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Wednesday, November 13th, 1895.

Vice-Admiral P. H. COLOMB in the Chair.

THE PRODUCTION OF MODERN WAR MATERIAL IN THE UNITED STATES OF AMERICA.

By Captain WILLIAM H. JAQUES
(Late United States Navy).

The CHAIRMAN: In his own country it would be unnecessary to say a single word in introducing the lecturer to-night. In this country it is not necessary to say much. Captain Jaques was a graduate of the Naval Academy in America, and served for some years in the American Navy. For a large number of years he has been directly connected with the matters of which he treats, and constantly employed by the United States Government on different commissions connected with these subjects; and he is, besides, in our own country, a member or a fellow of most of the great societies which deal with the matter he has in hand. Therefore, there is no man more qualified to address us on this subject than Captain Jaques.

LECTURE.

THE indifference of the United States for nearly a quarter of a century to the question of national military defence placed a somewhat unusual responsibility upon the members of the Gun Foundry Board, which visited this country in 1882. Although I have prepared for the British societies, with which I am connected, several papers on the subject of war material, this is the first chance I have had to personally thank His Grace the Duke of Devonshire, who, at that time Lord Hartington, was Secretary of State for War, and also many of you who so courteously extended to us those civilities and opportunities, which enabled us to lay the foundation of that report upon which was based the development of the modern war material now used in the United States.

The freedom with which the results of our experiments and the details of our productions are exploited in the daily press somewhat

handicaps a lecturer when he desires to present the conclusions reached, or describe the methods employed and the productions themselves. The press of the United States is not alone in its desire to give readers the very earliest possible information; for the editors of our scientific journals and the secretaries of our technical institutions are also fully alive to the necessity of giving early publication of all progress made to the members of their associations.

My own very close connection with what has been done in the United States in the production of war material has necessitated a frequent expression of my opinion; and, in order not to repeat, except by way of emphasis, my estimates and conclusions upon the different elements of war-ship design and equipment, I have asked the privilege of presenting to you graphically what has been accomplished in my own country in the construction of war-ships, the building of guns and armour, and their tests, calling to my assistance the power of lenses and the oratory of photography, in lieu of scientific word expression.

Since February 16th, 1884, we have made wonderful strides in the development of war material, and we feel that we are again coming to the front rank in quality and type, even if we may be wanting in quantity.

Although the demands upon the ordnance engineer are enormously greater in England than in the United States, it is difficult to realise even in Great Britain what extensive sums have been expended by the leading Powers of the world for the care and development of their armies and navies.

I have heard many expressions of surprise at the rapidity with which we accomplish great undertakings. In many directions this is true, but you still have the advantage of us (and it is but natural that you should) in the time and cost of construction of the larger types of war-ships.

For convenience, I will divide my paper to-day into three parts, relating, respectively, to the built-up gun, the wire-wrapped gun, and armour; and, as most of my initial work was done at the Bethlehem Iron Company's works, I will ask you to spend a few moments with me there (in South Bethlehem, Pennsylvania), where, as ordnance engineer, I was so intimately associated with Mr. John Fritz, for many years its chief engineer and superintendent, and before the Directory of which I laid in May, 1885, a detailed plan for the erection and equipment of suitable works for the production of guns, armour, and shafting, transferring to them the inaugural machinery and information for the successful accomplishment of my project, which was based upon the investigations and conclusions of the Gun Foundry Board of 1882 and 1883.¹

Notwithstanding the extent to which experiments in gun construction have been conducted, all the principal nations in the world use one of two types, viz., the built-up, or the wire-wrapped; and the steel-cast gun remains further than ever from general service use. As the means have been supplied for producing larger parts, their number and proportions have decreased and increased, respectively, and nearly every metal, except gold

¹ The lecturer here exhibited several lantern views of the Bethlehem Iron Works.

and silver, has been alloyed with iron with a view of securing increased elastic strength.

The substitution of smokeless powders having for their base nitro-glycerine and gun-cotton, has, perhaps, been a more radical departure than anything that has been done in gun construction itself, and there is no element in the provision of gun construction which has a more important bearing than the powder which is to be employed.

