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Ordnance
Armor

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CONFIDENTIAL

Section 7
Envelop 4

Year 1910.

No. 138.

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Contents: Lecture Conference 1910.- Recent developments in Ordnance and Armor.

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Ordnance

LECTURES

DELIVERED AT

NAVAL WAR COLLEGE

BY

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U.S.N.

JULY - 27 AND 28

1910.

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

1st. Very marked increase in the size and power of guns.

2nd. Some improvement, not very marked, in powder, and a gradual improvement in our knowledge of the behavior of powder in the gun.

3rd. Improvements in armor, confined chiefly to thin plates.

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

5th. Improvements in mechanical details of ordnance material, such as mounts, sights, etc.

G U N S.

In the development of the gun, we have passed rapidly from the 12-inch 40-caliber of the NEBRASKA Class to the 45-caliber 14-inch which will be carried by the ships to be laid down this year, with a jump in muzzle energy from 45,000 to 65,000 ft.-tons.

The sketches on the walls show rather strikingly the gain in power and danger space as well as the increase in size and the changes in details of construction, corresponding to the successive steps of this advance.

As between the 12-inch 45 and the 12-inch 50 (sketch), the gain in power results principally, of course, from the greater length of the gun; that is to say, from the greater space through which the projectile is subjected to the acceleration of the powder gases; but this condition leads to other changes, in that it calls for a somewhat greater charge of powder and for a slower burning grain, which admits of keeping up the pressure throughout the greater length of bore. Moreover, as it is desirable to keep down the weight of charge as much as possible, a somewhat greater "density of loading" is provided for than has heretofore been used in our guns. This "density of loading", which plays an important part in all problems of interior ballistics, is the ratio of the actual volume of the powder to the volume of the chamber. By increasing this ratio we get higher pressures, but use the powder more economically, - getting more work per pound of powder. The ratio commonly varies from about .45 to .65.

One of the principal difficulties connected with the design of a gun 45 or 50 calibers in length is to provide for longitudinal <u>stiffness</u>. Such a gun has necessarily a tendency to droop, first because of the elasticity which is inherent in a girder of this length and second because of the accentuation of this feature through the <u>slip</u> between the parts of a structure built up of successive layers shrunk one upon another. This droop is a particularly serious feature of wire-wound guns and one of the most serious objections to the wire-wound system. The English, who have used this system for many years, have had a great deal of trouble with their 50-caliber 12-inch guns, and it is reported that a large number of these guns have been withdrawn from the dockyards to which they had been sent, for modifications which amount almost to rebuilding. Not only was the droop excessive, but the bore was found to choke after a comparatively small number of rounds, so that there was actually danger of the projectile jamming in the bore. This was associated with other features which seemed to prove that the contraction was really a squeezing in of the tube by the tension of the wire. The net result of the whole trouble is that the English will probably give up wire-winding altogether. It is known that their latest 12-inch guns are built up like ours, and that the same system has been adopted for the 13.5 guns with which their latest Dreadnoughts will be armed.

The advantages claimed for the wire-wound system are -

1st, that it is cheaper.

2nd, that a flaw in the wire cannot escape detection, and -

3rd, that the gun can be given a greater ultimate strength, so that it is less likely to burst.

Its elastic strength is no greater than that of a built-up gun, so that the wire gives no gain in working strength, since a gun which is worked beyond its elastic limit becomes deformed and loses its accuracy even though it does not burst.

There is, of course, a certain advantage in an increased security from explosive rupture; and the question of cost can not be disregarded. But these advantages are gained by a sacrifice in longitudinal strength and longitudinal stiffness, and, if we may judge from the English experience, in a tendency of the wire to close in upon the bore, with an accompanying tendency for the tube to creep, - a tendency which would manifestly be resisted much more by a heavy hoop or jacket with a long bearing surface held in contact by shrinkage, than by the turns of a coil of wire.

A representative of the Vickers Ordnance Company - the firm which is building the 13.5-inch guns for the new Dreadnoughts - stated in the Bureau of Ordnance a few weeks ago, that his Company will never again have anything to do with wire-winding, and that the system would have been given up in England years ago, but for the influence of Sir William Armstrong, who owns the patents for wire winding.

The wire-wound gun shown in the sketch herewith is the present standard of the United States Army.

As regards the power of our guns, this appears to be in all cases equal to that of similar guns abroad, although it is possible to juggle with figures in such a way as to make it appear that this is not the case.

There are two ways of rating guns; first with reference to the maximum power that can be obtained by forcing them up to the highest pressure that they can be expected to stand; and second, with reference to the work which it is proposed to require of them in service.

Naturally, those firms abroad - and in this country too, for that matter - which manufacture guns for sale, give out the highest results that they can obtain from their guns, and in many cases results which are only estimated; and which neither have been, nor can be, realized. By taking velocities and energies of foreign guns from data sent out by Vickers and Schneider and Krupp and comparing these with the service velocities established for our own guns, it can be made to appear that the United States Navy is behind, when the exact opposite is the actual fact.

The following tables illustrate this point:

	Length in Cal.	Muzzle Energy f.t.	Initial Velocity.	Weight Gun Tons	Weight Projec Lbs.	Weight Charge Lbs.	Maximum Pressure Tons.
U. S. (Mk. VI)	45	48,984	2,850	53.6	870	340	17.8
British (Mk. X)	45	47,697	2,900	58	850	325 Cordite	
Austria (Skoda)	45	47,402	2,625		992		
U. S. (Mark V)	45	43,964	2,700	52.9	870	305	16.5
Japan (1907 Mod)	45	42,900	2,700	57	850	250	
French (1906 Mod)	45	42,890	2,870		750		
Italian	40	36,925	2,500		850		
Russian	40	33,750	2,600	59	720		
Krupp	50	56,473	2,877	62.4	981	375	
Schneider	50	55,717	3,116	57.3	826		
Beth.	50	54,280	3,000	66	870		
Vickers	50	53,400	3,010	65	850	344	18.5
Elswick	50	51,640	2,960	69	850	318	
U. S. (Mark VII)	50	50,700	2,900	56.1	870	325	17.
U. S. (14" Mk.I)	45	65,606	2,600	63.3	1400	360	17.

Our 12-inch 50 gun, which is credited in this table with 2900 f.s. initial velocity has actually given 3031 f.s. and could undoubtedly be made to give 3100, but this would call for something like 20 tons pressure, which is more than we think best to give for service. Nor does any foreign Navy use such pressures as this in service, or the velocities corresponding. The English 12-inch Mark X gun, credited in the table with 2900 f.s.,uses 2700 f.s. in service. And so with most of the other guns, and probably with all of them.

The German Navy has, until within the last two years, been satisfied with 11-inch guns, and this is the caliber used on the first of the German Dreadnoughts. The later ones are to have 12-inch guns, probably of 45 calibers; that is to say guns about equal to our Mark VI on the CONNECTICUT Class.

France has a new 12-inch, of 50 calibers, but none of this type will be in service within three years.

Japan has also adopted a 50 caliber 12-inch, but will not have the first one of these afloat for at least two years.

It is impossible to get any exact figures about the English 13.5 gun, but it is probably a little inferior to our 14-inch. It may be that the velocities will be forced to give a muzzle energy somewhat beyond this; but if so the increase in power will be gained at a high price in the wear of the gun.

It has been suggested that our 14-inch might be crowded up to 2700 f.s. This would give a small increase in energy and a very marked increase in wear, together with more or less irregularity in velocity, such as always results from crowding a gun to its utmost capacity.

Time will permit me to call attention to only a few of the points in which the latest guns differ from the earlier ones. The most important of these has to do with the use of a liner in the most recent designs of large caliber guns, to be inserted as a part of the original construction.

It seems to be very generally believed that the object of the liner is to make relining easy when the bore becomes much worn. This may be, and probably is, an incidental advantage of the liner, but the reason for its adoption is something quite different. It has been discovered within the last few years that as the wear of a gun progresses, there are developed heat cracks in the metal of the bore, chiefly at the corners of the grooves, which, starting as very minute hair cracks, gradually widen and deepen until they reach dimensions which threaten to be dangerous. There is no evidence that they have ever contributed to the bursting of a gun; but there is no question that they might do so, if they increase progressively and indefinitely. The object of the liner is to localise them and prevent them from spreading beyond a certain point. It is made as thin as is consistent with the mechanical requirements for inserting it, and is held only by friction and by its bearing on the shoulders indicated in the drawing - not by shrinkage.

There are many difficulties connected with the manufacture and insertion of a liner in a gun 50 feet long, and difficulties of a different kind to be dealt with after it is in place. As it is inserted with very little shrinkage, it has a disposition to creep forward, being dragged by the tremendous friction of the forcing band on the projectile. These and other considerations, which cannot be disregarded, such as the additional cost of manufacture and the greater time required, may lead to a decision not to use the liner in the guns as built originally.

Another feature of the latest designs has to do with the angle of the band slope. This angle was very greatly reduced a few years ago, chiefly to facilitate hand-loading. With a sharp slope at this point there is a chance that the projectile may jam as it is rammed home. The longer slope is unquestionably helpful in this respect, but it has a disadvantage in that a very small amount of wear permits the band of the projectile to go forward by a considerable amount; thus virtually increasing the volume of the chamber and shortening the travel of the shell, - both of which changes have the effect of reducing velocity. The serious factor here is not that the velocity is reduced, but that the ballistics of the gun and the resulting ranges are changed from those for which the sights are graduated.

In the latest designs, the band slope is made so sharp that a large amount of wear will carry it forward very little.

To meet the difficulty in the guns which actually have the long slope, a device is being tested at the Proving Ground in which "augmenting strips" are added to the bands of the projectiles, increasing the diameter of the band and so holding the projectile back in its normal position. These augmenting strips, if they are found to work well, can be sent to ships and put in place on board.

A uniform twist has been adopted for the rifling of all guns in place of the increasing twist which has been in use heretofore.

There has been no change in the material of guns since the adoption of nickel steel. There are various alloys in sight which may become very valuable for guns, but none have yet been so far proved as to justify their adoption. It is particularly desirable to find a metal for the bore which will resist erosion better than the steel now used. This matter of erosion is assuming greater and greater importance with every increase in the power of guns.

