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THE ARMOR QUESTION.

LETTER

FROM

THE SECRETARY OF THE NAVY,

TRANSMITTING CERTAIN DATA AND INFORMATION COLLATED AND ARRANGED BY THE CHIEF OF THE BUREAU OF ORDNANCE RELATING TO THE ARMOR QUESTION.

DECEMBER 6, 1899.—Referred to the Committee on Naval Affairs and ordered to be printed.

NAVY DEPARTMENT,
Washington, December 4, 1899.

SIR: Apropos of the matter of procuring armor for naval vessels, in connection with which so many difficulties have been met by the Congress and the Department, I have the honor to inclose herewith a typewritten copy of certain data and information collated and arranged by the Chief of the Bureau of Ordnance relating to "the armor question," and to recommend the same to the attention of the Senate.

Very respectfully,

JOHN D. LONG,
Secretary.

The PRESIDENT PRO TEMPORE, UNITED STATES SENATE.

THE ARMOR QUESTION.

In order that Congress may be fully informed concerning this important subject, the following data have been compiled by the Bureau of Ordnance, and are respectfully submitted by the Department:

Prior to battle ships 7, 8, and 9 (*Alabama*, *Illinois*, and *Wisconsin*) no limit was fixed by law as to the price which might be paid for armor.

The armor for the two preceding battle ships, Nos. 5 and 6 (*Kearsarge* and *Kentucky*), the construction of which was authorized by the act of March 2, 1895, was contracted for at an average price of $550.33 per ton of 2,240 pounds, the Government supplying the nickel on a basis of 98 pounds of nickel-in-oxide per ton of finished plate. The amount of armor purchased for these two vessels was 5,873 tons, at a contract price of $3,232,080. The cost of nickel supplied by the Gov-

ernment, at 28 cents per pound, amounted to $161,155.12, making the total cost to the Government, exclusive of freight and ballistic tests, $3,393,235.12, an average cost of $577.93 per ton, to which must be added $11.20 per ton for royalty for face-hardening process (if it is decided that such royalty has to be paid).

LAWS GOVERNING THE PRICE OF ARMOR.

Under existing provisions of law armor has been or may be contracted for as follows:

The first restriction as to the cost of armor was applicable to that for battle ships 7, 8, and 9 (*Alabama*, *Illinois*, and *Wisconsin*), the construction of which was authorized by the act of June 10, 1896; the limit of price of armor for these vessels being fixed by the act of May 4, 1898, at $400 per ton, including nickel, but exclusive of a royalty of $11.20 per ton for face hardening process (if the same has to be paid).

A similar restriction applies to armor for battle ships 10, 11, and 12 (*Maine*, *Ohio*, and *Missouri*), and to harbor-defense monitors 7, 8, 9, and 10 (*Arkansas*, *Connecticut*, *Florida*, and *Wyoming*), the construction of which was authorized by the act of May 4, 1898; the limit of cost of armor for these vessels being fixed by the same act at $400 per ton, including nickel, but exclusive of royalty of $11.20 per ton for face-hardening process (if the same has to be paid). The same limit of cost was reaffirmed by the act of March 3, 1899.

From the above it will be seen that $400 per ton is the limit of price fixed by law for armor for the following vessels now under construction, viz: Battle ships *Alabama*, *Illinois*, *Wisconsin*, *Maine*, *Ohio*, and *Missouri*, and harbor-defense monitors *Arkansas*, *Connecticut*, *Florida*, and *Wyoming*.

A restriction of $300 per ton, including royalties, applies to armor for three battle ships, Nos. 13, 14, and 15 (*Georgia*, *Pennsylvania*, and *New Jersey*), and to that for three armored cruisers, Nos. 4, 5, and 6 (*West Virginia*, *Nebraska*, and *California*), the construction of which was authorized by the act of March 3, 1899, said restriction being contained in the act which authorizes the vessels which also contains the following provision: "And in no case shall a contract be made for the construction of the hull of any vessel authorized by this act until a contract has been made for the armor of such vessels."

EXISTING ARMOR CONTRACTS.

The contracts for armor for the *Kearsarge* and *Kentucky* are just completed, at an average contract price of $550.33 per ton, exclusive of nickel and royalty of $11.20 per ton for face-hardening process (if the same has to be paid).

Contracts were made in June, 1898, for armor for the *Alabama*, *Illinois*, and *Wisconsin*, aggregating 7,677 tons (2,559 tons for each vessel), at $400 per ton, including nickel, but exclusive of royalty of $11.20 per ton for face-hardening process (if the same has to be paid).

About two-thirds of the above armor has been completed and accepted (November 1, 1899), and there remains to be delivered about 2,481 tons, namely, 832 tons for the *Alabama*, 1,255 tons for the *Illinois*, and 394 tons for the *Wisconsin*. Of the amount yet undelivered, about 1,000 tons will probably be completed by the middle of November, 1899; and the armor contracts for these three vessels should be completed by March 1, 1900, or thereabouts.

Contracts were made on August 30 and on October 4, 1899, for 2,152 tons of armor for harbor-defense monitors *Arkansas*, *Connecticut*, *Florida*, and *Wyoming* (538 tons for each vessel), at a price of $400 per ton, including nickel, but exclusive of royalty of $11.20 per ton for face-hardening process (if the same has to be paid). These contracts will probably be completed by June, 1900.

Contracts were also made on August 30 and on October 4, 1899, for 116.58 tons of armor for the *Maine*, *Ohio*, and *Missouri* (38.86 tons for each vessel). This small lot of armor consists of an armored tube and four small triangular plates for each vessel, necessary to be worked into the hulls during the early stages of their construction.

KIND OF ARMOR ORDERED FOR THE FOREGOING VESSELS.