You appear to have been more successful here with your cordite than anyone else has been. In the United States we are still quite at sea as far as powder is concerned. Three or four makers have spent a great deal of money, and have on many occasions more than fulfilled the conditions laid down by the Departments, but the Navy Department especially has such fear of nitro-glycerine powders that it has practically prohibited their use. Very little smokeless powder has been issued in the United States for general service, but the Navy Department believes that it has secured at its torpedo station manufactory a smokeless powder with a gun-cotton base that will give high ballistic results, combined with safety and stability. A considerable amount of Leonard and Peyton American powder has been ordered for the new army rifle, and several lots for experimental work have also been purchased.

A new American smokeless powder, known as the Maxim-Schupphaus, differs from the Leonard and other nitro types by combining from 5 per cent. to 10 per cent. of nitro-glycerine with from 94 per cent. to 89 per cent. of military gun-cotton. The advantage claimed for this composition over cordite and Leonard, which contain 50 per cent. of nitro-glycerine, is its low temperature of combustion, which would reduce the erosion of the bore or the gun lining, if this is due to the heat of the powder gases or liquid products. This advantage is obvious when the temperatures of combustion of nitro-glycerine and gun-cotton are considered; the former burning at 3,000° Fahr., the latter at 2,500° Fahr.

The grain of this powder is also a radical departure from any shape employed heretofore, consisting of a cylindrical stick with seven or more longitudinal perforations of such a size that the area of burning increases as the projectile travels towards the muzzle, thereby giving high velocity with comparatively low pressure. There is no other powder grain that gives such an increase in area of combustion, a large decrease being the rule.

With the 3.2-inch field gun at Sandy Hook, fired under the Government requirements (velocity 1,450 f.s., pressure not to exceed 30,000 lbs. per square inch), 1 lb. 4½ oz. of this powder did the same work with less pressure (22,644 lbs.) than 3¼ lbs. of black powder. Other tests of this powder have been reported from time to time in *Engineering*, *Arms and Explosives*, and other journals.

In laying before you very rapidly the methods employed in the United States for the manufacture of built-up ordnance, I will not repeat the views I have expressed in relation to material, furnace practice, treatment, shrinkage, and erosion, except to emphasise my belief that suitable and sufficient mechanical work is quite as necessary, if not more

so, in the finish of the bore as the selection and chemical proportions of the composition.¹

A study of the various types of torpedo-boats and destroyers and the changes in yacht design in the search for high speed have led Mr. Herreshoff to suggest the use of some of the ideas introduced into the "Defender" for torpedo-boats, and the United States Government has just given him an order for two.

A glance at the two yachting machines which recently competed for the America Cup will be interesting, although it is not expected that the naval architect will gain much from them that will be useful in war-ships. In fact, they have ceased to be yachts; they are simply racing machines, the hull a fulcrum with the fin, or fixed centre-board, on one side, and the sail power on the other.

In assembling the parts of the gun the degree of accuracy of the shrinkage is at least 98 per cent. of the calculations. It is more difficult, however, to prevent the erosion of the bore. Until we get a propelling agent that will not cut the bore so badly, we must keep in the mechanics' hands, increase the work, and construct the gun so that the barrel can be readily and economically replaced.

By cold-rolling the tubes higher elastic strength and greater resistance to erosion will be obtained, and if the life of a gun is limited by its erosion (which is apparently the case) the increased cost to provide the power requisite for this additional mechanical work will be more than compensated by the longer life of the gun. If the addition of an alloy will facilitate this work, so much the better.

The nickel-steel gun forgings made while I was at Bethlehem show an increase of 25 per cent. in elastic strength, with but a slight reduction of the contraction of area as compared with plain steel.

If we can still further increase these qualities by cold rolling, we shall have material that will not only stand the increased pressures demanded, but will also withstand the erosive inroads which so manifestly control the life of our heavy ordnance.