There have been many theories put forward to account for erosion. One of these attributes 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. Another attributes the trouble to the friction of the band. It seems now, however, to be pretty well established that while both of the causes 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 the gases as they rush down the bore, there is undoubtedly something of a vortex-action, which carries the mass of the gas <u>around</u> 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.

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 calibers 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 sheared 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.

(Exhibit bands.)

This difficulty has been met, for the present, by a change in the size of the rotating bands, the new band being much 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 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 shearing, has been made, in changing the material from the soft copper, which has been used for many years, to cupro-nickel. As a result, we have a band of harder metal and with much more metal to be sheared. With this band, 12" guns have been fired up to 110 rounds, and the projectiles are still steady.

The further trouble which results from erosion, - the change in the position of the band, with the resulting change in ballistics - has been already described.

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 are 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 to be 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. A Japanese officer who was in Washington a year after the war stated that practically all of their turret guns were worn out.

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

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 low carbon steel, without nickel, is the best material available at present for the tubes of guns.

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, than 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.

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 .... 350 rounds.

8-inch guns .... 200 rounds.

12-inch guns .... 140 rounds.

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 in 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, and we must expect to reline our large caliber guns from time to time. This calls for a reserve supply of guns to replace those which are withdrawn and sent to the shops. The policy has been adopted of building one spare for every four guns assigned to ships and I am glad to be able to state that this reserve is practically in existence today.

It is of course not permissable to wait until a gun is really worn out before relining it. This might result in our entering upon a war with guns so nearly worn out as to make the situation critical. It is proposed, as far as possible, to reline turret guns when they have fired from 80 to 100 rounds.

PROJECTILES, EXPLOSIVES and FUZES.

After a period of several years, in which the development of projectiles was altogether unsatisfactory, a marked advance has taken place within the last year; and two firms, the Bethlehem Steel Company and the Crucible Steel Company, are now manufacturing projectiles up to the 12-inch caliber which are unquestionably superior to any heretofore made in this country. Moreover, there is every reason to believe that they are at least as good as any that are being produced abroad.

An important change in the type of projectile is the introduction of the long point, the ogival of which has a radius of seven calibers as against two and one-half calibers which was used until two years ago.

The advantage of this shape is - for the present at least - confined to an increase in range and in remaining velocity at long ranges; - in other words, to the reduced resistance of the air to the new form of the projectile. With a muzzle velocity of 2900 f.s., the striking velocity of the old shell at 6,000 yards is 1950f.s., and of the new, 2350 f.s. At 10,000 yards, the figures are 1600 f.s. and 2029 F.S.

The result is that at 6,000 yards the new projectile will penetrate about 20% more armor than an old one, and at 10,000 yards nearly 30% more.

Please observe, however, that this is a question of velocities only. For a given velocity, the old point has greater penetrative power than the new one, the reason for this being, in all probability, analogous to that which makes it easier to punch a hole through boiler plating and similar material with a blunt tool than with a tapered one. The blunt tool - or projectile - drives the metal before it in the line of its own momentum, which is at the same time the line of least resistance for the plate; that is to say, to the rear of the plate. The tapered tool or projectile attempts to wedge its way through, to do which it must force the metal to the sides, where it is resisted by the mass of the surrounding metal and so has no chance to flow. The effect is very strikingly illustrated in the photograph of a number of long-pointed 5-inch projectiles which were practically "wire-drawn" in passing through a 6-inch plate.

This being the case, it is desirable to combine the long and the short points on the same projectile, the long point serving for flight and the blunt one for penetration. This is accomplished by the use of a false cap, or "wind-shield", which is attached to the blunt point and carries forward the contour of the long point. This shield gives way upon striking, without playing any part in penetration; and the blunt point, with its regular cap, is left intact to do the work against the plate.

The improvement which has been referred to in the quality of the steel comes partly from the use of special alloys, which are secret, but 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 are believed to contain chromium and vanadium and probably tungsten, and their effect is to produce a fibrous structure in the head of the projectile, without sacrificing the hardness which in ordinary steel is invariably accompanied by a crystalline and rather brittle structure. There is no other line of ordnance material in which the field for special alloys seems as promising as is that of projectiles, nor any in which the improvements actually accomplished are more striking. The net result of these improvements, taken in connection with the use 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 caliber of Krupp armor, not only without fracture, but without deformation. This makes the explosive action a much more important feature than it has heretofore been, since we can now expect to burst the shell inside the ship. At the same time, the very great increase in the toughness of the shells makes the problem of bursting them a difficult one, and adds enormously to the desirability of using a high explosive bursting charge.

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 possible at that time to manufacture a projectile, the walls of which were thin enough to leave room inside for a large bursting charge, and which nevertheless could be driven through a thick armor-plate. The desirability was recognized, however, of having for some purposes, a shell carrying a large bursting charge, and since such a shell could not be expected to penetrate armor, it was necessarily provided with a very sensitive fuze. This was our "common shell" of ten years ago. Manifestly, this shell would be useless if it struck an armored part of the ship; and similarly, the armor-piercer of that day, being practically non-explosive, could do little damage if it struck an unarmored part. In seeking for a compromise between those two types, the semi-armor piercing projectile was evolved, with the idea that it would be fairly effective against armor of moderate thickness, and equally so 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 against a battleship, where it is important to produce the maximum effect whether we strike thick or thin armor.

The logical projectile for use here is one which is capable of penetrating armor 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.

This calls for certain characteristics in the projectile, the explosive and the fuze.

The projectile must have a rather large cavity in order that it may take a fairly large charge of whatever explosive is to be used, and it must be made of the highest grade of steel that can be had in order that it may be driven through thick, hard-faced armor, without fracture. As already explained, this projectile has been developed and is now available.

The explosive must be so insensitive that it can be driven through any armor which the projectile will penetrate, without danger of exploding by the shock and friction of the impact; - it must, in fact, be so insensitive that nothing will explode it except the action of a fuze. It must, on the other hand, be so powerful that when exploded, it will rupture the very tough shell which has been described with a fragmentation of such character - neither too coarse nor too fine - as will make it effective against either material or personnel. It is evident that if the explosive will stand the shock of impact against the plate, it is in no danger of exploding in the gun.

As regards the fuze, this must be secure from the possibility of explosion in the bore, and must have a delay action of such a length and such a character that it will act with equal certainty whether it strikes a thick or a thin plate, giving, in each case, an explosion behind the plate; - that is to say, inside the ship.

Such a combination of projectile, explosive, and fuze, is, I believe, in sight. For the past five years, the Bureau of Ordnance has been engaged in tests of an explosive and fuze which seem to meet all the requirements, and these tests have come to a successful termination coincidently with the successful development of the projectile. This means that we shall shortly have a single type of projectile for all purposes, that it will be loaded with a high explosive which is safer than black powder, and incomparably more powerful, and that it will be fitted with a fuze which explodes the projectile immediately after the penetration of a thick plate, and about 25 feet beyond the thinnest structural plate.

As establishing the safety of the explosive, which is known as Explosive D, I may state that more than two thousand rounds have been fired with shells charged with this explosive without a single accident. In many of these rounds, the pressures have run up well above 20 tons. In many instances the projectile was broken up on the face of the plate, scattering the explosive about, unexploded and unburned. In a considerable number of other cases, either because no fuze was used, or because the fuze if used, did not act, the projectile was driven through thick armor unexploded.

These facts may be taken as absolutely conclusive with regard to the safety of Explosive D from accidental explosion by shock of any kind, since it is evident that the shock of impact of a projectile against a thick plate is enormously greater than any other shock by which the explosive could be subjected. As no precautions were taken in loading any of these shells to reduce friction against the walls, the material being packed into service shells without burster bags or lacquer, the evidence of the above rounds is as conclusive with regard to friction as it is with regard to shock, and demonstrates conclusively that as regards both shock and friction, Explosive

D is safer than black powder, which, as we know, is exploded by impact against thick armor, and not infrequently by the firing of the gun.

There are, of course, many other points to be considered in connection with a subject of this kind. One of the weak points about picric acid, for example, is that it may combine with metals under some conditions, forming picrates which are much more sensitive than the acid itself. Explosive D is absolutely inert in this respect. It undergoes no change when subjected for a long time to excessive temperatures. And so with regard to other points. It is, in short, the safest explosive of which we have any knowledge, with the possible exception of wet gun-cotton.

The question of a fuze to be used with such an explosive as has been described, involves certain considerations beyond those already referred to. The most important of these has to do with the results of an accidental explosion of the fuze in handling or transportation. It is evident that the results of such an accident on shipboard would be far more serious than on shore, so that a fuze which is satisfactory for the Army may be less so for the Navy.

The Army has a fuze which gives fairly satisfactory results, and with which no accident has ever occurred. It has, however, two features which are not satisfactory to us. The detonating compound of the fuze is immediately surrounded by the explosive charge of the shell, so that an accidental explosion of the fuze cannot fail to explode the shell. And the delay action of the fuze - in cases where a delay is used - depends upon the burning of a column of compressed powder; always an unreliable method of getting delay.

The fuze which we expect to adopt carries the detonating compound in a safety chamber which is cut off from the interior of the shell by barriers, which open automatically after the projectile has left the gun, opening a passage through which the detonating charge moves forward when the projectile strikes. The distance through which this charge must move determines the interval of delay. To accelerate this in case of striking a thin plate, a small black powder charge is ignited by a primer, and drives the detonator forward like a projectile from a gun.

In certain experiments which have recently been made at Sandy Hook under the direction of the Board on Ordnance and Fortifications, some very interesting points have come up, with regard to the effect of high explosive projectiles striking thin plates at such angles of impact that the projectile cannot bite.