All the above armor is of nickel steel, reforged and face-hardened, and for the purpose of distinction is referred to as "Harveyed armor," because the process of cementation is accomplished by means of charcoal. The Harvey patents, however, specify certain temperatures at which the process must be carried on, which are said to be higher than those employed by the manufacturers; and in consequence certain suits have arisen, to which the Government is not a party; but, pending a judicial settlement of the matter, the Department has held in abeyance the payments for royalty for face-hardening process on the armor for the *Kearsarge* and *Kentucky* and all subsequent vessels; hence the term "Harveyed armor" used in this memorandum is not to be construed as an admission on the part of the Department that the process covered by the Harvey patents has been used.

ARMOR AUTHORIZED, BUT NOT CONTRACTED FOR.

For battle ships *Maine*, *Ohio*, and *Missouri*—vessels now under construction, and for which "armor of suitable quality" may be procured at a cost not exceeding $400 per ton (exclusive of royalty of $11.20 per ton, if the same has to be paid)—7,359.42 tons of armor is required; namely, 2,453.14 tons for each vessel.

The above armor should be contracted for early in the year 1900; otherwise there is reason to fear that it can not be procured in time to meet the requirements of the shipbuilders.

In order that the six armored vessels authorized by the act of Congress, approved March 3, 1899, may be contracted for (unless the provisions relating to armor in said act are changed) there will be required about 2,700 tons of armor for each battle ship and about 1,200 tons for each cruiser a total of about 11,700 tons. There is, however, no immediate necessity for considering or contracting for this armor, aside from the fact that the vessels can not be contracted for under existing law until the armor therefor is contracted for.

WHY ARMOR HAS NOT BEEN CONTRACTED FOR FOR THE THREE VESSELS OF THE MAINE CLASS.

The reasons why armor has not been contracted for for the *Maine*, *Ohio*, and *Missouri* (except the small quantity previously referred to) are as follows:

First. Because the contracts for the hulls and machinery of these vessels were not made until October, 1898, and the keel of the first of them was not laid until February 15, 1899, consequently there was no pressing necessity of contracting for their armor. In fact, the keel of one of them, the *Missouri*, is not yet laid (November 1, 1899).

Second. The armor manufacturers have practically all the work on hand that they can accomplish until about June, 1900, on armor for the *Alabama* class, the monitors, and on contracts for foreign vessels, and, therefore, could not turn out any armor for the *Maine* class prior to about June or July, 1900.

Third (and most important). Because the Department desires to supply these vessels with the best quality of armor that can be made in this country, in order that they may be on an equality with contemporaneous vessels of other powers, to do which it was necessary to again present the matter to Congress for consideration, as under existing conditions the Department is unable to procure within the limit of cost fixed by law the best quality of armor, and such alone as is, therefore, deemed to be "of suitable quality."

REASONS WHY CONTRACTS HAVE NOT BEEN MADE FOR ARMOR FOR THE SIX ARMORED VESSELS AUTHORIZED BY THE ACT OF MARCH 3, 1899.

The act of March 3, 1899, limited the price which might be paid for armor for the vessels authorized by that act to $300 per ton, including royalties. No armor, not even that of inferior quality, could be procured for this price; hence no contracts could be made.

STEPS TAKEN BY THE DEPARTMENT TO OBTAIN ARMOR "OF SUITABLE QUALITY" FOR VESSELS OF THE MAINE CLASS.

In order to ascertain if the best quality of armor, and such alone as the Department considers of suitable quality, could be procured within the limit of cost authorized by law, and in order, if possible, to attract bidders, all the armor required for vessels authorized was included in one lot, and on March 29, 1899, advertisements were published in leading daily papers in Boston, Mass.; New York, N. Y.; Philadelphia, Pa.; Atlanta, Ga.; Birmingham, Ala.; Chattanooga, Tenn.; Pittsburg, Pa.; Cleveland, Ohio; Chicago, Ill., and San Francisco, Cal., inviting bids for about 24,000 tons of armor plate and appurtenances for seven vessels authorized by the act of Congress approved May 4, 1898, viz, three battle ships (Nos. 10, 11, and 12) of the *Maine* class, and four harbor-defense monitors (Nos. 7, 8, 9, and 10) of the *Arkansas* class, for which $400 per ton might be paid; and for six armored vessels authorized by the act of Congress approved March 3, 1899, viz, three battle ships (Nos. 13, 14, and 15) and three armored cruisers (4, 5, and 6), for which $300 per ton might be paid. To be exact, 24,500.5 tons of armor, for which the sum of $8,385,700 might be paid.

The circular prepared in connection with the Department's advertisement stated in general terms the quality of the armor required, and a table therein showed the ballistic tests to which it would be subjected for acceptance. The striking velocities of the projectiles, given in this table, were considerably higher than those now or heretofore required for the acceptance test of service armor plates in this country for United States vessels, but not higher than are now required abroad or in this country for armor manufactured for vessels building in the United States for a foreign power.

May 31, 1899, was designated as the date for opening the bids, and notwithstanding the unprecedented quantity of armor called for, the large sum of money involved, and the long period over which deliveries might extend, only one bid was received, and that named a price of $450 per ton—a sum in excess of that authorized—and named the date for beginning delivery as January, 1904.

It was ascertained on inquiry that the bidder had no manufacturing plant whatever, but was a dealer on a moderate scale in scrap iron and steel; and this bid being otherwise irregular, was not deemed worthy of serious consideration.

WHY ARMOR MADE BY THE SO-CALLED HARVEY PROCESS WAS ORDERED FOR THE HARBOR-DEFENSE MONITORS AUTHORIZED BY THE ACT OF MAY 4, 1898.