Although, since my entry into civil life, I have had a definite plan of gun construction, I have not presented it before, because I wanted first to accomplish the means of producing the few parts I deemed necessary for a stiff, elastically strong, high-power gun. My gun will be made of a few hollow, press-forged, cold-drawn, taper cylinders of alloyed steel, one in each layer, assembled by hydraulic power in such a manner that it can be taken apart as easily as the wire-wrapped guns now being fabricated at your Royal Arsenal.

Unge, the Swedish engineer, proposes to construct all guns as smooth bores and to fit the projectiles with gas-checks, proposing to give the gun itself an axial rotary motion. Fitting gas-checks to the projectiles them-

¹The lecturer here exhibited seventy-seven views, representing all the operations of the production of gun steel and shafting, army and navy gun shops with their equipment, comparisons of steamships and cruisers, torpedo-boat destroyers, the bearing of yacht-design on naval construction, accompanied by an elaborately-detailed explanation of methods and operations.

selves is undoubtedly a move in the right direction, but giving an axial rotary motion to the gun itself is a novelty that may involve too many complications of carriage and fitting.

While the types of breech closing are very prolific, modifications of the Canet-Whitworth devices seem to be most generally accepted, and the de Bange gas-check is adopted by both branches of the Service in the United States.

In presenting illustrations showing the danger of using material that has not been adequately worked, one is impressed with the value of fluid compression and the employment of nickel alloys. I know of no other two things connected with the metallurgy of steel of so great comparative value, and I shall never tire of expressing my surprise at the marked opposition in England to their use. When I first heard of the fluid compressed ingots of Manchester, I was told by some of Whitworth's competitors that the machinery was kept there as a toy to amuse official visitors. When I first saw this so-called toy I received the impression that, if such, it was rather a powerful and expensive one. When I saw it in operation I very readily discovered the benefits of the process, and lost no time in including it in my details of a plant to be erected in the United States.

I am a stronger convert than ever of the value of nickel, and have found it one of the kindest alloys in the composition and treatment of steel that I have ever had to deal with. I am sure its universal use cannot much longer be delayed, even in conservative England.

At the last Summer Meeting of the Naval Architects in Paris I called attention to the fact that in the United States nickel steel has been largely employed for armour, guns, shafting, hammer and piston rods, torpedo reservoirs, bicycle tubing, and wire; and that it had been ordered for ship and boiler plates. Since then, the boiler plate which has been delivered by the Carnegie Company to our Navy Department has shown the following excellent physical properties:—

Tensile	..	..	..	85,000 lbs.
Elastic	..	..	..	60,000 „
Elongation	..	..	..	25 per cent. in 8 inches,

and also passed excellently the usual quenching and bending tests.

In gun carriages and mounts both our Navy and War Departments have followed European practice—our mortars are mounted on Canet, Whitworth, and Easton and Anderson types; while Krupp and Schneider have furnished working samples for the development of carriages for the heavier guns.

Gorden and Crozier-Buffington modifications have been adopted by the army.

Whether the apparent slowness in the development of armour-piercing projectiles is due to the rapidity with which increased ballistic resistance of armour has been obtained, or whether the want of advancement is due to the extreme difficulty in securing uniform composition and treatment, which will fit the projectiles for the enormous amount of work they are called upon to perform, is, perhaps, difficult to decide; but in

this direction the United States seems to have gone rapidly to the fore, and, apparently, in the Wheeler-Sterling projectiles we find a type combining uniformity, surety of production and perforating power which are not so readily obtained by any other makers in the world.

The works of the Sterling Steel Company are situated in Pittsburg, Pennsylvania, where in addition to projectiles, a large quantity of mercantile crucible steel is turned out. The capacity of the projectile department is equal to twenty 10-inch armour-piercing shells per day, or an equivalent tonnage of other calibres. This is a very large output, when compared with establishments in other parts of the world making armour-piercing shell.