In such cases, the projectile is ordinarily thrown off without important effect, the plate being, at the worst, dished and cracked. It is found, however, that in cases where the projectile greatly overmatches the plate, - as for example, where a 12-inch projectile was fired against a 5-inch plate, (15° between the face of the plate and line of fire) the high explosive, if it can be detonated while the projectile is in contact with the plate, adds enormously to the effect of the blow. In the case above referred to, for example, where a 12-inch projectile was used against a 5-inch plate, the projectile when loaded with sand glanced off without appreciably damaging the plate, whereas the same projectile when loaded with a high explosive, which was detonated by an instantaneous action fuze while the projectile was in contact with the face of the plate, blew in a large fragment of the plate, and completely wrecked the compartment behind.

The explanation of this effect seems to be that the impact of the heavy projectile against the light plate drives back the plate locally, setting up strains which weaken the plate for the instant and prepare it to yield under the added effect of the high explosive, which, being confined by the <u>strong walls</u> of the armor piercing projectile until the gases have developed their full pressure, detonates with maximum effect against the plate. It is important to recognize the difference between these conditions and those which exist in the case of the Gathmann and Isham projectiles, where the characteristic feature of the plan is to use a very thin walled projectile which crumbles against the plate without setting up any strains, and without permitting the development of the full explosive force of the gases.

It should be remembered, moreover, that the effect above described has no application to the case where the armor and the projectile are even approximately matched. In this case, assuming such an angle of impact that the projectile cannot bite, there is found to be no important difference between the impact of a projectile loaded with high explosive and one loaded with sand; and as this case is the only one in which a <u>vital</u> effect can be hoped for, (since the vital parts of a battleship are necessarily protected by thick armor) it would seem to be an error to select our projectiles, explosives, and fuzes with reference to the effect of a heavy projectile against a thin plate. These remarks are suggested by a discussion which recently took place at Sandy Hook, following upon one of the firings above mentioned, in which the view was expressed by several officers that the best projectile to be used against a battleship was one carrying a large charge of high explosive, (viz., a common shell) with a fuze so sensitive as to act instantaneously upon impact.

With such a projectile there is no chance of piercing thick armor - if such armor is struck at a penetrating angle, - or of securing an inside explosion. In other words, this view sacrifices all chance of vitally damaging the enemy, and limits itself to exaggerating as much as possible the effect of blows which, at their best, could never destroy a ship or determine an action.

The experiments which have just been described have suggested several important points to those officers who are charged with the design of ships. One of the most interesting of these has to do with the effect of a 12-inch high explosive shell striking a turret roof and detonating instantaneously. The roofs of some of our turrets have an inclination of about 5°. If the ship is rolling toward the enemy, it may be necessary to add several degrees to this. And if we allow for an angle of fall to the projectile of 3 or 4 degrees more, we have an impact angle of approximately 15° for a plate only 2 inches thick.

In the experiment to which I have referred above, a large hole was blown through a 5-inch plate, with an angle of impact of 15°, and the compartment behind this was absolutely wrecked. As a result of this experiment, the turret roofs of future ships will be made flat and their thickness increased to 4 inches of special treatment steel. Observe that in this experiment there were combined two features which logically should not go together; - a thick-walled armor-piercing projectile and an instantaneous fuze.

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 <u>in the air</u> against the armor of a ship would do great damage.

To test this theory, the Board on Ordnance and 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, etc. 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 side plating of the ship was torn away from the frames and a very large hole opened, starting leaks which would have been very serious if not fatal to a battleship.

This experiment, like the one with thin plate already described, has had important results upon the designs of our ships, - taken in connection, as it naturally has been, with the action of mines in the Japanese-Russian War.

As it happens, several other questions have come up quite recently which are closely related to those which have just been discussed. It is held by some authorities that there is great danger of penetration of the hull of a ship below the armor belt by large projectiles which fall short of the ship and run like torpedoes under water. A recent invention, the Davis "Torpedo-gun", aims to discharge a projectile from an automobile torpedo striking the bottom of a ship or even a net at a distance from the hull. Thus many factors are combining to demand more protection for the hull of the ship below the armor belt. As you are all aware, this demand has been met to some extent in recent designs of battleships by a marked increase in cellular division of the underwater hull, but it is not improbable that a certain thickness of armor - perhaps 2 or 3 inches, of special treatment steel - will be used on the sides, below the belt and extending down to the turn of the bilge.

I think it safe to say that in adopting a high explosive of the kind that I have described above, we are taking a step which places us, so far as this particular point is concerned, well in advance of all other Naval Powers of whose policies we have any information. It is true that other Powers use high explosives for shells. England, France, Germany and Japan, for example, use Picric Acid under the names of Lyddite, Melinite and Shimose.

But none of them use this, or can use it, in armor-piercing projectiles, because it is so sensitive to shock that it explodes by impact without penetration, when fired against a thick plate.

This at once limits its use to thin walled common shells. Even for these it is far from satisfactory, because it frequently explodes in the bore of the gun. It is well known that several of the MIKASA'S turret guns were disabled during the action of the 10th of August outside Port Arthur, through the premature explosion of shells loaded with Shimose. There have been numerous accidents in England with Lyddite and in France with Melinite. The fact that Picric Acid continues in use in spite of these accidents and in spite of the further fact that it is not available for armor-piercing projectiles, proves the importance that is attached to the use of high explosives by the leading Naval Powers of the world, and justifies the statement that in adopting the explosive which I have described, we have taken a step in advance of the four Powers named above.

Before leaving the subject of explosives, I may mention that a good deal of attention is being given at present to tri-nitro-toluol, - a substance which stands between Explosive D and Picric Acid in sensitiveness.

The Army has been more or less dissatisfied with Explosive D because it is too insensitive. Their fuze will not detonate it directly, and they have to use a booster of Picric Acid. They have been experimenting with toluol, which at first seemed very promising. It turns out, however, to be so sensitive that it cannot be driven through thick armor without exploding. So it has been rejected for armor-piercing projectiles, but will probably be used for field gun ammunition.

CAPS FOR PROJECTILES.

In connection with the new long-pointed projectile, there has been much discussion of the shape and material best fitted for caps, and, in general, of the part which the cap plays in connection with penetration. One theory 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 piercing instrument into a smashing 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.

The behavior of the cap is not altogether consistent, 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 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.

P O W D E R S.

I come now to the subject of Smokeless Powder, with regard to which it seems worth while to remark, first of all, that the term "smokeless" is far from being completely descriptive, its smokelessness being, as a matter of fact, an incident rather than an essential. The principal characteristic of nitro-cellulose powders, as compared with other powders, is their enormously greater force. Gun-cotton was invented about the middle of the last century, and almost immediately artillerists began to speculate as to the possibility of utilizing its tremendous power for propulsive purposes. Its expansive force is something like five times that of black powder, and it was this fact which attracted attention to its possibilities as a propellant.

It is the realization of these possibilities in our present powder which has carried the velocity of the 12-inch gun from 2000 to 3000 foot-seconds, and the energy from 26,000 to 50,000 foot-tons. By 1895, when brown powder may be said to have been perfected, a point had been reached in the development of charcoal powders where practically their full power was being utilized and the only hope of any material improvement lay in the discovery of some entirely new propellant. In the search for this, very little thought was given to the question of smoke, although it was realised, of course, that one of the features which contributes to the great power of gun-cotton, - the fact that all the products of its combustion are gaseous, must make it smokeless or nearly so.

For many years, - from about 1850 to, let us say, 1885, - the efforts which were made to tame the new explosive and to make it give out its power progressively, were failures. However finely it might be divided, and however tightly it might be packed, it burned irregularly and often violently, giving results which at the best were unreliable and at the worst were exceedingly dangerous. Two things were needed:- first, to destroy the woody cellular structure of the cotton, and second to weld the particles into a mass so compact that the flame could not flash through it, and so tough that it could not break up. Both of these requirements were met, and the problem of a gun-cotton powder solved, by the discovery that certain substances had the power to dissolve the cotton, entirely destroying its cellular structure and forming a pasty glutinous mass, from which the solvent could be afterward dried out, leaving a hard, tough, horn-like substance, so entirely impervious to flame that it could burn only in concentric layers from the outside. Such a substance is called a colloid, a term for which it is difficult to find a satisfactory definition, but of which glue, gelatine, and collodion are familiar examples.

Of the solvents which have this property of forming a colloid with gun cotton, one is a mixture of alcohol and ether; aceton is another, and nitro-glycerine, singularly enough, is another. In certain proportions, the combination of gun-cotton and nitro-glycerine produces explosive-gelatine, a high explosive, incomparably safer than either of its component parts. In other proportions, and with the addition of a certain quantity of acetone, it produces Cordite, the best known, and probably the best of the so-called nitro-glycerine powders, with regard to which we must not forget that they actually contain from fifty to seventy-five percent of nitro-cellulose. Our own service powder is practically all nitro-cellulose, the ether and alcohol being nearly all driven off in the long and tedious process of drying, which intervenes between the manufacture of the powder and its issue to service. This delay for drying is a marked disadvantage of our powder as compared with Cordite. The necessity for it comes from the fact that the solvents used are both volatile and would evaporate gradually in any case;

and as their evaporation radically changes the character of the powder, - making it much quicker, - the only way to secure a reasonably uniform product is to drive off the solvents as completely as possible before testing the powder and issuing it to service. The drying is continued until the solvents are so far reduced that they come off very slowly, but they do continue to evaporate more or less almost indefinitely, with the result that the powders grow somewhat quicker as time goes on. Neither the acetone nor the nitro-glycerine used in Cordite is volatile to any important degree, so that it is not necessary to take time for drying, - though the large grain powders are dried for a few weeks - nor does the powder change with time, so far as its quickness is concerned.

With regard to stability, there does not seem much to choose between the two powders. There have been some serious accidents supposed to have resulted from the decomposition of nitro-cellulose powders in this country; but these were in the very infancy of the manufacture, when many precautions were omitted which are now known to be essential. Sunlight, for example, is now known to have a powerful chemical effect upon the powder, decomposing it rapidly. Yet at one time, the powder was dried in the sun. It was found that powder stood the heat-test better if treated with mercuric-chloride. So mercuric-chloride was added to the powder for a time, before it was discovered that its effect was, not to improve the powder, but to mask the heat-test. These things had to be learned by experience, and other people had to learn them just as we did.

