectiles, we might be sure that hard-faced armor would be an advantage. But if they are to be racked and smashed by heavy projectiles, as in many cases they must be, then there is much reason to contend that a tough homogeneous plate like a chrome-steel plate uncemented and unhardened, is to be preferred. The matter is an important one, because the search for a reliable method of face-hardening thin plates has for its object the use of such plates for armored decks, casemates, &c. This may be a great improvement. But that it is so, has not yet been demonstrated, though it seems to be taken for granted.

For thick plates, there is, of course, no question about the advantage of the hard-face, and it was for the attack of such plates that capped projectiles were introduced some ten years ago. The action of the cap is somewhat inconsistent, but it appears upon the whole to give an advantage in penetration of from 15 to 25 per cent, at normal impact and at fairly high velocities. As the velocity falls the advantage decreases, and the English claim to have found that with velocities under about 1500 f.s. it disappears altogether. There is some evidence, moreover, for the belief that the advantage falls off at very high velocities. At inclined impact, the cap seems to be of value so long as the angle between the line of impact and the face of the plate exceeds about 20°. With a smaller angle than this, it probably does harm, as it has a tendency to throw the point of the projectile off from the face of the plate.

Several theories have been put forward to explain the action of the cap. One of these is that the cap, being of soft metal, acts in some way as a lubricant for the point of the projectile. if this theory needed refutation, the refutation might be found in the frequently observed fact that the cap on striking splits into a small number of pieces - rarely exceeding three or four, - which rebound and may usually be picked up in front of the plate. Another theory, which is probably in a measure correct, suggests that where no cap is used, the heat of impact being concentrated on the point of the projectile draws the temper of the point and softens it. This would of course be prevented by the cap. The theory now generally accepted is simpler than either of the preceding. Recognizing the fact that the hard face of the plate is designed to break up the highly tempered point of the projectile before this point can get in far enough to find support from the material of the plate, this theory regards the function of the cap as two-fold; first, to support the point in the first instant of impact, distributing the shock over a considerable area of the head; and second, to transform the projectile for a brief interval from a <u>piercing</u> instrument into a <u>smashing</u> one. Although the analogy is far from perfect, it is a little as if we fired at the plate first with a flat-headed projectile, breaking up the brittle face, and then followed this up with a pointed projectile fired with reduced velocity at the same impact.

POWDERS.

I now come to the subject of powder, which, however, I shall treat only from the ballistic, not at all from the chemical, point of view.

It is now about fifteen years since smokeless powders came into rather general use for military purposes, but up to a very few years ago nearly all of the great Naval Powers hand on hand large supplies of brown powder, and were still using this powder in their current work. It may be assumed that they have by this time accumulated full supplies of smokelss powder for all purposes.

The definite adoption of smokeless powder by our own Service goes back only six or seven years. Within this time, the Powder Factory at Indian Head has been developed to a capacity of 1,000,000 lbs. per year, and four other establishments have been built up in the country as commercialenterprises, each of these establishments having a capacity of something like 2,000,000 lbs. per year. We are thus in a position, so far as manufacturing knowledge and facilities are concerned, to turn out for the Army and Navy combined from eight to ten million lbs. per year. *

It may be safely asserted that the powder which we are manufacturing at Indian Head and elsewhere today, is in all respects equal to the best powders that are being made abroad. It is, as you are all aware, a pure nitro-cellulose powder, as distinguished from nitro-glycerine powders, of