The present requirement for armour-piercers in the United States is, that they shall perforate, unbroken, an ordinary steel, oil-hardened, and annealed plate of a thickness equal to a calibre and an eighth. The Sterling Steel Company has proposed to submit its shells hereafter to tests against face-hardened plates. There have been no instances in the United States of armour-piercing shell perforating nickel-steel Harvey-treated plates unbroken, or being fired against them and rebounding, or remaining in the plate uninjured, with the exception of those made by the Sterling Steel Company, although a considerable number of imported armour-piercers have been used in the ballistic tests.

The following tests of Wheeler - Sterling armour-piercers are interesting:—

July 12th, 1894.—A 12-inch projectile weighing 850 lbs. was fired at a 17-inch nickel-steel Harvey barrette plate, with a striking velocity of 1,858 f.s. It went through plate and backing and an 18-inch oak upright, and was recovered but slightly injured.

November 2nd, 1894.—A 6-inch projectile weighing 100 lbs. was fired at a 6-inch nickel-steel Harvey plate. It perforated the plate and was recovered practically uninjured.

December 15th, 1894.—A 12-inch projectile weighing 850 lbs. was fired at a 17-inch nickel-steel Harvey barrette plate with a striking velocity of 1,410 f.s. It penetrated $16\frac{6}{16}$ inches and rebounded unbroken set up only $\cdot 15$ of an inch.

February 24th, 1895.—A 12-inch projectile weighing 850 lbs. was fired against a 14-inch nickel-steel Harvey plate with a striking velocity of 1,858 f.s. It went through the plate and backing, and was recovered whole, with the exception of 1 inch of the point.

June 15th, 1895.—A 4-inch projectile weighing 33 lbs. was fired against a $5\frac{1}{4}$ -inch nickel-steel Harvey turret plate with a striking velocity of 2,000 f.s. It penetrated 9 inches, remaining in the plate uninjured.

This company is also supplying the United States Navy Department with a type called "semi-armour-piercers," which have thinner walls and carry a bursting charge. They are built to perforate such a considerable thickness of armour and to burst sufficiently inside, that they have become a new and most formidable kind of shell. They promise to replace not only the ordinary steel-cast explosive shell, but in the quick-firing calibres particularly will undoubtedly be substituted for both ordinary

explosive shell and armour-piercers, because in action it will not be practicable to choose between two or more kinds of shell when fired so rapidly.

Great Britain and Russia are the only nations which have given enough attention to wire-wrapped ordnance to effect a service supply. To enter into a discussion of the value of the two methods would take too long to even suggest a consideration of it at this time.

It is much easier for me to accept the commercial results and to express my appreciation of the value of wire-wrapped ordnance. Mechanically, I like it and believe it can be as efficiently, economically and quickly supplied as the built-up type. It remains, therefore, simply a question of selection.

Wire has been so extensively used in other engineering work that it is remarkable its employment for guns and shafting has been so long delayed. In bridges its graceful value is especially emphasised, and I see no reason why wire-wrapped guns, shafting, and fly-wheels should not attain the same eminence in their respective branches as the Brooklyn Bridge has in bridge construction.

Woodbridge, Longridge, and Schultz lay about equal claims to the paternity of wire-wrapped guns. Woodbridge is an American, Longridge an Englishman, and Schultz a Frenchman.

At the present time, Moch and Very are the principal exponents of the system in France, Schultz having died in 1880. Longridge has been pensioned off by Great Britain, while Woodbridge still continues to design experimental guns which, thus far, have been doomed.

A comparison of the methods of construction of the three types under consideration in the United States—the Brown, Crozier, and Woodbridge—proves that the Brown utilises to the greatest extent the high elastic properties obtained in the segments and wire.

In the built-up gun narrow hoops leave weak zones, and it is probably easier to meet the progressive action of the powder pressure with wire than with taper hoops.

The material should have abundant elastic strength, and the wire should be wound continuous in order that the vibration shall not be broken; if it is, rupture is not only possible but probable. In all cases of ruptures of wire-wound guns they have not been violent; further, in no case has the wire been broken.

I think, with Moch, that the consideration of heat in its effect upon the tensions of wire when the gun is being fired is of value only to emphasise that the gun should not be composed of different metals, whereby different extensions are produced.