There have been a good many accidents with French powder, which is practically identical with ours, but the investigation of the JÉNA accident has made it clear that these were to a great extent, at least, due to a lack of care in manufacture and subsequent inspection.

As to Cordite, it has been held responsible for the destruction of the MIKASA, though on what evidence we do not know, and there have been several accidents with it in the English service.

The truth seems to be that nitro-cellulose is inherently unstable and that all powders made from it are subject to a deterioration with time. This is not by any means the same thing as to say that they are dangerous, if properly made, properly cared for in storage, and properly watched. They must be properly made, because the slightest trace of free acid left by the processes of purification will enormously hasten the deterioration. They must be kept at as low a temperature as possible in storage, because the deterioration increases rapidly with high temperatures, - especially after the temperature rises above 100°. And they must be carefully watched, because, in spite of all precautions that can be taken, a slow deterioration will take place, and there is good reason to believe that this can be detected in ample time to prevent accident if the powder is watched with reasonable care, although the conviction on this subject is not held as positively as it was at one time.

Our tests of powder on shipboard as they were prescribed until quite lately, are doubtless familiar to you all. They were certainly not lacking in thoroughness. The only criticism which could be made of them was that they called for rather more refinement than could always be counted upon under service conditions.

They have now been supplemented by another test in which there is no excuse for mistakes. This is the "surveillance test" in which samples of the various powders on board are exposed in an oven to a constant temperature of 65.5° Centigrade. If the powder is in any degree unstable, it will give off red fumes within a length of time which varies with the degree of instability. If it stands for 60 days without giving off fumes, it is perfectly satisfactory, and the test is discontinued. If it gives off fumes in less than 20 days, it is more or less unstable.

Between these extremes are many gradations of stability. A large grain powder which stood for 40 days and then began to give off fumes would be good, but not perfect. One which stood for 20 days, but began to give off fumes after 25 days would be safe enough, but not satisfactory for indefinite retention on shipboard, etc.

This test is the result of several years experience at the Powder Factory, where it has been proved that a powder which stands up for 60 days under a temperature of 65.5° Centigrade will stand up indefinitely under a temperature of 95° Fahrenheit.

A change has recently been made in the composition of our powder which has undoubtedly increased its stability very greatly - probably doubling the life of the powder at least. This is the addition to it of a small percentage of diphenylamine, which is found to act as a stabilizer. In the deterioration of powder, gases are given off which are acid in character and which are identified as the oxides of nitrogen - No_1 No_2, and others. These acid gases, through what is known in chemistry as catalytic action, tend to decompose the powder still further, producing constantly increasing quantities of nitrous oxides.

The diphenylamine is a strong base, or alkali, and its function is to neutralize the acid gases as fast as they are formed, producing a harmless salt.

To a considerable extent, the volatiles in the powder - the ether and alcohol - perform the same office, neutralizing the acids as fast as formed. Green powder - containing considerable quantities of ether and alcohol - practically never decomposes to any serious extent. For this reason it would be a good plan from the point of view of stability alone, to leave a large quantity of volatiles in the powder, but the objection to this is that they would evaporate gradually in spite of all that we could do to retain them, and this would change the ballistics of the powder. (Show samples of powder and explain difference in appearance).

The fact that nitro-cellulose is inherently an unstable substance has only been recognized within the last few years. Up to that time it was believed that the troubles with unstable powder came from a lack of thorough purification of the cellulose, and that as the methods of purification were improved, we should in the end arrive at a perfectly stable powder. This has contributed - perhaps rather illogically - to the belief that the more nearly homogeneous we could make our powder, the better it would be; in other words, it has been considered that the ideal powder would be one which contained absolutely nothing but nitro-cellulose. It looks now as if this view was incorrect, and the theory is suggested that the more we can reduce the percentage of nitro-cellulose, the better; provided always that the materials which we substitute for it are perfectly stable, and that they are of such a nature that they enter completely into the combustion of the powder, giving only gaseous products.

This theory is to some extent supported by the perfectly well established fact that in adding water to gun-cotton we make it enormously more stable chemically as well as physically. Gun-cotton is in existence today which was made more than fifty years ago and has been kept wet all that time. It is as stable now as the day it was manufactured. The same cotton if stored dry would probably have burnt itself up years ago by spontaneous combustion. The effect of the water is to dilute the cellulose, separate the molecules, and preventing them from acting one upon the other. It is something of an anomaly that moisture, as distinguished from water in considerable quantity, accelerates decomposition, heat and moisture acting together in this as in other cases to hasten chemical action.

Several formulae have lately been submitted to the Bureau of Ordnance in which the theory is embodied that dilution by other substances than water may be favorable to stability. I have here a sample of one of these, called Stabilite, which is very promising. In the tests which have been made of it up to the present time, it has developed only one defect - that it apparently causes more erosion than the standard formula. This point has not yet been completely covered. The powder has many things to recommend it. It seems to be at least as stable as our present powder. It is easier to manufacture, and it requires no drying. It may, in fact, be fired the same day that it is made. This is an enormous advantage in view of the fact that our present standard powder takes from two to four months to dry. The solvent used with Stabilite remains in the colloid, just as nitro-glycerine remains in the colloid of Cordite.

Before leaving this branch of my subject, I want to go a little further into the direct comparison of our present service powder with English Cordite. There is no evidence that Cordite is any more stable than nitro-cellulose powder, but as it contains only seventy instead of ninety-seven per cent of nitro-cellulose, it ought to have an advantage in this respect if there is anything in the theory which I have already explained as to the inherent instability of nitro-cellulose.

In both Cordite and nitro-cellulose, the products of combustion are entirely gaseous. But there is a great difference in the gases formed. Nitro-glycerine is richer in oxygen than nitro-cellulose, and Cordite has oxygen enough to burn its carbon completely to Co_2.

Thus most of the gases which remain in the bore are uninflammable and flare-backs are not to be anticipated. A pure nitro-cellulose powder burns partly to Co_2 and partly to Co. At high temperatures, Co combines with oxygen wherever it can get it and burns to Co_2. Thus the gases from the bore coming in contact with the air from an explosive compound which ignites if a spark is touched to it and possibly in some cases without a spark, its own residual temperature being presumably high enough.

Cordite has considerable greater power, for a given weight, so that there is great economy in its use, so far as the weights to be handled are concerned.

I have already called attention to the fact that the Germans, who prefer a nitro-cellulose powder, and use it exclusively on shore, are compelled to use a nitro-glycerine powder for naval guns because with all such guns, up to and including the 11-inch, they use cartridge cases. This makes it necessary to stick to a powder which admits of small charges. They accordingly use a Cordite with more than 50% of nitro-glycerine, and even of this they use a relatively small charge.

It is possible to use a smaller charge of Cordite than of our service powder because the Cordite is a quicker powder in burning. But this has its disadvantages. The rapidity with which it burns gives a high breech pressure and a curve which drops off rapidly toward the muzzle. The result is that it is impracticable to get as much energy out of Cordite as we can get from nitro-cellulose alone, because, if the charge is forced to give a high muzzle energy, the breech of the gun is endangered, whereas in forcing nitro-cellulose powders we endanger the muzzle, if anything, which is much less serious.

This fact has doubtless had something to do with the change which the English have made in their powder - a change which has brought them very much closer to us than they seem willing to admit. They have reduced the percentage of nitro-glycerine from about 60% to about 28%. This change is attributed to the excessive erosion of the original Cordite, and in all probability that was the controlling consideration. But if this consideration had not entered into the matter, they would have been obliged to make a change or to continue to content themselves with considerably less energy than we are able to get from nitro-cellulose.

I propose now to consider the behavior of the powder in the gun somewhat more in detail. This may properly be considered under the head of recent advances in Ordnance because it is being studied constantly and we are learning more and more about it every day.

For a given composition, the behavior of smokeless 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. In describing the effect of colloiding the powder, I called attention to the fact that in the colloidal form the powder burns in successive layers from the outside in. The evidence of this fact is found in the partially burned grains which are blown out from the gun. The whole story of the action of the powder 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 problems of ballistics will become simple. In the meantime we can do something. A very interesting series of experiments has been carried out at the Proving Ground, by means of which we have determined with what we believe to be a fair degree of accuracy, the pressure at various points along the bore of the gun. This has been done with several different calibers of guns and with powders differing widely in characteristics, and a formula has been deduced which gives rather surprisingly accurate results when used to predict the performance of a new powder in a new gun.

We have still much to learn about the subject of interior ballistics, but there is no question that we are learning more and more as time goes by.

DEVELOPMENT OF TURRET ORDNANCE.

Within the last few years turret ordnance has undergone considerable modification in design.

Three years ago the mounts of the turrets of the U.S.S. CONNECTICUT class were the examples of the highest development of this material in our Service. These were of the type known to the Service as "side lever" or "grasshopper" mounts. (Sketch). Their recoil cylinders were single, and secured to the underneath part of the slide, the counter recoil springs being mounted in brackets attached to the turret structure, and connected to the guns by a system of levers. This recoil system gave good satisfaction, but the side levers took up a great deal of room and interfered considerably with sight installation work and the checking of the sights, as the joints of the levers covered the trunnion centers when the guns were out to battery. The side lever mounts were superseded for all vessels after the IDAHO and MISSISSIPPI, by mounts having recoil and counter recoil systems very similar to those ordinarily to be met with for broadside mounts. In all recent actual and projected construction for heavy mounts there is a single recoil cylinder, and four counter recoil spring cylinders attached to the lower part of the slide.

The CONNECTICUT'S 12-inch mounts had trunnion bearings of the usual roller spring-bearing type. This type, with certain modifications designed to pivot the guns nearer the turret front plate so as to reduce the necessary size of the port opening, and modifications to permit of adjusting the guns parallel to one another, is still in vogue and most probably always will be. Beginning with the WYOMING, the trunnions are as near the front plate as it is desirable to have them, considering the necessary clearance which must be left between the mount and the armor. The maximum clearance between the top of the port and the chase of the guns is about one inch for the WYOMING mounts. This clearance at the bottom of the port is slightly greater, but the opening is masked by the gun.