About the middle of the present year (1899) some of the builders of the four harbor-defense monitors began sending in the armor drawings for these vessels, and made requests for early delivery of armor, and for the following reasons the Department decided to order for them armor made by the so-called Harvey process, which could be procured within the limit of cost allowed by law for armor "of suitable quality," namely, $400 per ton:

First. In order that the completion of the vessels might not be delayed by the nondelivery of armor, as they are of small displacement, and consequently can be quickly built.

Second. To avoid possible complications and claims, were such delays due to the nondelivery of armor.

Third. Because the quantity of armor carried by them is comparatively small.

Fourth. Because the vessels, being of a low-free-board type, present but small targets.

Accordingly contracts were made at $400 per ton for armor for the above vessels, and these contracts should be completed about June, 1900.

KIND OF ARMOR THAT THE DEPARTMENT DESIRES TO OBTAIN FOR THE BATTLE SHIPS OF THE MAINE CLASS AND FOR THE SIX ARMORED VESSELS AUTHORIZED BY THE ACT OF MARCH 3, 1899.

The Department desires to supply the vessels above referred to with armor made by the new Krupp process, as it represents the most advanced state of the art of armor manufacture and is superior in resisting quality to that made by the so-called Harvey process. The manufacturers offer to supply armor plates made by the Krupp process, and to submit them to ballistic tests for acceptance 25 per cent more severe than are now applied to service plates made by the so-called Harvey process; that is, the same test to be applied to a 6-inch Krupp plate that has heretofore been applied to a 7½-inch Harveyed plate; to an 8-inch Krupp plate that which has been applied to a 10-inch Harveyed plate; to a 10-inch Krupp plate that which has been applied to a 12½-inch Harveyed plate; to a 12-inch Krupp plate that which has been applied to a 15-inch Harveyed plate.

The difference in ballistic requirements is shown in the following table, giving striking velocities in feet per second for Harveyed and Krupp armor, the Krupp plates receiving three shots and the Harveyed two shots at the velocities named:

Caliber of gun.	Thickness of plate.	Harveyed armor.	Krupp armor.
Inches.	*Inches.*	*Foot-secs.*	*Foot-secs.*
4	4	1,676	1,818
5	5	1,717	2,045
6	6	1,659	1,885
8	8	1,558	1,772
10	10	1,502	1,765
12	12	1,469	1,661

The differences in ballistic requirements as expressed in the preceding table in foot-seconds of velocity are apt to be misleading except to those familiar with the fact that energies are not directly proportional to velocities, but to the squares of velocity; hence the following table is given, showing the energies corresponding to the different striking velocities of the projectiles, which indicates more clearly the severity of an attack due to an increase in velocity; hence a comparison of velocities alone should not be considered in forming an estimate of the work done by the projectile.

Caliber of gun.	Thickness of plate.	Velocities for test of Harveyed plates.	Energies corresponding to velocities for Harveyed plates.	Velocities for test of Krupp plates.	Energies corresponding to velocites for Krupp plates.
Inches.	*Inches.*	*Foot-seconds.*	*Foot-tons.*	*Foot-seconds.*	*Foot-tons.*
4	4	1,676	1,285	1,818	2,271
5	5	1,717	2,044	2,045	4,348
6	6	1,859	3,729	1,885	7,221
8	8	1,558	8,413	1,772	16,325
10	10	1,502	15,639	1,765	32,391
12	12	1,469	25,430	1,661	45,513

EXTENT TO WHICH KRUPP ARMOR IS BEING USED.

It is understood that armor made by the new Krupp process is being used, or now being manufactured for use, on the latest vessels of England, Russia, Germany, Japan, and France.

A Russian battle ship, now building in this country at the works of Messrs. Wm. Cramp & Sons, is being supplied with armor made in the United States by the Krupp process, the ballistic plates of which are being tested at the naval proving ground at Indian Head by United States naval officers, as an act of courtesy to the Russian Government, at the expense of the contractors.

Positive assurances have been received from leading armor manufacturers in Europe that they are making nothing but Krupp armor, and it may be asserted without fear of contradiction that Harveyed armor has been superseded by that made by the Krupp process, except for thin plates.

WHO CONTROLS THE KRUPP PROCESS.

It is learned that the so-called new Krupp process was developed at the works of Fried. Krupp, at Essen, Germany, but that the rights to manufacture are held by the Harvey Continental Company, which disposes of them for a fixed sum and in consideration of a royalty at an average price of $50 per ton on all armor manufactured by that process; the agreement providing that the information necessary to manfacture the same shall not be imparted to any but authorized agents, and that no tests shall be agreed to in this country more severe than those specified in Europe.

It is further understood that certain features of the process are patented; probably certain details of the apparatus used in the process of cementation; but little importance, however, is attached to this fact. Parties acquiring the rights to manufacture are instructed in the metallurgical and other details of the process at Krupp's works. So far as secrecy is concerned, it will be impossible to maintain it absolutely, and there would be but little difficulty in learning all the details of manu-

facture if it was desired; but a mere knowledge of the methods employed in making Krupp armor would not alone be of much value to anyone, as possessing information is one thing and having the means and ability to use it is another. Experience and expert knowledge are indispensable and it requires time and costs much money to gain them.

Secrecy is understood to be an obligation imposed by the company which controls the Krupp process, but such provision is not uncommon in manufacturing industries where so-called trade secrets are frequently met with. The method of making certain kinds of powder, armor-piercing projectiles, alloys of various kinds, and processes employed in producing articles is often not patented, but is guarded as a trade secret for reasons easily understood; hence no significance should be attached to the fact that the Krupp process for making armor is referred to as a secret process.