The series of hooping or winding offers us less guide to the size and form of the wire to be employed than the mechanical and economical requirements. The construction should not be complicated by an exaggerated number of layers.

That form of wire which is most easily wound, tensioned, and best to receive the subsequent layer and of a size that can be given the high physical characteristics desired, and which has not an abnormal difference

of tension and extension between its axis and exterior when wound, would appear to best suit the conditions of wire construction.

Although piano wire of circular section was used in the beginning, all of the manufacturers and designers of wire guns now use a square or rectangular section.

In modern armour the United States has an enviable record. For the past eighteen months there has been no marked improvement in Bethlehem's plates, the Carnegie Company having at the present time a decided lead. Although Bethlehem's products just manage to pass the first, or cracking shot, cracks are invariably produced by the second; whereas, Carnegie and Krupp are both making plates of superior resisting qualities, frequently standing several blows without developing any important cracks.

Very practical and noteworthy advances in armour making have been given to the public this year, viz., the gas-hardening methods of Schneider and Krupp, and the re-forging process for which the Carnegie Company has been granted patents.

Many elaborate arguments in relation to carburisation have been published, and many novel statements have been presented. The generally accepted view is, that it is effected by the direct and simple contact of iron and carbon. It is well known, however, how important a part the gas carbonic oxide plays in this operation.

As far as I know, I was the first to suggest in the United States that in the carburisation of armour-plate the carbonisation was effected by the gas generated by heat from the carbon, and that it would be more economical to carburise with gas than with solid materials. This view has been substantially endorsed by the latest most successful practice.

Strains are produced by hammering, rolling and wire drawing, or by slow or rapid cooling from an elevated temperature. Long-continued hammering and vibration will produce crystals. Hence the necessity for the adoption of some means to prevent this.

Compression, at a temperature, where true molecular flow takes place, increases the density, and in every way improves the product molecularly.

The re-working and compression toughen the plate, decrease the tendency to brittleness, and restore the fine grain of the metal, which becomes crystallised during the long period the plate is undergoing the carburisation treatment and by reason of the high temperature employed. The re-working further has the effect of closing pipes, blow-holes, and fissures, that may have originally existed as minor defects, and have developed into injurious ones during the process of carburisation.

In other words, the molecular structure impaired or damaged by the cementation is restored or repaired, the density is increased, crystallisation broken up, elastic strength increased, and the product made tenacious, tough and hard.

That these conclusions may not be accepted as theories only, I am glad to be able to present the following reports of tests of re-forged armour manufactured by the Carnegie Steel Company, and of gas-hardened plates manufactured by Mr. Krupp.

"BALLISTIC TEST OF 'IOWA'S' SIDE ARMOUR-PLATE.

"On September 4th, 1895, at Indian Head, Md., the 'Iowa's' 14-inch side armour ballistic plate was tested. The plate was mounted on backing, and a structure representing a section of the ship's side. The 10-inch B.L.R., with Carpenter armour-piercing shell, weighing 500 lbs. each, were used in the test.

This plate was press-forged, under a Whitworth press, to 17 inches, carburised and reformed to 14 inches.

"The left-hand end of the plate as mounted was the bottom end with reference to the ingot. The first point of impact was taken at a point about 10 inches above the line of the bevel, and about 2 feet to the left of the middle of the plate. The shots were fired through the screens; the striking velocity as measured was 1,482 f.s., the contract velocity being 1,472 f.s. The shell broke up on the plate, leaving the point embedded in the face of the plate to a depth of about $3\frac{1}{2}$ inches; there were no cracks. The second point of impact was taken about 8 inches above the bevel line, and 29 inches to the left of the first point of impact. This distance should have been 35 inches, but as the plate showed no disposition to crack, the shot was placed nearer. The velocity on this round was 1,856 f.s., the contract velocity being 1,859 f.s. The shell broke, leaving the ogival, much distorted, buried to a depth of about 9 inches in the plate. There were no cracks. The plate thus passed the contract test with a large margin to spare.