All deck lugs down to the 14-inch mounts are single castings, with a heavy web connecting the two flanges. For the 14-inch mount the deck lug is to be divided into two parts, the strength usually afforded by the connecting web being here furnished by a stronger structure. Dividing the deck lug and omitting the connecting web leaves room for elevating pointers' stations underneath the gun.

E L E V A T I N G G E A R.

The elevating gears continue to be of the screw type, actuated by electric motors which, for all recent construction, are of 15 H.P. capacity and controlled by hydraulic variable speed gears with suitable manual control systems extending to the pointing stations. For all turrets beginning with the FLORIDA the manual controls for both power and hand operation are combined at the pointer's stations, shifting from one to the other being effected by suitable clutches. The aim has been to make the manual control systems as direct as possible so as to eliminate backlash.

R A M M E R S.

Of the CONNECTICUT class all vessels except the NEW HAMPSHIRE had telescopic chain rammers mounted on the fixed structure. The NEW HAMPSHIRE'S 12-inch turrets are equipped with link rammers mounted on the slide. This special design was to permit of loading the guns at any angle of elevation. These rammers were designed and furnished by the Bethlehem Steel Company, and are not very satisfactory.

Beginning with the SOUTH CAROLINA all vessels down to the WYOMING have 12-inch rammers of the link type. These rammers are mounted on the slide so as to permit of their being used at all angles of elevation. When extended, the unsupported links are rigid against upward thrust, but will fold downwards. To meet the requirement that the rammer must be rigid so as not to need the support of the shell tray of the ammunition car during withdrawal across the car space, especially after ramming home the last sections of the charge, special type supports had to be fitted to carry the rammer head across this space until it was supported by the gun in extension or back in its casing upon withdrawal. These supports have greatly complicated these link rammers and constitute their greatest source of weakness and nonreliability. Their value, all things considered, is very doubtful. For the WYOMING and ARKANSAS, the rammers are secured to the fixed structure and are stowed in casings attached to the roof of the turret. Stowing these rammers overhead was a matter of necessity and not of choice, as there was not sufficient room in the rear part of the turret for them. The links of the 14-inch rammers will stow on the rear shelf plate. These rammers are also to be mounted on the fixed structure. In all cases the rammers are actuated by electric motors of ample capacity. In the control, improvements have been constantly sought so as to make the rammers more nearly obey the will of the operators, especially upon withdrawal.

The power rammers fitted in vessels beginning with the SOUTH CAROLINA and down to, but not including, the WYOMING may be operated by hand in case the motors fail. With this type rammer it would be extremely difficult, if not impossible, to use a loading staff. The rammers for the WYOMING and ARKANSAS and those for the 14-inch turrets are so arranged as not to interfere with efficient loading of the guns by means of hand rammers.

S I G H T S.

Beginning with the MICHIGAN and down to the 14-inch turrets, the type trunnion sights designed by Lieutenant-Commander H.C. Mustin, U. S. Navy, have been supplied in the pointing stations. This type sight has the obvious advantage of being mounted only on the slide, no part of it being attached to the structure. It thus moves in every direction with the slide and when once correctly installed should remain in adjustment. This is a very great advantage, especially from the point of view of fire control. In the two after turrets of the DELAWARE and NORTH DAKOTA, and in the three after turrets of the FLORIDA and UTAH parallelogram sights with telescopes looking through sight holes in blast hoods mounted on the turret roofs are fitted. This was necessary on account of interferences between the turrets unduly limiting the field of fire in case trunnion sights were employed. The 14-inch pointer's sights are to be of the yoke type, mounting two telescopes, and secured to the underneath part of the slide. They are thus not essentially different from the ordinary yoke sights to be seen on broadside mounts. The extra telescope is to permit of the use of a firing pointer so as to relieve the elevating pointers of a part of their duties. This arrangement promises increased efficiency, especially when firing in a seaway. The sighting is done through notches cut in both lower quarters of the gun port. The increased size of the port opening is inconsiderable, and is blanked by the gun. The pointers are stationed so that the connections for control of gun elevating are direct and simple. The telescopes for all turret sights, beginning with the MICHIGAN, are of the hyposcopic type.

TURRET TRAINING GEARS.

Beginning with the SOUTH CAROLINA all vessels have the training motors mounted in the wings of the revolving structure of the turrets. Three types of control have been fitted, two all electrical, and one mechanical. The electrical systems are the Cutler-Hammer Manufacturing Company's differential control system, and the General Electric Company's rotary compensator system. The mechanical type employs the Williams-Janney hydraulic transmitter. Experience appears to point towards the latter type as being the best. In all cases the trainer's station is in the forward part of the turret pan, between the inboard gun girders. The turret trainer's telescope looks through an opening in the turret front plate. Auxiliary training control gear is fitted at each elevating pointer's station.

AMMUNITION HOISTS.

The CONNECTICUT'S 12-inch turrets are fitted with the old type reciprocating hoists having open cars, closure between the handling room and the turret chamber being effected by automatic shutters installed in a position approaching the horizontal. From the SOUTH CAROLINA to the WYOMING, two-stage hoists have been fitted. These are parallel in all cases with auxiliary hand hoists. The SOUTH CAROLINA and MICHIGAN have two-stage hoists of a special type. The size of the upper handling room not permitting of separate motors for the upper and lower stages, two rope drums were mounted on the countershaft of the motor; on one drum was wound the cable of the upper stage car, on the other drum that of the lower car. This arrangement involved some complication, but has proved to be fairly efficient.

The DELAWARE and NORTH DAKOTA turrets have two-stage power hoists of a type designed and furnished by the Bethlehem Steel Company. In the light of experience these hoists leave much to be desired, particularly from the point of view of simplicity. (Sketch).

The two-stage turret ammunition hoist for our Service reached its highest development in those supplied for the FLORIDA and UTAH. The two-stage hoists are entirely independent, their cars being driven by separate motors. (Sketch). Suspended from the bottom of the turret pan is a circular handling room in which the lower cars are unloaded and the upper cars are loaded: The cars are themselves of the flame-proof pattern, common in all recent construction, and travel in individual trunks. Separation of the turret from the upper handling room is effected by doors on the upper cars operating in conjunction with other doors on the upper car trunks. The lower hoists are dumb-waiter like affairs, the cars being loaded in the usual manner at the bottom and automatically dumping their loads on waiting trays in the upper handling room. From the waiting trays the rounds of ammunition are transferred to the upper cars at the right moment when these cars come down and automatically open up their own doors and those on the outboard sides of the trunks in which they travel. Auxiliary hand hoists parallel the power hoists, and the two systems may readily be used in combination. There is stowage in the upper handling room and in the turret for a limited number of shell. The control of the ammunition hoist motors is electric and either automatic or hand at will of the operators. The time of hoist for the upper car from the handl room to the mean loading position is about 3-1/2 seconds. As the mounts are designed to permit of loading in any position, the control system is arranged to suit this, the apparatus being adjustable, so that whatever the position of the guns, the cars slow down at a predetermined distance from them and bring up against the buffers on the gun and on the rammer beam without undue violence. To hold the car against the buffers, a balancing current is kept on the hoisting motor, the strength of this current being automatically varied as the pointer moves the gun in elevation or depression.

The handling room arrangements for all recent turrets having power ammunition hoists are similar. A ready shell table, secured to the revolving part and taking the place of the former saddle casting or rest of the ammunition hoist cars, carries about twenty shell. The shell to be hoisted are slid into position for automatically loading into the lower cars when these strike their buffers near the lower limit of their travel.

The turrets of the WYOMING and ARKANSAS will have both combined power and hand and auxiliary hand shell hoists. The charges will be passsed by hand all the way from the magazines to the guns, as is now the general practice for 8-inch turrets. Shell will be loaded either by power or by hand, with the guns in a fixed position in elevation. Powder will be loaded by hand, with the guns either at rest or moving. The power shell rammer will be of the link type and so arranged in the rear of the turret as not to interfere with the use of a loading staff should it be desired to employ one.

Suspended from the bottom of the turret pan there will be an upper handling room of cylindrical shape. The rear part of this room is for the handling and stowage of shell and location of the hoist motors, the front part for the handling, and possibly stowage, of powder. These two spaces are separated by a transverse bulkhead.

When the turret is in use, the sealing of the turret chamber from the handling rooms will be secured by having the shell hoist tubes sealed by the shell carriers and the powder charges passed up through a revolving air-lock wheel in an opening in the pan plating.

Ordinarily there will be for each gun eleven shell stowed in the turret and ten in the upper handling room, and this condition will be maintained while firing during the normal operation of the shell hoists. Before going into action this allowance may be very conveniently increased by at least two shell in the turret and six in the upper handling room, thus making for each gun a total ready allowance of thirteen shell in the turret and sixteen shell in the upper handling room.

The combined power and hand shell hoists will be driven by 40 H.P. electric motors, of which there will be two for each turret, located in the upper handling room. These motors will be arranged to lift the shell somewhat after the manner of ordinary cargo winches. The shell carriers are hoisted by wire ropes attached to them leading over pulleys in the usual manner and winding on drums riding loose upon or clutched to the back shaft of the motor at the will of the operator. The motors will thus be continuously turning over when the hoist is in use. To give the load an easy start, there will be a special type accelerating friction clutch interposed in the gearing between the motor armature shaft and the counter or drum shaft. When operating these hoists by hand power, the drum shaft will be revolved by means of a chain drive connecting it with the hand-power shaft. Manual power will be applied to the latter through hoist chains after the usual manner for such devices.

Shell will be hoisted up to the turret in two stages. For the combined power and hand hoists there will be for each gun a shell-hoist tube, with a dumbwaiterlike carrier traveling within it from the lower to the upper handling room and a similar tube and carrier from the upper handling room to the turret. Transfer will be made in the upper handling room. In the lower tube the shell will be hoisted point up; in the upper tube, base up. The upper hoist tube for each gun will stand over against the inboard gun girders approximately in a position corresponding to that of the ammunition-hoist guide rails in most existing types of turrets.