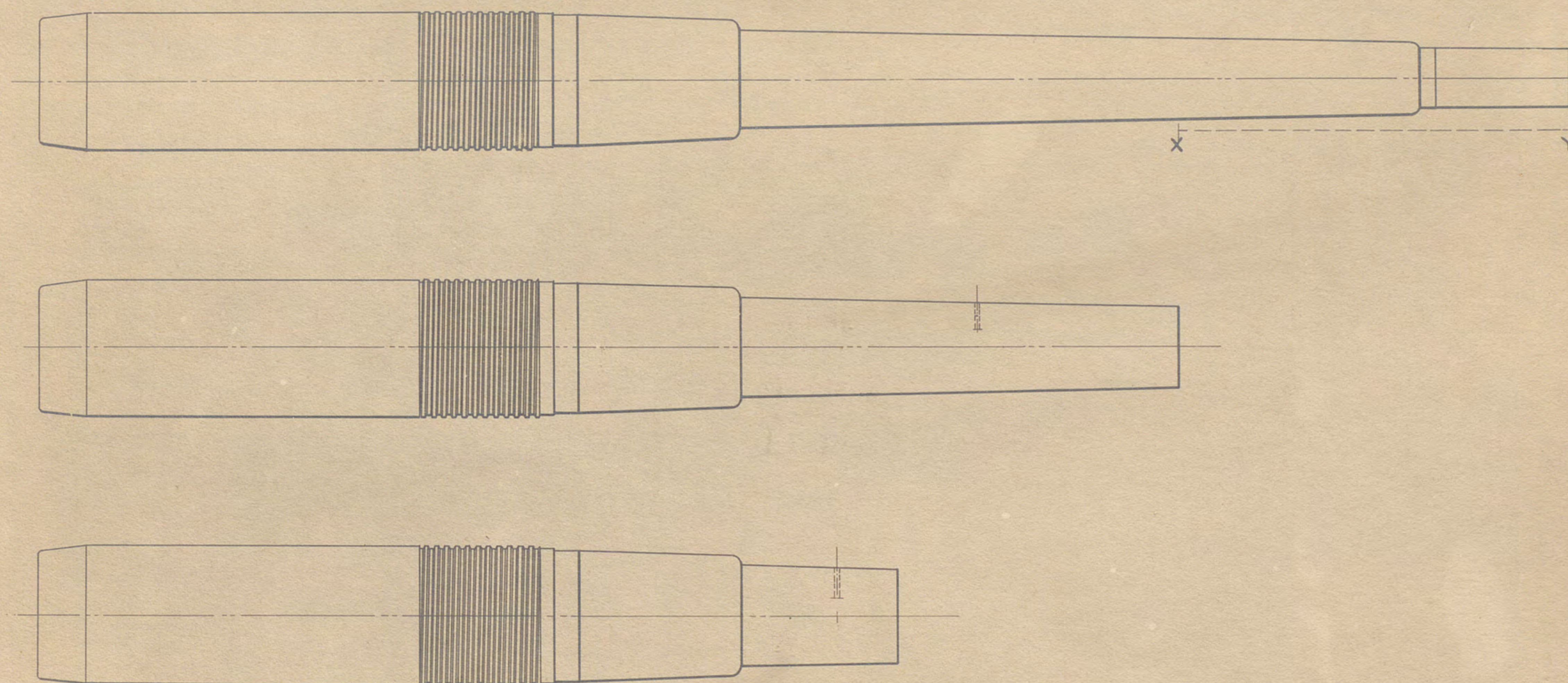
* At this point a statement was interpolated of the supply of ammunition on hand, the dangerous insufficiency of this supply, the need of a large reserve, and the effort that has been made to secure appropriations for this reserve.

which the English Cordite is a type. It should be explained that Cordite and the other so-called nitro-glycerine powders in reality have nitro-cellulose for a base, but associated with this they contain a quantity of nitro-glycerine, which may be anywhere from 5 to 65 per cent.

As regards the relative merits of nitro-glycerine and nitro-cellulose powders, there seems to be very little to choose. England, Germany, Italy and Japan have adopted the nitro-glycerine form, while France, Russia and the United States have preferred a pure nitro-cellulose. Germany has tried both, and it is reported to have decided definitely upon nitro-cellulose. The nitro-glycerine powders are more powerful, as might be expected, and a smaller charge is required for a given energy of projectile. They burn more rapidly in the gun and produce a higher chamber pressure, which however falls off more rapidly toward the muzzle. Their most serious defect is that their heat of combustion is greater than that of nitro-cellulose powders and that they are therefore more active in producing erosion. So serious has this feature become since the recent great increase in the power of guns that the English have felt obliged to cut down the percentage of nitro-glycerine in their powder from 68 per cent to something less than 30 per cent. It remains to be seen whether they can afford to continue using even as large a percentage as this. It should be noted, further, that Cordite is incapable of giving the very high velocities obtained from nitro -cellulose powders as the breech pressures would be dangerously high. This has had something to do with the change in England to M.D. cordite.

The most important disadvantage of our nitro-cellulose powder is the weight of charge required and the comparative difficulty of inflammation, calling for rather a large ignition charge of black powder at the base of the cartridge. It may be added that nitro-cellulose powders are slower in drying than are those that contain nitro-glycerine, making the total time of manufacture considerably greater.