"The third round was fired with the 12-inch B.L.R. A Wheeler-Sterling shell, weighing 850 lbs., with a striking velocity of 1,800 f.s., was used. The point of impact was taken about 30 inches to the right of the first point of impact, and about 8 inches above the bevel line. The shell broke across the forward part of the body, about two-thirds of the body of the shell being found in one piece in front of the target. The point of the shell penetrated to about the back of the plate, which was cracked across from top to bottom through this impact.

"As the contract velocity for the second shot against a 17-inch Harvey plate is 1,858 f.s., and as the additional 58 feet would not have caused this shell, although a very good one, to have perforated the plate and backing, it appears that this plate, after having stood the test of a 14-inch plate, has passed the test of a 17-inch plate. This is a better record than any other thick plate heretofore tested. The 14-inch re-forged plate, tested in February last, was perforated by a Wheeler-Sterling shell with 1,858 f.s., although it kept out a Carpenter 12-inch a.p. shell with the same velocity. This plate, therefore, although a beveled one, stood a better test than the 14-inch experimental re-forged plate of last February.

"A fourth round was fired at this plate later, the point of impact being taken on the right-hand portion. A Wheeler-Sterling 13-inch a.p. shell, weighing 1,100 lbs., was fired with a striking velocity of 1,800 f.s. The shell perforated the plate, backing, and structure, and was recovered unbroken. The plate was comparatively but little cracked." (See Plate 3.)

The excellent resistance of this plate will be better understood if you recall that the second, or higher velocity shot, for an 18-inch Harvey plate, with the 13-inch gun, requires a velocity of 1,810 f.s.

These tests justify the conclusion that the forging after carbonisation, as practised by the Carnegie Company, benefits very materially the body of the plate, while at the same time it does not appear to impair the efficiency of the carbonised surface.

The target structure for this test was built to represent a section of the battle-ship "Iowa" as actually constructed. The object was to study the effect of the impact of heavy projectiles at striking service-velocities on the framing when protected by the best armour ever made.

You will note that the 13-inch projectile (an exceptionally good one) was the only one that seriously damaged the framing.

This is a very strong endorsement of the opinion I have so often expressed, that we must not reduce the calibres of our heavy ordnance. On the contrary, for naval batteries especially we should increase the calibre and elastic strength and use nitro—high velocity—powders in shorter guns. If we cannot find a powder that will not cut out our bores, build guns in four or five pieces and so assemble their parts that you can re-tube them on board ship; it will be much easier to do this than to find a suitable powder.

Krupp's gas-hardened 11·81-inch nickel-steel plates, tested in March last with 8·264-inch, 11·02-inch, and 12-inch armour-piercers, at velocities ranging from 1,752 f.s. to 2,240 f.s., certainly afforded remarkable results.

The absence of serious cracks after such a tremendous battering testifies to the great value of the methods now employed by Carnegie and Krupp—processes containing fewer objectionable features than the so-called Harvey.

A novelty in armour was tested at the U.S. Naval Proving Ground, October 15th, 1895. It was a type proposed by Mr. D'Humy, and consisted of thin slabs placed edgewise—it was 6 inches thick and was tested with a 6-inch projectile. The first shot completely demolished the plate, the projectile breaking up at the same time.

Before closing, I wish to present to the Institution a 6-inch Wheeler-Sterling armour-piercer that has perforated 7 inches of nickel steel Harvey armour; and a sample of Leonard smokeless powder, which gave in a 5-inch B.L.R. a muzzle velocity of 3,235 f.s., with a pressure of 65,000 lbs. per square inch. As it was manufactured in 1893, it has at least been stable for a period of two years.

I must now thank you for your patience and attention, and trust the many details, so hastily passed before your eyes, will leave a favourable impression of what we have commenced to do in supplying ourselves with modern war material.

[The paper was illustrated with 375 specially-prepared lantern views, thoroughly explaining the opinions and comparisons presented by the lecturer.]

Captain ORDE BROWNE (Retired, late R.A.): Might I ask what was the velocity with which that Wheeler-Sterling shell was fired, and the thickness of the plate at which it was fired?