When shell are to be hoisted by means of the combined power and hand hoists, they will be supplied from the shell rooms by the usual type overhead trolleys to a transverse loading table located in the lower handling room on the after side of the central column of the turret. Sections in this table abreast the lower ends of the shell tubes will be arranged to tilt the shell over, base first, into the shell carriers. The shell will then be whipped (hand or power) to the upper limit of the travel of the carrier, which is in the upper handling room. Here they will be tilted out by hand upon transfer trays, from which they will be tilted over, point down, into the carriers of the upper hoist. They will then be hoisted to the turret and landed automatically, point muzzleward, upon waiting trays. All this handling may be done without interference with loading or firing. The shell will next be rolled from the waiting trays, outboard, upon the fixed sections of the loading trays, which stand upon the rear shelf plate of the turret. They will then be ready for loading either by power or by hand.

The auxiliary hand shell hoist is in two stages. The first or lower stage will hoist shell by means of hand purchases from the lower to the upper handling room. From the upper handling room they will be hoisted into the turret wings by other hand purchases. Thence they will be transported on overhead trolleys to the rear of the turret ready for loading.

The powder charges will be passed from hand to hand to the upper handling room by men stationed on platforms one above another on the front side of the central column. In a casing secured to the turret pan plating there will be, under the breech of each gun, a powder-passing wheel with three compartments, each holding one-half charge, and rotatable about a horizontal transverse axis. When in operation, the compartments of the wheel will be successively filled below the pan and rotated upward and emptied there by powder men stationed in the rear part of the gun pit. These powder men will control the opening, rotating, and closing of the powder wheel. From the powder wheel the charges will be passed up to men stationed on the loader's platform attached to the slide. For the purpose of loading powder with the gun moving in elevation there will be fixed to the slide a loader's platform, on which will be pivoted a powder-loading tray, which also serves as the other half of the shell tray. This arrangement will permit of loading the powder very smoothly. The powder tray will be arranged to tilt back clear of the gun in recoil.

That there will be considerable reduction in the amount of electrical apparatus may be inferred from the fact that the turrets were originally intended to have each 10 Ordnance motors of a total capacity of 237 H.P., whereas there will now be installed 6 Ordnance motors of a total capacity of 130 H.P. The reduction of electrical control apparatus is even greater, being about 75 per cent.

The 14-inch turret ammunition hoists will probably be in all respects similar to those for the WYOMING and ARKANSAS.

12 IN 40 CAL. MARK III.

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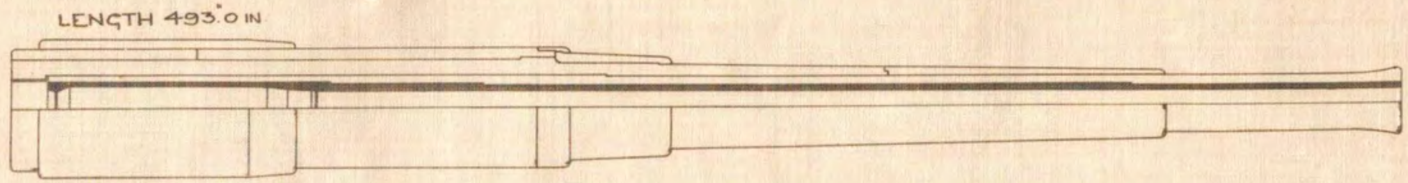
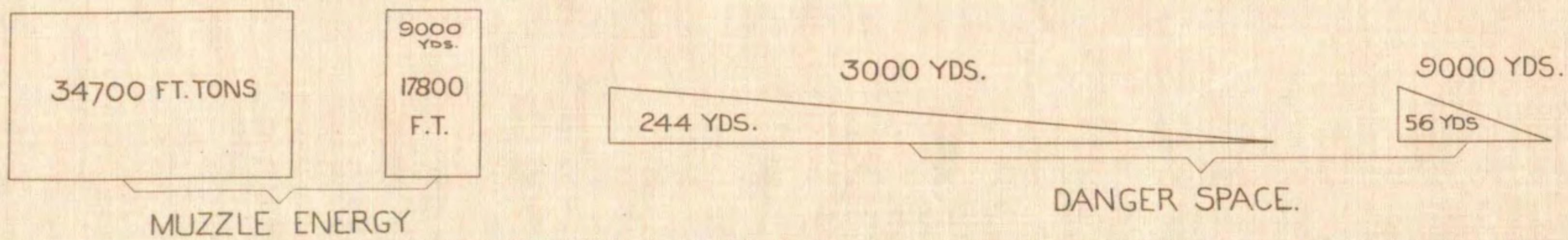
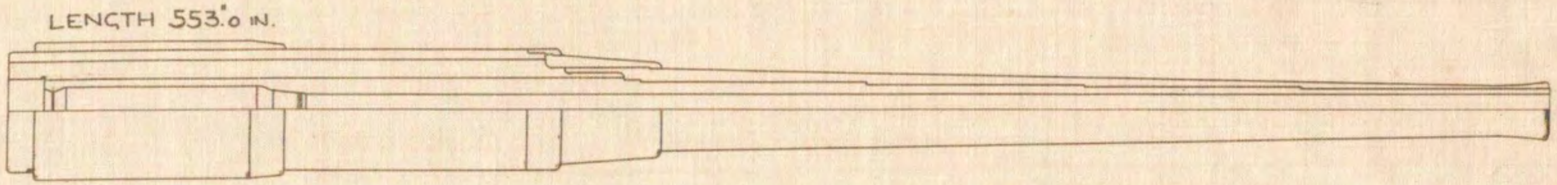
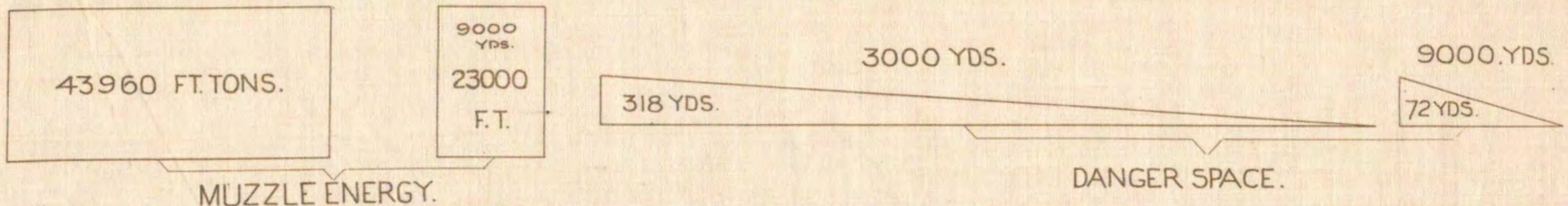