DIFFERENCE BETWEEN HARVEYED AND KRUPP ARMOR.

Aside from the difference in the charactor of the alloy, there is a marked difference in the process of manufacture. Without entering into minute details, it may be stated that armor made by both processes contains nickel to nearly an equal amount, Krupp armor having about three-fourths of 1 per cent more of nickel than the Harveyed, entailing an additional cost of $5.61 per ton of plate. The charge for the ingot for a Krupp plate contains about 45 pounds of chrome metal per ton of ingot, costing 25 cents per pound, or $11.25 per ton of ingot; but as the ingot weighs on an average two and one-quarter times as much as the finished plate, the addition of chrome would cost $25.31 per ton of plate. On remelting scrap containing chrome, the chrome contained in it is entirely lost.

In addition to the above-mentioned alloys, a special alloy is incorporated, the character of which is not known to the writer, but which is said to cost $2.25 per ton of plate.

At the above figures the increased cost of material per ton of plate is $33.17, to which, if a royalty of $45 per ton is added, the additional cost of Krupp plate would be $78.17 per ton. The increased price asked by the manufacturers over that now paid for Harveyed plates ($400 per ton) is, however, $145 per ton, or $66.83 in excess of the above figure; and this difference is claimed by the manufacturers to be a legitimate charge, due to decreased output; to losses in ingots and plates; to a greater number of processes necessary to produce Krupp plates; to extra cost of machining on account of the great hardness of the Krupp plates; to the cost of materials necessary to produce the deep, hard face which characterizes Krupp plates, and to interest charges on plant and working capital, which must be divided up on a less number of tons output; and further, that if they supply armor having greater resisting qualities than that heretofore possessed by plates of equal thickness, it is a better article, and hence is worth more money, aside from its intrinsic value.

The use of chrome in steel is known to be attended with considerable difficulty. It was tried years ago in connection with the manufacture of armor, but without success; but improved methods and increased knowledge have overcome difficulties which then seemed insurmountable.

Ingots containing chrome are liable to crack in the early stages of the manufacture of armor plate, and in casting they are not infrequently lost, owing to the flowing of the chromium into the slag, and it some-

times happens that no trace of chromium is found in the ingot, although the proper quantity had been introduced into the charge.

It is well known that steel containing a certain portion of chromium is susceptible of taking a high degree of temper, and that its presence imparts to steel the property of keeping carbon in the form of "hardening carbon," and that it raises the limit of saturation for carbon, and, therefore, its presence in armor plate undoubtedly greatly facilitates the process for supercarburization.

Harveyed armor is supercarburized by contact under a high and prolonged degree of heat, with a solid carburizing material (charcoal), oxygen being carefully excluded. The process can not be reduced to an exact science, nor by means of it can carbon be introduced into the face of a plate beyond a certain depth, namely, from 1 to 1¼ inches.

Experience has shown that plates of given thickness, when treated by the Harvey process, under certain conditions of heat for a given time, may be expected to give fairly uniform and satisfactory results, and such is often the case; nevertheless, there is an element of uncertainty about it.

In the Krupp process supercarburization is accomplished by means of a hydrocarbon gas, and treatment can be carried on until satisfactory results are obtained, frequent tests being made to determine when such is the case.

Harveyed plates are water-tempered only, whereas Krupp plates are both oil and water tempered, and in the manufacture of the latter it is essential that the plates be not allowed to get cold between certain stages of the process.

The number of processes is said to be greater in the case of Krupp than of Harveyed armor, and this is believed to be correct; but the process of reforging is not applied to Krupp plates, nor is the process applicable to very thin plates or to those likely to require much rectification, unless they are left untempered.

The temperatures of supercarburization are said to be considerably lower in the Krupp than in the Harvey process, which is favorable to the product.

When properly carburized and tempered, which operations frequently have to be repeated several times, the face of the Krupp plate has an extraordinary degree of hardness, which extends into it with gradual decreasing hardness to any desired depth, in which respect it possesses a decided advantage over the Harveyed plate. The back of the plate also becomes exceedingly tough, its tensile strength being much greater than that of the Harveyed plate, and plates made by the Krupp process possess remarkable immunity from cracking under numerous heavy impacts.

Unquestionably the manufacture of armor by the Krupp process is more difficult and attended with greater risk than of that made by the Harvey process—requiring greater skill, knowledge, and experience—and there is no doubt whatever that the output of the factories will be considerably lessened if they manufacture Krupp instead of Harveyed armor.

KRUPP'S NEW PROCESS.

The first important mention of the new Krupp process dates from the test of an 11.8-inch plate at Meppen on September 15, 1895. The published statements concerning this plate credited it with having successfully withstood the impact of three 12-inch armor-piercing projectiles having striking velocities of about 1,993 foot-seconds. This

plate, according to the formula used for computing velocities necessary for the perforation of face-hardened plates, should have been perforated by a 712.6-pound 12-inch projectile (the kind used), having a striking velocity of 1,829 foot-seconds; whereas it successfully resisted projectiles having 164 foot seconds greater velocity. None of the three shots perforated the plate, but from the fact that the back bulge, due to the third impact, was 3 inches high and slightly cracked, it would appear that the limits of its resistance had been almost reached; its most notable feature was the absence of cracks.

This plate was tested at Krupp's proving ground, with projectiles of his own make; nevertheless the test and its results seem to have been accepted, and the plate is referred to as the champion thick experimental plate.