For a given composition, the behavior of powder in the gun depends upon the size and shape of the grain, as determining the extent of initial burning surface and the way in which this surface must change as the burning proceeds. If the surface of the grain is large, the gases will at first be given off rapidly and we shall have a high pressure developed early in the burning of the charge. If, as the grain burns, its surface decreases, the gases will be given off more slowly; if the surface increases, they will be given off more and more rapidly. Thus the size and form of grain determine how the powder shall do its work, and by varying the size and shape we may change its performance radically. The whole story of its action could be told if we had the means to trace a curve of pressure following the length of the bore, and corresponding to the indicator diagram of a steam engine. Unfortunately, we have no gauge by which to record the pressure continuously. When we get such an instrument, - and it does not seem impossible that one should be devised, - the

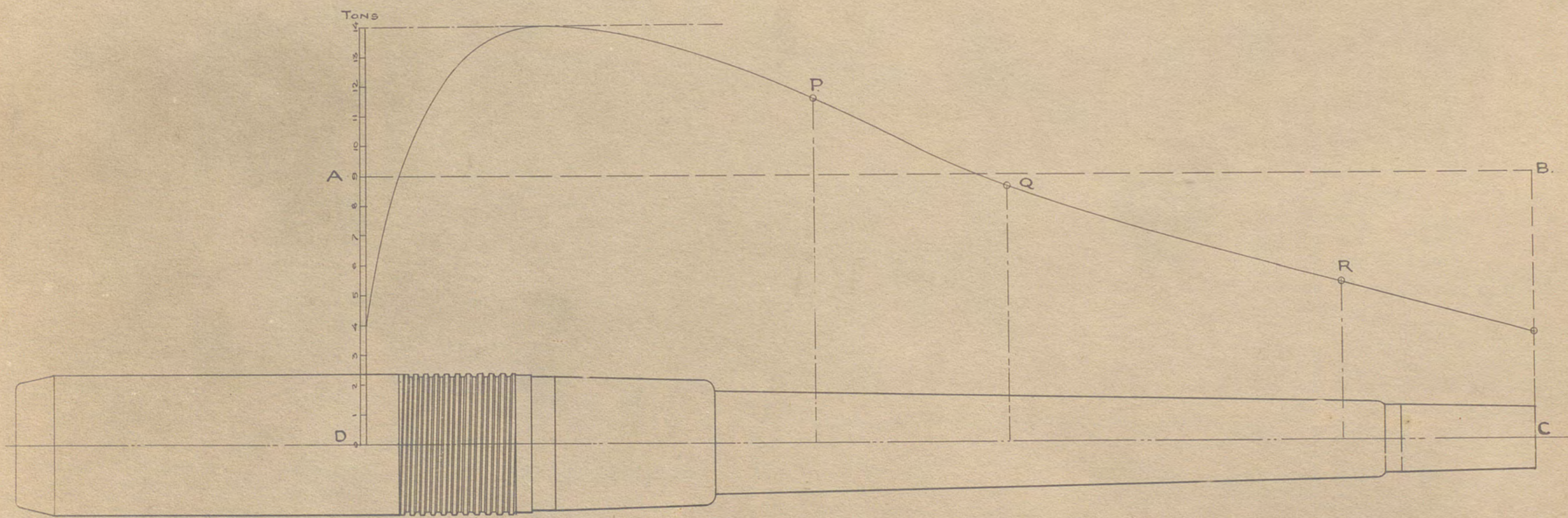


8 INCH. B.L.R. MARK. IV
(35 CAL.)
U.S.S. "IOWA"

problems of ballistics will become simple.

In the meantime, we can do something. A very interesting series of experiments has been in progress at Indian Head for more than a year past, under the direction of the Special Board, as a result of which, pressure curves have been traced for every one of our Service guns. These curves are not exact, but they are sufficiently close approximations to admit of many very valuable deductions. As illustrating the application of these curves, I will refer again to the drawing already shown of the 8-inch Mark III gun (IOWA'S), giving the curves of two powders;- one, manifestly too slow for a gun with an unhooped muzzle; the other, well suited to such a gun. Plate III.

Before showing the other curves which I have here, I will explain the process by which they were obtained. As you know, there have been several accidents to the 8-inch Mark III guns, in which the muzzles of the guns were blown off. The Board obtained permission to use these disabled guns for experiment. The guns were cut-off to different lengths, as shown in the accompanying sketch, and pressure gauges inserted at points along the chase, near the muzzle. (Plate VII).
These guns were fired with identical charges of powder, and the velocities noted. Pressures were also noted, both by the regular chamber gauges and by those along the chase. Comparing now, two guns of different lengths, the difference in energy given by the two affords a means of determining the mean effective pressure which was acting on the projectile



8 INCH B.L.R. MARK IV. (35 CAL)

(U.S.S. IOWA)

PLATE VIII.

while it passed over the length x.y. of the longer gun. For, it was this mean pressure, acting through the space x.y., which caused the difference in energy. Enough rounds were of course fired to eliminate accidental variations. The pressures thus deduced were compared with those recorded by the pressure gauges along the chase. But here, an allowance was necessary. These gauges are so suddenly un-masked to the effect of the gases as the band of the projectile passes them, that they feel the pressure as a blow, and are compressed just twice as much as they would be if the pressure were applied to them gradually? Again, the pressure recorded by the gauges should be greater than that which appears in the energy of the projectile, by the amount wasted in overcoming friction, imparting rotation, &c. Making allowance for these points, the pressures obtained by the two methods agreed rather surprisingly. We had then the following data: (Refer to sketch of type curve) Plate VIII.