12 IN 45 CAL. MARK V.

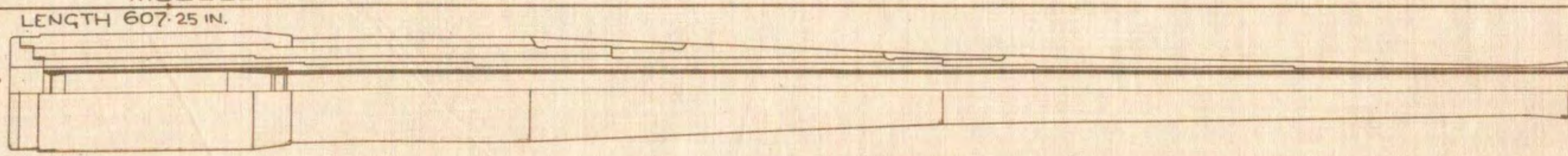
- SCALE $\frac{1}{20}$ -

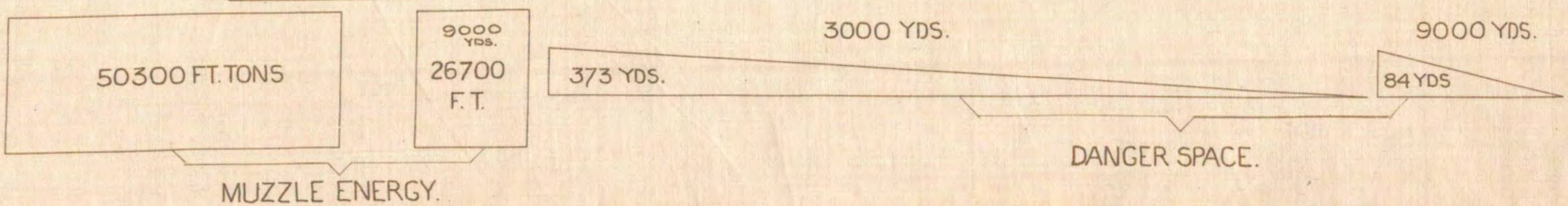




12 IN 50 CAL. MARK VII.

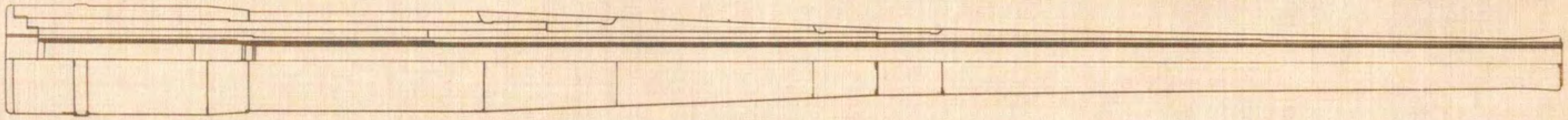
- SCALE $\frac{1}{20}$ -

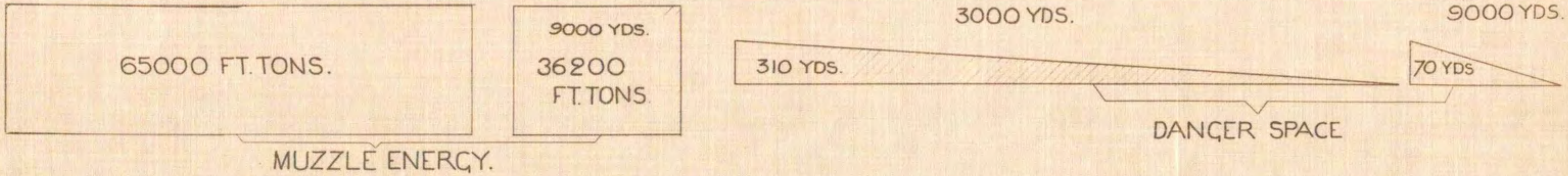




14 IN- 45 CAL. MARK I. LENGTH 642.5 IN

SCALE $\frac{1}{20}$

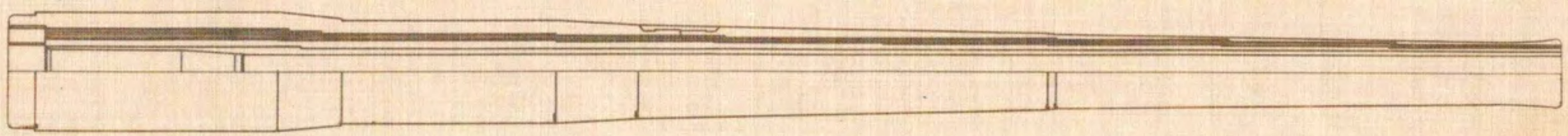


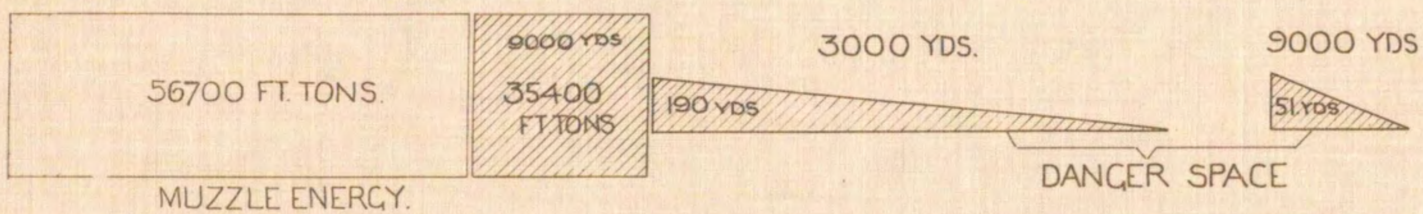


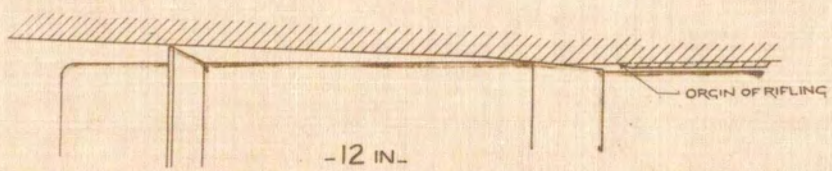
14 IN-ARMY WIRE WOUND GUN. LENGHT 579.0 IN

40 CAL

SCALE $\frac{1}{20}$







-12 IN-

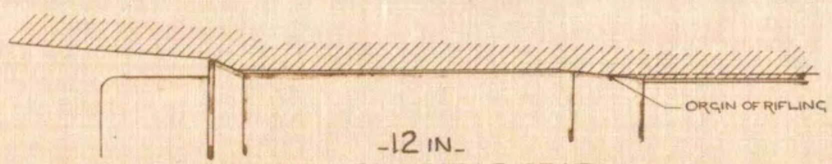
OLD PROJECTILE SEAT.

SCALE $\frac{2}{1}$

-12 IN-

SECTION OF RIFLING.

SCALE $\frac{4}{1}$



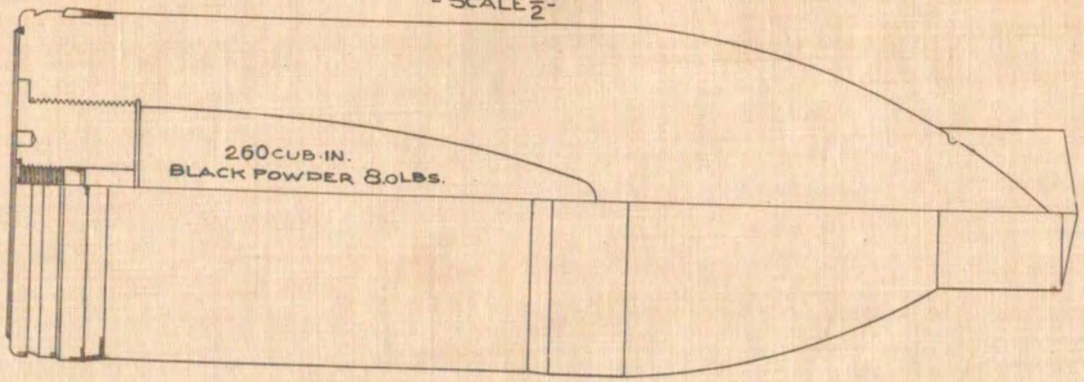
-12 IN-

NEW PROJECTILE SEAT.

SCALE $\frac{2}{1}$

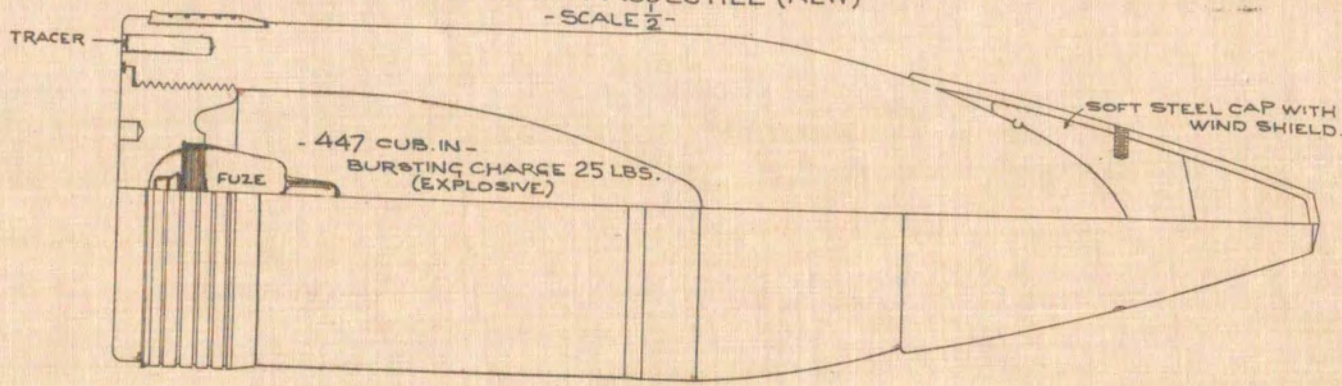
12 IN A.P. PROJECTILE (OLD)

- SCALE $\frac{1}{2}$ -

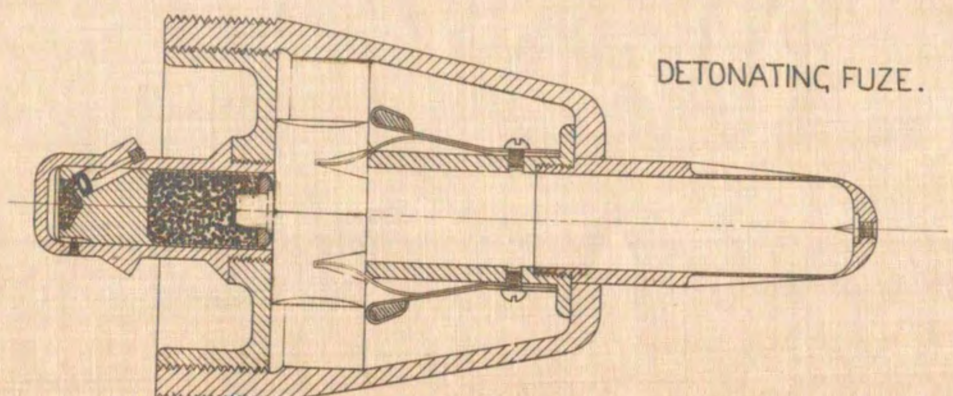


12 IN. A.P. PROJECTILE (NEW)

- SCALE $\frac{1}{2}$ -



DETONATING FUZE.