On August 19, 1897, an official test was made at Shoeburyness, England, of an $11\frac{11}{16}$-inch plate made by Vickers Sons & Co., British manufacturers of armor. This plate was attacked by three 12-inch Holtzer projectiles, weighing 714 pounds, with 1,861, 1,868, and 1,860 foot-seconds' velocity, respectively, which only penetrated $2\frac{5}{8}$ inches. This plate successfully withstood the attack without cracking, and made a record about equal to the plate made by Krupp, above referred to. By calculation it should have been perforated by a velocity of 1,814 foot-seconds; whereas it was not perforated with a velocity of 51 foot-seconds greater.

The advent of these plates created some stir in naval circles, as it indicated a decided improvement in the ballistic properties of armor plate. In March, 1897, the English firm of Vickers Sons & Co. presented for test a 6-inch plate, which was officially tested under the direction of the British Admiralty. It successfully resisted, without perforation or serious cracking, the attack of five 6-inch Holtzer projectiles of 100 pounds weight, having a striking velocity of 1,960 foot-seconds. This is considerably in excess of the tests required in the United States for the present Harveyed armor, which consists of one low-velocity shot at 1,472 foot-seconds, and of one high-velocity shot for penetration at 1,659 foot-seconds, or 301 foot-seconds less than that used against the Vickers 6-inch plate. The calculated velocity (verified by practice) for the perforation of 6 inch Harveyed plates by a 6-inch projectile of 100 pounds weight is 2,084 foot seconds.

July 20, 1897, Messrs. John Brown & Co. (British) submitted two 6-inch plates, which were officially tested by the British Admiralty under the same conditions as the 6-inch Vickers plate, and both of them fulfilled the requirements.

It will be seen, therefore, that the appearance of armor superior in quality to that made by the Harvey process dates back to September, 1895. Since that date numerous tests have been made abroad, including those above referred to.

In 1898 this fact had evidently become generally known, as on the occasion of a hearing before the Senate Naval Committee on January 9 of that year, on which occasion the Secretary of the Navy and the Chief of the Bureau of Ordnance were present, when the question of armor for the vessels of the *Alabama* class was under consideration, Senator Chandler put the following question (Senate Doc. No. 127, second session Fifty-fifth Congress, bottom of page 7): "I want to ask whether any new process for making armor has been discovered which we ought to wait for rather than contract for armor made according to the present process." Some further discussion followed, and at a subsequent hearing on February 2, 1898, the chairman of the committee

addressed the following remark to the Secretary of the Navy: "By direction of the committee, Mr. Secretary, I wrote you a letter asking you to furnish any further information for the committee in relation to the new process for hardening armor, which has to some extent been adopted by European powers, and to which you alluded in your previous hearing before the committee. You were also informed that the committee desires full information as to whether such process may be utilized in the armor plate for the three new ships, the *Illinois*, *Alabama*, and *Wisconsin*, now being built. If you have any statement to make giving your views in reference to the question whether we should wait for that development, the committee will be glad to hear you."

In accordance with the request of the committee, the Secretary of the Navy directed the Chief of the Bureau of Ordnance to prepare a statement concerning the information desired, and such statement, having been prepared, was read to the committee on this occasion; the conclusion to be drawn therefrom being that Krupp armor was at that time in an experimental stage, and therefore could not properly be considered for use on the vessels of the *Alabama* class, especially as the armor manufacturers in this country were not then prepared to make armor by the Krupp process and could not even state approximately when they would be able to submit a trial plate. Presumably the committee accepted this statement as correct, and Congress during the session appropriated money for armor at $400 per ton, exclusive of royalty, for the vessels of the *Alabama* class. Since that time Krupp armor has passed the experimental stage and is being manufactured commercially both in this country and abroad.

It became known as far back as the spring of 1898 that the American armor manufacturers had sent their armor superintendents to Europe to learn the Krupp process and intended to submit a trial plate as soon as practicable, and on July 19, 1898, the first Krupp plate manufactured in this country was submitted by the Carnegie Steel Company and tested at the naval proving ground at Indian Head. The plate was 6 inches in thickness and was attacked by three 6-inch projectiles of 100 pounds weight with the following results:

First shot, 2,021 foot-seconds velocity; penetration, 2½ inches.

Second shot, 2,237 foot-seconds velocity; penetration, 5 inches.

Third shot, 2,350 foot-seconds velocity; just perforated, but did not get entirely through the backing.

The velocity required to perforate this 6-inch plate was that required to perforate a 7½-inch Harveyed plate.

The 6-inch Vickers plate previously referred to as having been officially tested by the British Admiralty was not tested to destruction, but received five impacts from 6-inch projectiles at 1,960 foot-seconds velocity, which is considerably lower than the velocities applied to the Carnegie plate.

In October and November, 1898, the Bethlehem Steel Company tested a 6-inch Krupp plate which was even better than the Carnegie 6-inch Krupp plate above referred to. The Bethlehem plate was attacked by six 8-inch projectiles, and about 1,820 foot-seconds velocity was required to get through the plate and backing, a velocity that would carry the projectile through nearly 7¾ inches of Harveyed armor.

In October, 1898, a 12-inch Krupp plate manufactured by the Carnegie Steel Company was tested at Indian Head, and the test showed that it would keep out 12-inch armor-piercing projectiles at all velocities below 1,900 foot-seconds, which is the required velocity for the perforation of nearly 15 inches of Harveyed armor.

These tests were sufficient to convince the American armor makers that they could successfully manufacture armor by the Krupp process, and that if they desired to keep in the front rank and abreast foreign manufacturers it was essential that they should be able to reach the highest standard attained abroad. They therefore proceeded to make such alterations in their plant as became necessary, and took steps to further perfect themselves in the manufacture of the new-process armor.

No overtures have ever been made to the Department by the American manufacturers to supply Krupp armor, but it being known that they were in a position to do so, the following letter was addressed on November 21, 1898, to each of them:

No. 14118.] DEPARTMENT OF THE NAVY, BUREAU OF ORDNANCE,
Washington, D. C., November 21, 1898.