Captain JAKUES: It was a 7-inch nickel steel plate. That shell did not go through the carburised plate. The 6-inch projectile had a striking velocity of 1,700 f.s.

Captain ORDE BROWNE: Do you consider, supposing the result of treating a 6-inch plate is to keep out a 6-inch projectile, that that plate is successful?

Captain JAKUES: The United States, with the exception of Mr. Krupp, who has attained equally good results, have made the best nickel steel that I am aware of, and these projectiles have perforated 7 inches of nickel steel. The penetration is $1\frac{1}{2}$, that is, $1\frac{1}{2}$ untreated is the specification.

Captain ORDE BROWNE: The statement is that you consider that a good-treated 6-inch plate in the United States would keep out a good 6-inch Holtzer projectile.

Captain JAKUES: I know it.

Captain ORDE BROWNE: We cannot compare with other nations, because we have not got that particular kind of projectile.

Captain JAKUES: The 6-inch Holtzers have no effect on the best 6-inch carburised nickel steel plates in the States.

Mr. HADFIELD: I am from Sheffield, and therefore I think perhaps I ought to say something on this matter. I am sure we thank Captain Jaques very much for his interesting lecture, though it is one we might have followed much better if we had had it in pamphlet form, so that we might have compared the results. Captain Jaques refers to the penetration of Harveyized plates. I do not know whether the members here would be interested in this, but about fifteen months ago Sir William White made some tests with our projectiles with the shape of the heads slightly altered, and I am glad to say an English-made projectile of 6-inch calibre and 1,840 feet velocity penetrated a 6-inch Harveyized plate. The projectile was broken, and I believe that was almost the first time it has been done in this country. I do not know what has been done in the United States beyond what Captain Jaques mentioned, but I think it very desirable that one point with regard to the Harveyized plate should be cleared up. So many of these plates vary, that one cannot say that a projectile is of exceedingly good quality and does exceedingly good work without having some idea of the condition of the plate that it is fired against. I may also say that some years ago we fired one of our 6-inch projectiles through a 9-inch compound plate, and it remained uninjured. It was put again into the gun and fired again, and again penetrated without being broken. The third time it was fired against a 9-inch compound plate treated by Harvey's in the same way, carburised and hardened, and it then broke up. I think that was a somewhat remarkable result. I do not know whether Captain Jaques has any reports of the Wheeler-Sterling trials; if so, I shall be very glad to get them. We all know that the Americans make very excellent projectiles, and I have seen a number of them in the Chicago Exhibition. With reference to the tests of the Government here, I may say they will not accept projectiles without penetrating a $1\frac{1}{2}$ -calibre plate, so that our English test is more severe than your $1\frac{1}{2}$ American test. We have supplied projectiles which have stood that test—mild steel. In speaking of compound plates, although in the excellent illustrations which Captain Jaques has put before us we have seen some very unfavourable results, still I think compound plates may give good results. Entirely uniform compound plates are very difficult to pierce sometimes. We had a trial some six months ago in which the face of the compound plates on which our projectile was fired contained no less than 1·6 per cent. of manganese to ·9 of carbon. I think that is an exceedingly severe test. I am glad to say that our projectiles successfully penetrated plates

of that description. I should very much like to have a little more information as to the quality of the plate at which this projectile was fired which Captain Jaques has mentioned to-day.

Captain JAKUES: I should be very happy to see the Wheeler-Sterling shell re-capped and fired again. I should like to take exception to Mr. Hadfield's statement that the British test for shells is more severe than ours. You fire at mild steel, and we fire at nickel steel. I think the test of $1\frac{1}{2}$ -calibre against mild steel is not equal to $1\frac{1}{2}$ of nickel steel, which is used in America. Mr. Hadfield knows that there is no one who, I think, in the United States, gives more consideration to this shell in the manner of its production than I have done. I carried on tests at Bethlehem with a great deal of confidence as to the very remarkable toughening quality of Mr. Hadfield's manganese products. I have answered with regard to the tests of the shell.