1st. - The rectangle representing the total energy of the projectile A.B.C.D.

2nd. - The maximum pressure (but we do not know at what point along the bore this must be placed).

3rd. - The pressure at the points P.Q.R. along the chase.

The problem is now to draw a curve which shall enclose an area equal to that of A.B.C.D., which shall have a maximum ordinate equal to the maximum pressure, and which shall pass through the points P.Q.R.

Having done this for one powder, the experiment was repeated with several others covering as wide a range of granulations as could safely be used with the 8-inch gun. From all the data thus obtained, a formula was derived, or more strictly, the data was applied to the formulae already known, and these formulae were modified by the introduction of constants deduced from the actual firings. In the end, a formula was developed which accorded so consistently with practice that with the use of proper constants we could use it with confidence to pass from one weight of charge to another, from one granulation of powder to another, and, in so far as it was possible to judge,- from one gun to another. This formula was accordingly applied to other guns, and curves were worked out for all calibres and all powders in Service. The results indicated that up to the present time we have been inclining to powders rather slower than is desirable, the pressure curves being rather flat, and the muzzle pressures rather high for guns like the IOWA'S 8-inch.

The experiments with cut-off guns will be continued, and are even now being extended to the 4, 5, 6 and 12-inch calibres, with a view to correcting by actual experiment any errors which may have been involved in the application to these calibres of the formula which has been described.

The mode of combustion of a powder in any gun depends, as has been said, upon the size and shape of the grain. This is because the powder, in its colloided form, is so hard and tough, and so impervious to penetration by flame, that it can burn only in consecutive layers from the surface in. If the surface increases as the grain is burned, the gas will be given off more and more rapidly, and we shall have what is called a progressive grain, with a tendency to carry the maximum pressure far down the bore and to keep the pressure high toward the muzzle. If, on the other hand, the surface decreases as the burning goes on, the tendency will be to develop the maximum pressure early in the movement of the projectile and to give slower pressures toward the muzzle. Furthermore, it is evident that the thickness of the individual parts of the grain will determine how long the grain will take to burn through; that is to say, how long it will take to give off all the gas that it represents. We have, then, as determining the burning of the powder gases, three factors, which, while closely related to and dependent upon each other, have their individual effect; - the initial burning surface; the rate of change of this surface; and the total time of burning. These three factors can be varied widely by variations in the size and shape of the grain. I have here a number of grains which illustrate this point.

Show:

Cordite - cylinders.

Strips.

Multiperforated (Service)

" long stick.

Tube, short.

" , long.

Discuss various granulations.

As illustrating and confirming the statement which has been made that colloided powders burn regularly by consecutive layers, I have here a number of partially burned grains which have been blown out of guns at the Proving Ground. (Show and discuss).

The fact that the English use a granulation of solid cylinders, the French of strips, and our own Army and Navy a multiperforated cylinder, proves that there is room for wide difference of opinion as to the best form of grain. The subject is a large one, and one in which theoretical calculations should be checked by practical experiments. Such experiments have been outlined by the Bureau of Ordnance and would have been completed long ago if the pressure of work at the Proving Ground had permitted. It is proposed, shortly, to enter upon a rather elaborate program of experiments, to be carried out with the various cut-off guns, and to include all the different granulations which have been exhibited here, together with another of which I have no sample, - a perforated strip. These experiments will probably occupy a year or more, and may lead to important changes in the granulation of our Service powders.

With regard to the <u>composition</u> of the powder, there are possibilities of change in the future, though none of which I am at liberty to speak at present. In this, as in other matters, suggestions are constantly being received by the Bureau, from inventors who claim to have ideas of value. One of the latest inventions in the powder line has been brought out in England under the name of "Axite". Tests of this powder in small arms seem to justify the claim of the manufacturers that it has some advantages over Cordite for small calibres, but no reports have come to hand of tests in larger guns.