SIRS: The Bureau requests to be informed whether your company is prepared to manufacture armor treated by the so-called "Krupp process," and, if so, to what ballistic tests you would agree to submit such armor, and what rate of delivery you can promise; also at what price per ton you would manufacture such armor.

Respectfully,

CHARLES O'NEIL,
Chief of Bureau of Ordnance.

BETHLEHEM IRON COMPANY,
South Bethlehem, Pa.

(Same to Carnegie Steel Company, Limited.)

To these letters the following replies were received:

THE CARNEGIE STEEL COMPANY, LIMITED,
Pittsburg, Pa., November 23, 1898.

SIR: Beg to acknowledge receipt of your letter November 21, in which you inquire as to whether our company is prepared to manufacture armor treated by the "Krupp process," and what ballistic tests we would agree to submit for such armor and what rate of delivery we can promise; also what price per ton we would manufacture such armor for.

In reply, permit me to advise that we shall take the matter up at once and hope to have the pleasure of calling on you soon and give you such information as you may desire.

Yours, very truly,

C. M. SCHWAB,
President.

CHIEF OF BUREAU OF ORDNANCE,
Navy Department, Washington, D. C.

THE BETHLEHEM IRON COMPANY,
South Bethlehem, Pa., November 23, 1898.

CHIEF OF BUREAU OF ORDNANCE,
Navy Department, Washington, D. C.

SIR: We are in receipt of your communication, No. 14118, under date of the 21st instant, and the writer will take an early opportunity of calling on you to give you, so far as he is able at this time, the information you desire.

Respectfully,

ROBT. P. LINDERMAN, *President.*

(Through Inspector of Ordnance, U. S. Navy, South Bethlehem, Pa.)

After the receipt of the foregoing letters an interview was had with the president of the Carnegie Steel Company and of the Bethehem Iron Company (now the Bethlehem Steel Company), which was followed by the following correspondence:

No. 14118-98.] DEPARTMENT OF THE NAVY, BUREAU OF ORDNANCE,
Washington, D. C., January 31, 1899.

SIRS: Referring to Bureau's letter No. 14118-98, of November 21, 1898, with reference to the price of armor made and treated by the so-called Krupp process, and to

a subsequent interview at which this matter was discussed and at which you stated that you considered $545 per ton would be a fair price, but did not state whether that was the lowest price you would accept:

The Bureau finds it necessary, in order that correct estimates may be furnished to Congress, to know definitely the lowest sum that will be accepted for the so-called Krupp armor. This matter will soon be under consideration by the Naval Committees, and an early reply is requested.

As the Bureau recalls the interview above referred to, your attitude was that if $400 a ton was a proper price for armor under present contracts, $500 per ton would be a fair price for armor 25 per cent better in quality, and that as the Government now agrees to pay such royalty as has to be paid for the face-hardening process, so it ought to pay the royalty on the Krupp process, if used.

The Bureau does not hesitate to say that it does not regard such reasoning as at all conclusive, and does not think the Department should take any cognizance of the question of royalty in any future armor contracts; and also thinks that $545 per ton is a considerably greater sum than is likely to be authorized.

Respectfully,

CHARLES O'NEIL,
Chief of Bureau of Ordnance.

CARNEGIE STEEL COMPANY, *Munhall, Pa.*

(Same to Bethlehem Steel Company.)

THE BETHLEHEM IRON COMPANY,
South Bethlehem, Pa., February 3, 1899.

SIR: Answering the Bureau's letter of the 31st ultimo:

The lowest price we are willing to accept for Krupp armor is $545 per ton.

We base this price on an average royalty we will be obliged to pay of $45 per ton, and on the fact that so far as our experience goes the additional cost of manufacturing Krupp armor over the cost of manufacturing Harvey armor will not be less than $100 per ton.

As already stated to you in conversation, we would prefer to manufacture Harvey armor at $400 per ton rather than Krupp armor at $545 per ton, not only on account of the increased cost of the latter, but also on account of the increased risk.

Respectfully,

THE BETHLEHEM IRON COMPANY,
ROBT. P. LINDERMAN, *President.*

CHIEF OF BUREAU OF ORDNANCE,
Navy Department, Washington, D. C.

(Through inspector of ordnance, The Bethlehem Iron Works, South Bethlehem, Pa.)

THE CARNEGIE STEEL COMPANY, LIMITED,
Pittsburg, Pa., February 4, 1899.

SIR: We acknowledge the Bureau's letter No. 14118–98, of the 31st ultimo, concerning price of armor manufactured by the Krupp process, and after most careful consideration beg to inform you that the price named at the interview referred to therein, i. e., $545 per ton, is the minimum we could accept for this type of armor.

Owing to the greatly increased cost and difficulties of manufacture, and the high rate of royalty required to be paid on this quality of armor, together with our product considerably curtailed in tonnage, with our present equipment, by reason of the above-mentioned difficulties, we consider the price quoted as being fair and equitable and the lowest we could afford to accept.

We also desire to reiterate our statement that we prefer to manufacture ordinary face-hardened armor at a net price of $400 per ton than Krupp armor at the price given above.

It is not specially desired that the Bureau pay the royalty on armor manufactured by this process, as in the case of ordinary face-hardened armor, the verbal proposition only being made as an alternative one; that is to say, we would accept a price of $500 per ton, provided the Bureau would assume the royalty, as in the case of the armor we are manufacturing for $400 per ton.

While it is now considered that Krupp armor is 25 per cent better in quality than the best Harveyed armor, continued improvement in manufacture will no doubt result in a product still considerably better.