Captain ORDE BROWNE: There is just one point on that. The shell is allowed to go to pieces in the English test. Is it allowed to go all to pieces in the American?

Captain JAKUES: It is not.

Captain ORDE BROWNE: It may come out in bits as it likes in the English test.

Captain JAKUES: This shell was a Wheeler-Sterling 6-inch armour-piercer. It perforated a 7-inch nickel armour plate, the striking velocity being 1,700 f.s.

Mr. HADFIELD: Have you any idea what was the proportion of carbon?

Captain JAKUES: The carbon was about 3.1 and 3.2 nickel, oil-hardened.

The CHAIRMAN (Vice-Admiral Colomb): Well, gentlemen, if there are no further remarks or questions to be asked, as the lecturer has answered the questions which have been put, it becomes my pleasing duty to offer on your behalf a vote of thanks to Captain Jaques for his most interesting paper—a paper a little too interesting for a man like myself, because the rapidity of the passages of thought through my brain had a certain tendency to confuse it, but no doubt to those who are familiar with the subjects dealt with that would not occur. It seems that the gist of the paper really turns upon the construction of shell, and whether it is more advantageous that a carburised plate should be also alloyed with nickel in preparation. I understand our rejection of nickel says nothing to the advantage, or rather disadvantage, of the alloy, but it is simply that resistance sufficiently good is got from hardened ordinary steel, and that the extra cost of the nickel is not thought worth incurring. I believe that is the condition of things. I have never heard the lecturer's position disputed as to the extreme value of nickel steel. But, gentlemen, the chief sensation that I derived from listening to the lecture was seeing the enormous advance which the United States is making in these directions. I hope that our rivalry may stop short at manufacture. As long as we both stick thus to the manufacture on our own sides of the water, we shall get on very well; but if we should venture to carry our rivalry further than manufacture perhaps it would not be quite so satisfactory. I am sure you will all join with me in heartily thanking the lecturer for the paper he has given to us.

Captain JAKUES: Mr. Chairman and Gentlemen,—I thank you for your appreciative acceptance of my paper, and Captain Browne and Mr. Hadfield for their complimentary consideration and criticism. All tests are made under such different conditions in the various countries that it is only by such impartial and complete comparison as that employed in the Annapolis armour trials of 1890 that final and absolute conclusions can be reached. I think a careful examination and comparison of the British and United States requirements for shell will show that a projectile which perforates *unbroken* an oil-hardened steel plate, of a thickness equal to $1\frac{1}{2}$ the calibre of the projectile, is superior to one that is broken up in getting through a soft steel plate (such as is used in England) of $1\frac{1}{2}$ the calibre.

Carnegie double-forged 14-in. nickel-steel Harvey plate for U.S. battle-ship "Iowa," after being fired at by two 500-lb. Carpenter, one 850-lb. and one 1,100-lb. Wheeler-Sterling Projectiles.

13-in. 1,100-lb. Wheeler-Sterling Projectile, recovered practically uninjured after penetrating 14-in. nickel-steel Harvey special refined plate, and 24-in. wood backing and framing.

My estimate of British compound armour is so well known that I need express no surprise to hear that a Hadfield shell twice perforated a compound plate. There can be no possible doubt, however, as to the superiority of the Wheeler-Sterling shell which I presented to the Institution, and I have no doubt the Sterling Steel Company would gladly join me in the desire to see it fired again either at compound armour or a soft steel plate. We all know the excellence of the shells that Mr. Hadfield has produced, and he will admit that no one, either here or in the United States, has been more friendly to his methods than I. In conclusion, I will suggest that the simplest way to decide the supremacy of British or American armour and projectiles is to make a thorough competitive test in England, and I am sure that the Carnegie Steel Company and Sterling Steel Company are quite ready to enter the field. I am still more certain that *nickel* steel cemented plates will show much greater resistance than simple steel Harveyized. I have only to say I shall be very glad to answer any questions in writing, if any of you desire to communicate with me through the Secretary of this Institution.