Whatever changes in the essential character of our powder may come with time,- there is no question that for some years we shall continue to depend upon the same composition that we are using at present. It is therefore of vital importance to perfect this in all details. For several months past, a Board has been engaged in revising the specifications under which this powder is manufactured, and while no radical changes have been found necessary, steps have been taken to perfect the product in two directions; in purity and in uniformity. As regards purification, there was not much that could be done, as our requirements have been gradually growing more rigid from year to year until there remained little more to be demanded. This little has, however, been insisted upon. In the matter of uniformity, there is room for considerable improvement. The ideal condition would be that every dimension of every grain should be absolutely identical with the corresponding dimension of every other grain. We shall never attain to this ideal with a powder which takes months to dry and which shrinks in drying. But the present conditions can be improved, and by making the requirements gradually more rigid, we can probably eliminate all sources of irregularity except those connected with shrinkage; and the irregularity resulting from this source can be overcome by careful blending.

With this increase in regularity and with more exact knowledge of the behavior of the powder in the gun, we may look forward to the time when no firing test of powder will be needed, the dimensions of the grain carrying with them full information as to the velocities and pressures for a given weight of charge in a given gun. Even where the powder is perfectly uniform, irregularities in its performance may result from imperfect inflammation of the charge, due to insufficient ignition. This is a reason for not reducing the present ignition charge, as has been suggested, with a view to getting rid of smoke. The question of ignition is one of the most important ones in connection with the use of nitro cellulose powder; and one which is receiving careful attention at present.

An important source of irregularity in actual firing will be reduced, if not entirely removed, by the change, already spoken of, from a slow to a quicker powder. The high muzzle pressure which results from the use of a slow powder means, among other things, that a large volume of gas rushes out immediately in rear of the projectile and continues to act upon the projectile for some time after both are clear of the gun. The projectile, in fact, moves forward for some time in an envelope of gas. Recent experiments at Indian Head indicate that this gas continues to accelerate the projectile for a considerable length of time after it leaves the muzzle, the increase in velocity outside the gun being in the case of a 6-inch projectile as much as

40 f.s. It is found that this gas not only acts somewhat irregularly in its acceleration, but that it is apt to make the projectile unsteady in flight. Naturally, the more of this gas we have to reckon with, the greater the irregularities which result from it. While on this subject there are certain other sources of irregularity in the behavior of powder which should be noted, though they are not of the same nature as those thus far referred, to. Differences in atmospheric conditions have an important effect upon any kind of smokeless powder, provided the powder is subjected to these conditions for some time before firing. The powder, if warm and dry, may give a much higher velocity than if cold or damp. A difference of 40° in temperature may make nearly or quite a hundred feet difference in velocity. The amount of solvent in the powder also has an important effect, an excess of solvent being unfavorable to high velocities. Although the powder is dried before issue to Service until it shows no change of solvent in several weeks, a slight evaporation goes on afterward and the powder gradually becomes quicker, with a tendency toward higher velocities and pressures.

Discuss toughness, critical point, &c.

PROJECTILES.

The last ten years have been marked by a steady improvement in the quality of projectiles, and by a pronounced advance in their efficiency due to the introduction of the cap. High explosives are also much more generally used for bursting charges - chiefly with common shells, but in some cases with armor-piercers.

The improvement in the quality of the steel comes partly from the use of special alloys which are doubtless allied to those used in high speed tool steel, and partly from new methods of tempering and annealing. As regards the alloys used, they all contain chromium and probably tungsten. And it is known that some manufacturers are experimenting with Vanadium. There is no other line of ordnance material in which the field for these alloys seems as promising as is that of projectiles. The net result of the improvements in composition and treatment, taken in connection with the introduction of the cap, is a shell which takes a bursting charge almost twice as large as the armor-piercer of ten years ago, and which, in spite of the thinning of the walls to make room for this charge, can be driven through its own calibre of Krupp armor, not only without fracture, but without deformation. The increased bursting charge which these shells carry makes their explosive action a much more important feature than it has heretofore been, and suggests the possibility of a change of policy with regard to the types of shells which should be used.

Ten years ago, the type of armor piercing projectile in general use was a thick walled shell carrying either a small bursting charge of black powder or no bursting charge at all. As indicating how little importance was attached to the explosive effect of these shells, it is significant that they were, in many cases, designated as shot. It was not considered practicable to drive through thick armor a shell with walls thin enough to carry a bursting charge large enough to be of any great importance. The necessity was recognized, however, of using, for other purposes than armor piercing, a shell of large cavity and thin wall, which should carry a large bursting charge and a sensitive fuse. The demand for such a projectile was met by a common shell of low penetrative power but great destructive effect. Manifestly, the armor piercer would be comparatively harmless if it struck an unarmored part of a ship, since it would pass through and out on the other side, damaging only such parts of the ship or personnel as might be directly in its path. On the other hand, the thin walled or common shell would be absolutely useless if it struck an armored part. In seeking for a compromise between these two types, the semi-armor piercing projectile was evolved, with the idea that it would be useful against armor of moderate thickness, and also against cruisers and the unarmored parts of battleships.