Respectfully,

THE CARNEGIE STEEL COMPANY, LIMITED,
ALEX'R R. PEACOCK, *First Vice-President.*

The CHIEF OF BUREAU OF ORDNANCE,
Navy Department, Washington, D. C.

On December 12, 1898, the Department forwarded to the Senate and House Naval committees a letter prepared by the Chief of the Bureau of Ordnance, containing certain data as to Krupp armor, and recommending its use, with reasons therefor. This letter is printed on pages 3175 and 3176 of the Congressional Record of March 4, 1899.

QUALITY OF HARVEYED PLATES.

Sometimes armor plates, especially thin ones, are produced by the Harvey process of very superior quality; but beyond a certain point they can not be reproduced with certainty; hence the manufacturers will not consent to have the ballistic tests raised, as they consider the risk too great. It would not be considered advisable to use very thin plates made by the Krupp process, except such as did not require face-hardening.

SUPERIORITY OF ARMOR MADE BY THE KRUPP PROCESS.

From what has already been said under the head of "Krupp's new process," from numerous tests other than those therein enumerated, and from the fact of its adoption for the latest vessels of leading maritime nations, it may be asserted without fear of contradiction that armor plates of 6 inches and upward, made by the new Krupp process, are superior to any others. As further evidence that such is the case, the following literal quotation is given from the published official "Statement of the First Lord of the British Admiralty explanatory of the naval estimates for 1899 and 1900, presented to both Houses of Parliament:"

> The manufacture of armor has been affected by the fact that the introduction of a new and superior quality (meaning Krupp armor) has necessitated the reconstruction of plant, and involved many difficulties only to be overcome by experience. * * * All the manufacturing firms have been kept full of orders and urged to increase production, but the earnings of the present financial year will fall considerably below the sum provided in the estimates.

Under the head of battleships, in the same document, appears the following with reference to four new ships of the *Duncan* class:

> All armor will be of the latest and most improved quality (meaning Krupp armor), possessing much greater defensive powers in proportion to its thickness than armor used in the *Majestic* class.

WHY THE UNITED STATES VESSELS SHOULD BE SUPPLIED WITH ARMOR MADE BY THE KRUPP PROCESS.

It seems unnecessary to enter into any argument on this point, as probably no one will dispute the advisability and propriety of supplying our new vessels with the very best armor that can be made in this country. The United States can not afford to build ships of war less efficient in any particular than those built abroad; still less can it afford to have a battleship built for a foreign Government in a private shipyard in this country superior in any respect to a vessel built for this Government in the same shipyard; and yet such will be the case unless means are provided whereby the Department can procure armor of the best quality for the ships now under construction whose armor has not yet been contracted for.

TESTS OF ARMOR.

The question has been asked whether the tests now applied to Harveyed armor are as severe as they should be, and the reply is that they

are as severe as the manufacturers will consent to; and while they are not as severe as the best Harveyed plates will stand, they are such as secures to the Government probably as good a quality of armor as can be commercially manufactured by that process. It is certain that no group of Harveyed armor could successfully pass the ballistic tests now designated for Krupp armor; and the preceding remark, as to the severity of tests of Harveyed armor will also apply to Krupp plates, as a reasonable factor of safety must be allowed; hence it may be said that the best Krupp plates would probably admit of a higher ballistic test than the one proposed.

Were special plates made for ballistic test, as is the custom abroad, there is little doubt but that higher ballistic qualities could, and would be guaranteed than is now the case; but in the United States the practice is to carry along together all the plates of a group, frequently upwards of twenty in number, and amounting to 500 or 600 tons in weight, to a point where all have been carburized and face-hardened, and then to select a plate from among the number, for ballistic test, upon which the acceptance or rejection of the entire group, or its retreatment will depend.

As plates made by the Harvey process can not be produced with exactness as to uniformity, it follows that a group will contain plates having different degrees of excellence; therefore the ballistic test must be such as will, within reasonable limits, admit of successful manufacture when the same is performed in accordance with the best practice. In fact, the ballistic requirements must be such as will allow for the probable and legitimate variation in the plates of a group, and the same will apply to Krupp armor; though with the latter greater uniformity may be expected, still there will be some variation.

A series of experiments extending over several years has been made at the naval proving ground at Indian Head, from which has been determined the mean velocity necessary to perforate face-hardened plates manufactured by the Harvey process.

It is self-evident that in testing armor plates for acceptance a less velocity must be used than that necessary for complete perforation. The prescribed acceptance test for Harveyed plates requires a velocity of about 82½ per cent of that necessary for complete perforation, with certain limitations as to cracks, etc.

It is proper to say that in most instances the plates selected for ballistic test exhibited a good margin in excess of the requirements, showing that they would often stand a higher test, though this is not always the case.

The ballistic test of armor throughout the world is based upon velocities required for the perforation of plates of plain steel or wrought iron. Empirical formulas have been deduced from numerous experiments which express with fair accuracy the perforating power of the projectile and the resisting power of such plates, and certain coefficients of these formulas are employed for determining the velocities for the ballistic tests of armor plates of different kinds. In the United States the De Marre formula is chiefly used, and the ballistic tests of Harveyed plates are graduated from 1.14 times that necessary for the perforation of plain steel plates of equal thickness as calculated by that formula, for plates of 12 inches in thickness, to 1.26 times the velocity thus calculated for plates of 4 inches in thickness.

The tests now offered by the manufacturers for Krupp plates range from 1.30 times the velocity necessary to perforate plain steel plates of equal thickness as calculated by the De Marre formula, for plates of

12 inches in thickness, to 1.38 times the velocity thus calculated for plates of 4 inches in thickness.

The test offered for Krupp plates is a velocity equal to about 95 per cent of that calculated as being necessary for complete perforation.