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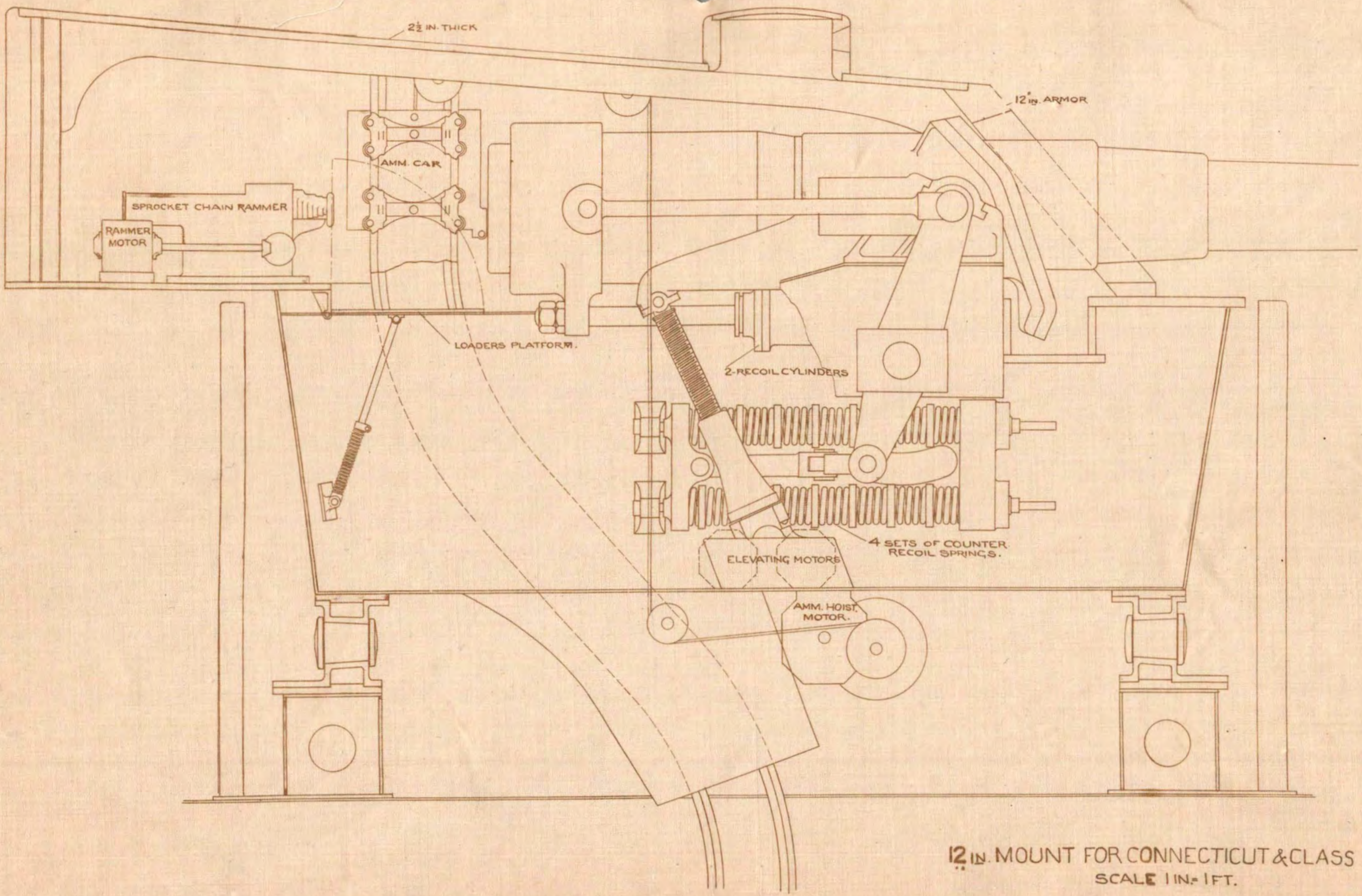
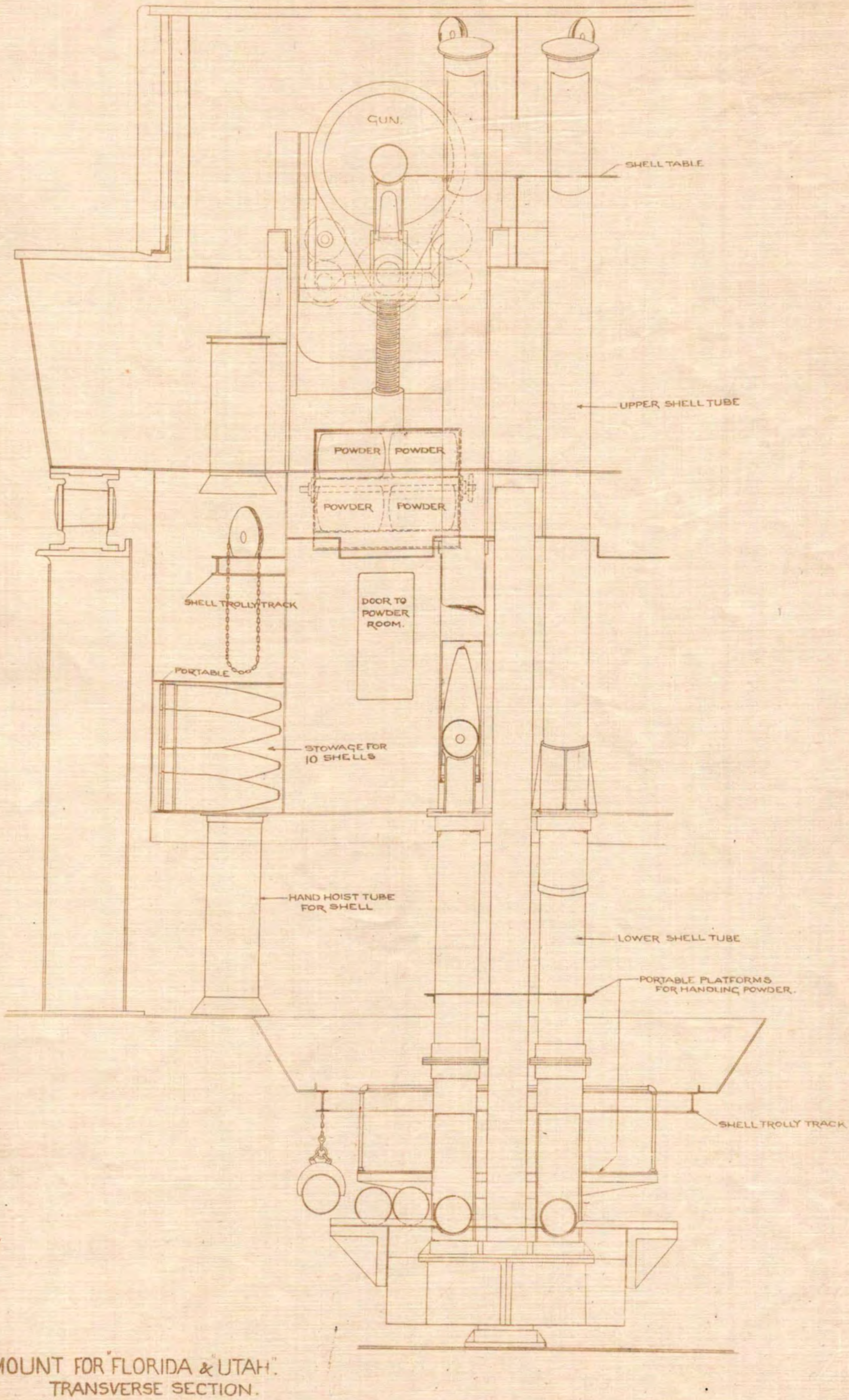
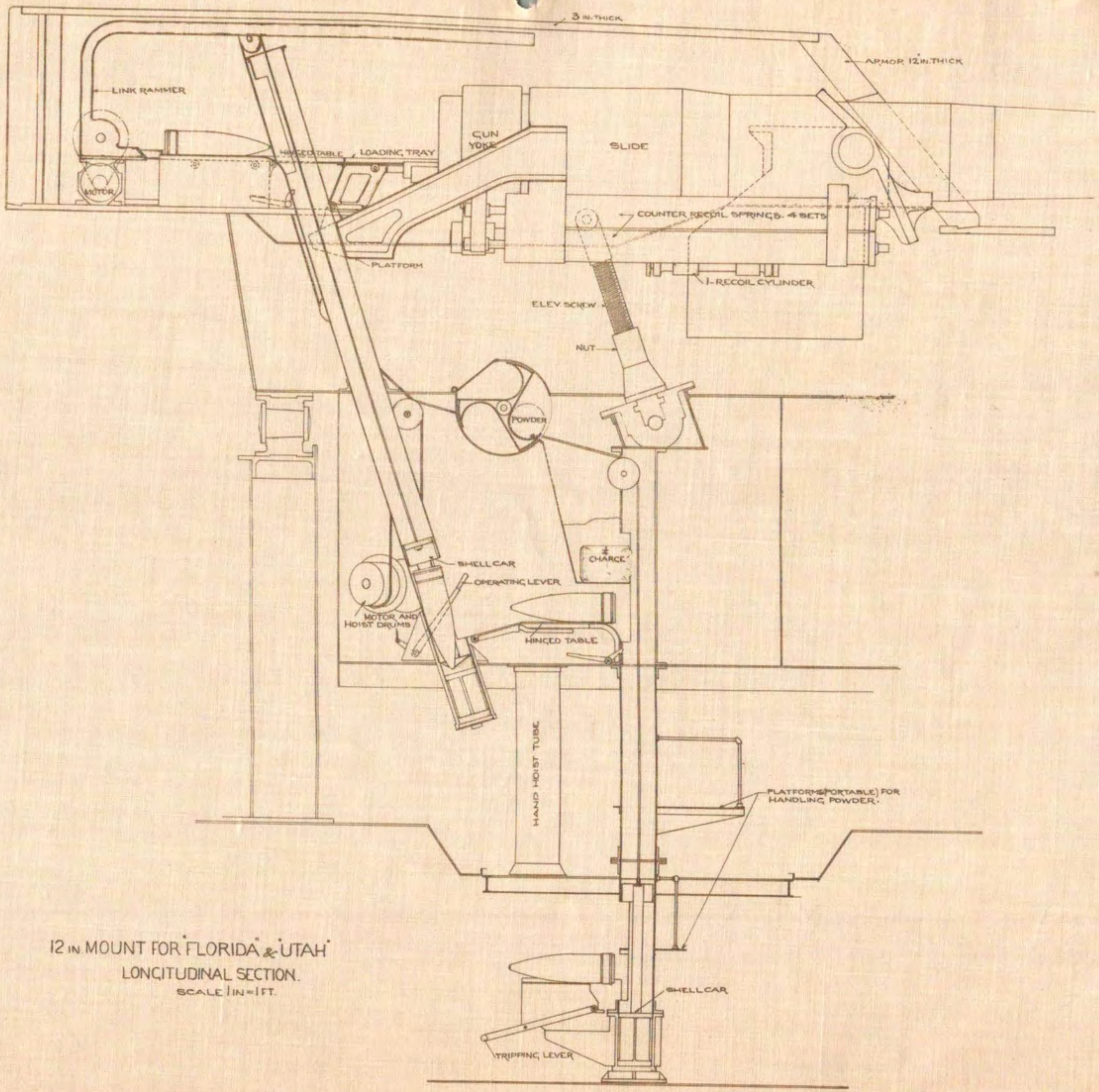


12 IN. MOUNT FOR CONNECTICUT & CLASS
SCALE 1 IN.= 1 FT.



12 IN. MOUNT FOR "FLORIDA & "UTAH".
TRANSVERSE SECTION.
SCALE 1 IN = 1 FT.



12 IN. MOUNT FOR "FLORIDA" & "UTAH"
LONGITUDINAL SECTION.
SCALE 1 IN = 1 FT.