It is evident that neither one of the three types which have been mentioned is satisfactory for use in an engagement where it is desired to make sure of obtaining the maximum effect without reference to the nature of the target. If we are firing at a battleship, we wish to insure both penetration and explosion with the maximum destructive effect, whether we strike the turret or the unarmored super-structure; and it is at least regrettable that we should be obliged to put into the shell rooms of any ship projectiles which, under many circumstances will be altogether useless. The logical projectile for use with all guns and under all conditions would seem to be one which is capable of penetrating armor of at least its own caliber in thickness, and of carrying through that armor, and exploding on the inside of the ship, a bursting charge sufficiently large to do the maximum possible damage to the interior of the ship; and which, furthermore, can be relied upon to explode inside the ship with efficient fragmentation even though the target which it encounters is the thin side of a cruiser or the super-structure of a battleship. The effort of the last few years has been toward the development of a projectile capable of meeting these requirements; and it will be clear from what has been said of the latest development in armor-piercing projectiles, that considerable progress has been made in this direction. It is probable, however, that for some time to come, two types of projectiles will continue in use, these types gradually approaching each other through further improvements in armor-piercing projectiles, as a result of which the cavity in these projectiles will be enlarged until it shall admit a bursting charge large enough to give satisfactory fragmentation for use against the unarmored parts of ships. Even now, this condition could be fulfilled if a high explosive were accepted as a bursting charge for armor-piercing shells. Up to the present time, our Service has not thought it wise to adopt a high explosive ~~even~~ for common shell. Nor does there seem any satisfactory reason for doing this. If a common shell is to be used, black powder is about as efficient as a high explosive, and much safer than most high explosives. If there is a premature explosion in the gun, the gun is not seriously injured. The fragmentation of a common shell of black powder is coarser than that given by a high explosive, and would probably do more damage. It is true that the shock of detonation of a high explosive - considered without reference to the fragmentation - has an importance of its own, but its effect is less than is generally supposed. I speak here from personal observation of experiments recently conducted at Indian Head, the results of which have never been published. The Japanese high explosive shells, which were very thin walled and carried a large bursting charge, did surprisingly little damage to the Russian ships in the engagement of August 10th, of which engagement we know the results in great detail. It is altogether probable that black powder would have been more effective. Moreover, it is understood that one of the MIKASA'S 12-inch guns was burst and that two others were ruined by premature explosions of high explosive common shells in the bore. In short, the latest developments in the matter seem to justify the policy of using black powder for common shells. With regard to armor piercers which actually strike thick armor, it probably makes very little difference what explosive they are loaded with, provided it is one which can be trusted not to explode too soon. If the shell gets through the armor and explodes on the inside, the difference in effect between black powder and high explosive will not be great, although I am inclined to think that there would be some advantage on the side of the high explosive. But to my mind, the important point is that the armor piercer does not always strike thick armor, and we must consider what its effect is going to be when it strikes an unarmored part. No attention whatever seems to have been given to this point in discussions of the best type of shell and explosive. Brassey says, (1902, page 330) - "The writer does not attach much importance to the use of high explosive bursting charges for projectiles used for the attack of thick armor. - - - If a barbette were pierced, the fragments projected by a shot would be sufficient to put the guns out of action without any explosion inside. And if the belt were pierced there are no men immediately behind it to be demoralized by an explosion". All of this, and nearly all the discussion that has appeared in the successive numbers of Brassey, assumes that armor piercing shells will always strike armor. Starting with this tacit assumption, the Annual of 1904 expresses the opinion that for the present the projectiles in common use will be:

Nose-fused thin-walled shells filled with high explosive.

Base-fused armor-piercing shell filled with black powder.

While this doubtless accords with the official view in England, it differs from the official practice, in that, so far as I have been able to learn, no high explosive shells larger than 5-inch are issued to ships. The large calibre shells, whether common or armor-piercing, are loaded with black powder. In my opinion, the rule just quoted from Brassey is exactly the opposite of what it should be. Assuming, for the moment, that we have a high explosive which is satisfactory for use as a bursting charge, and assuming also that we are to continue to use two types of shells, I would load the thin walled shell, which is to carry a very large bursting charge, with black powder, which will give perfectly effective fragmentation, and which, if it explodes in the bore will do no serious damage. And I would load the armor-piercer, which carries a small charge at best, with high explosive, in order that, if it struck an unarmored part, it might still be effective, - which it would not be if loaded with powder. If this shell explodes in the bore it may destroy the usefulness of the gun, but will not burst it.

Brassey gives two reasons for preferring black powder for armor piercing; first, that a Lyddite shell fired against armor is likely to explode by shock before complete penetration; and second, that base-fuzes must be used with armor piercing shells, and there is danger with a base-fuze that flame will penetrate to the bursting charge and cause a premature explosion in the gun.

Now as to the first of these points, - the danger of explosion against the plate before penetration,- this danger does exist in the case of Lyddite, but there is no difficulty in finding explosives with which it would not exist. As to the second point,- the danger of premature explosion in the gun where a base-fuze is used,- this depends altogether upon the fuze and how it is protected. We may admit that it is not worth while to use, in armor piercing shells, a high explosive which is liable to detonate prematurely, whether against the face of the plate or in the gun. In other words, the adoption of a high explosive for any type of shell can only be justified if both the explosive itself and the fuze to be used with it are thoroughly trustworthy.

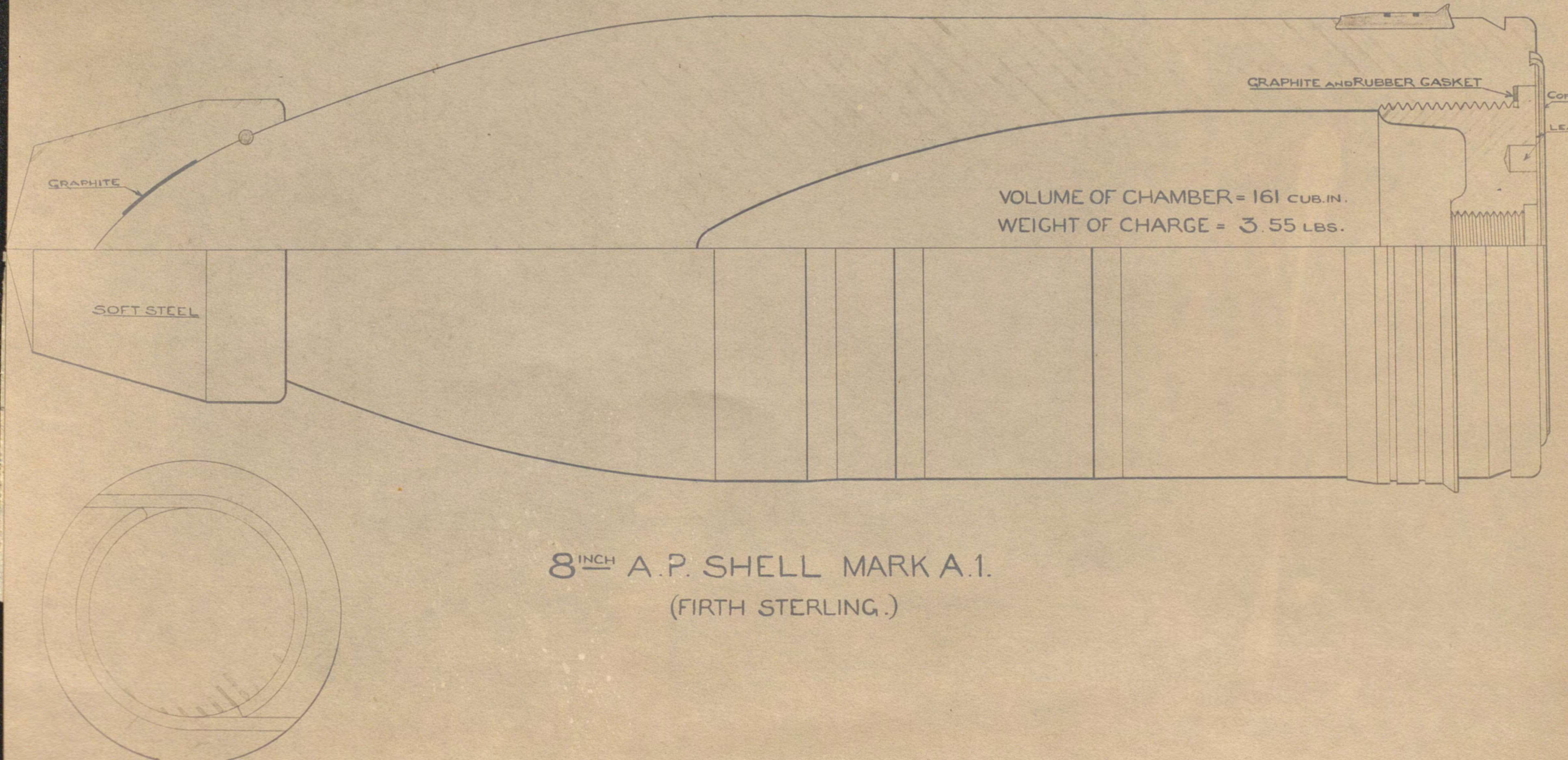
About three years ago, the United States Army adopted, after very thorough test, a high explosive for use in shells, which they call "Explosive "D". Since that time something over 1000 rounds have been fired with this explosive in guns of all calibres, from 3-inch to 16-inch, many of them with excessive pressures, without accident of any kind. The material seems to be absolutely stable and inert under all conditions of temperature, showing no disposition to either decompose or to form compounds with other substances. As far as can be seen, it is much the safest explosive that has ever been proposed for military use. It can be detonated by a suitable fuze, but in no other way that has been yet discovered. It has been repeatedly fired against armor plates, thick and thin, and in no case has it ever exploded by the shock of impact. The Naval

Bureau of Ordnance is at present experimenting with this explosive and there is much reason to believe that it will be adopted, for use with one or both of our Service shells. An important feature about it is that shells can be loaded with it quickly and safely by the use of very simple tools which require neither experience nor special skill. In the Army, the shells are stored empty, and the explosive is kept in boxes in the magazines. On the threat of war, the shells are to be loaded and fuzed. A similar plan might be adopted on shipboard, a small number of shells being always ready. There is, however, no necessity for this, as the material does not deteriorate in the least by keeping.

(Show sample of Explosive "D").

The fuse which the Army has adopted is ingenious and has shown itself abundantly safe, but it has some features which are not entirely satisfactory from a naval point of view, and we are at present experimenting with a fuze which gives promise of answering our purposes perfectly. The characteristic features of this fuze are that the detonating fuze compound is carried in a safety chamber from which it cannot escape until the projectile is clear of the gun; and that the action of the fuze is as certain against a thin plate as against a thick one.

If we finally adopt "Explosive D", it may be possible for us to do away with common shells and use only one type for all purposes. Attention has already been called to the advantages of adopting this policy whenever circumstances make it practicable to do so. The latest type of armor-



8 INCH A.P. SHELL MARK A.1.
(FIRTH STERLING.)

piercing shell lends itself well to this change. As already stated, it has thinner walls than any projectile heretofore used for armor piercing, and therefore carries a larger bursting charge. In spite of this thinning of the walls, it penetrates its own calibre of Krupp armor, withour fracture or deformation. Its walls are too tough to give satisfactory fragmentation with black powder, on striking thin plating, but with "Explosive D", the fragmentation is all that could be desired. It is, in fact, quite as satisfactory as that of a common shell, the pieces being larger, without being too large. The accompanying sketch shows the details of this shell, (Plate IX) together with the latest form of band, and details of the base-cover used to protect the fuse and the bursting charge from danger of premature ignition. This is essentially the arrangement which has been used by the Army in all their experiments with "Explosive D", with the result that, as already stated, more than 1000 rounds have been fired without accident.

The development of armor-piercing shell abroad has just about kept pace with that in this country, but it is interesting to note that the Firth Sterling Company of Pittsburg was the first firm in the world to produce a shell with a large cavity which would penetrate its own caliber of armor and remain in efficient condition.

Hadfield, in England, claims to have penetrated a 12-inch Krupp plate, with a 9.2 inch shell. If this is true, he has beaten the world.

An interesting application of "Explosive D" by the Army, is its use in what is called a "Torpedo Mortar Shell". This is a very thin walled shell, holding in the case of a 12" mortar, 130 lbs. of explosive. Such a shell if landed on the deck of a battleship would go through at least to the armored deck before exploding, and would, in all probability, wreck pretty much of the interior even if it did not sink the ship. But the Army Officers believe that this is not the only advantage of their "Torpedo Shell". They hold that if it strikes the water within 20 feet of the ship's side and explodes after penetrating to some little depth, say 10 or 20 feet, it will still damage the ship very seriously if it does not sink her. It should be noted that this view has nothing in common with the theory held by Gathmann and others, that the detonation of a large charge of high explosive in the air against the armor of a ship would do great damage.

To test this theory, the Board on Ordnance & Fortifications had a target constructed at the New York Navy Yard representing a section of a battleship, complete in all details of plating, rivetting, bulkheads, &c. This target was towed to Sandy Hook and moored in 30 feet of water. A torpedo shell such as has been described was suspended in the water and exploded 15 feet from the side of the target, and at a depth of 15 feet below the surface. The photographs herewith exhibited show the rather startling result.

PB