The following table shows in detail the velocities required for the perforation of plain steel as calculated by the De Marre formula and the coefficients of the same for the test of Harveyed and Krupp plates, respectively:

Caliber of gun.	Thickness of plate.	Weight of shot.	Velocity by the De Marre formula for perforation of plain steel.	Velocity for ballistic test of Harveyed armor.	Coefficient of De Marre formula for Harveyed armor.	Velocity for ballistic test of Krupp armor.	Coefficient of De Marre formula for Krupp armor.
Inches.	*Inches.*	*Pounds.*	*Foot-secs.*	*Foot-secs.*		*Foot-secs.*	
4	4	33	1,328	1,676	1.26	1,833	1.38
5	5	50	1,491	1,717	1.15	2,058	1.38
6	6	100	1,373	1,659	1.21	1,895	1.38
6	7	100	1,530	1,816	1.18	2,065	1.35
8	8	250	1,318	1,558	1.17	1,779	1.35
8	9	250	1,431	1,672	1.16	1,932	1.35
10	10	500	1,288	1,505	1.16	1,739	1.35
10	11	500	1,377	1,595	1.15	1,790	1.30
12	12	850	1,284	1,475	1.14	1,669	1.30

The energy that a 6-inch plate is required under present specifications to absorb is 3,324 foot-tons, while that it will be required to absorb under the proposed specifications for Krupp armor is 7,389 foot-tons.

The energy that a 12-inch plate is required under present specifications to absorb is 15,972 foot-tons, while that it will be required to absorb under the proposed specifications for Krupp armor is 50,310 foot-tons.

The Department has no doubt whatever as to the superiority of thick armor plates made by the Krupp process over those made by the Harvey process; otherwise would not recommend its adoption.

The table on the following page will perhaps more clearly illustrate the difference in the ballistic quality of Harveyed and Krupp armor, as an inspection of it will show the different thicknesses of each that can be perforated at given ranges by guns of all calibers from 3 to 12 inches. For example, at a range of 3,000 yards a 12-inch gun will perforate 17.92 inches of Harveyed armor or 14.34 inches of Krupp; that is, 25 per cent more of Harveyed than of Krupp armor.

The perforation of Harveyed nickel-steel is calculated by Davis's formula for the penetration of hard-faced armor, which was deduced from a long series of firings against such plates at the naval proving ground. The perforation of Krupp armor is based upon such experiments, both at home and abroad, as are obtainable, and is believed to be correct.

All tests of armor for acceptance and all official tests of experimental plates are made at the naval proving ground by and under the personal supervision of naval officers, the manufacturers being merely spectators.

Table of elements of latest types of naval guns (models of 1899), giving perforation of face-hardened armor at ranges up to 3,000 yards, with smokeless powder and uncapped armor-piercing projectiles, at normal impact.

Caliber of guns.	Length.	Weight.	Weight of projectile.	Muzzle velocity.	Muzzle energy.	Perforation at muzzle, Harveyed nickel steel.	Perforation at muzzle, Krupp armor.	Remaining velocity at 1,000 yards.
	Calibers.	*Tons.*	*Pounds.*	*Foot-secs.*	*Foot-tons.*	*Inches.*	*Inches.*	*Foot-secs.*
3-inch	50	0.87	14	3,000	874	4.19	3.35	2,328
4-inch	50	2.56	32	3,000	1,999	6.12	4.90	2,477
5-inch	50	4.46	60	2,900	3,503	7.51	6.01	2,460
6-inch	50	8	100	2,900	5,838	9.35	7.71	2,516
8-inch	45	18	250	2,800	13,602	13.57	10.66	2,531
10-inch	40	33.4	500	2,800	27,204	18.57	14.86	2,587
12-inch	40	52	850	2,800	58,221	23.42	18.74	2,619

Caliber of guns.	Perforation at 1,000 yards of Harveyed nickel steel.	Perforation at 1,000 yards of Krupp armor.	Remaining velocity at 2,000 yards.	Perforation at 2,000 yards of Harveyed nickel steel.	Perforation at 2,000 yards of Krupp armor.	Remaining velocity at 3,000 yards.	Perforation at 3,000 yards of Harveyed nickel steel.	Perforation at 3,000 yards of Krupp armor.
	Inches.	*Inches.*	*Foot-secs.*	*Inches.*	*Inches.*	*Foot-secs.*	*Inches.*	*Inches.*
3-inch	2.98	2.38	1,806	2.13	1.70	1,401	1.52	1.22
4-inch	4.77	3.91	2,046	3.68	2.94	1,690	2.85	2.28
5-inch	6.03	4.82	2,087	4.85	3.88	1,771	3.89	3.11
6-inch	7.74	6.19	2,183	6.40	5.12	1,893	5.30	4.24
8-inch	11.86	9.49	2,288	10.37	8.30	2,068	9.06	6.61
10-inch	16.71	13.37	2,391	15.04	12.03	2,209	13.53	10.82
12-inch	21.42	16.84	2,450	19.60	15.68	2,291	17.92	14.34

With capped projectile an increased thickness of from 15 to 20 per cent may be perforated.

NAVY DEPARTMENT,
BUREAU OF ORDNANCE, *October 5, 1899.*

PRICE ASKED IN THE UNITED STATES FOR ARMOR MADE BY THE KRUPP PROCESS.

The armor manufacturers have informed the Department that they will manufacture armor by the above-named process for $545 per ton, but state that they would rather make Harveyed armor at $400 per ton (plus $11.20 for royalty for face-hardening process, if it has to be paid) than Krupp armor at the price named.

The Department does not assume to say whether the above price represents a fair profit to the manufacturers or otherwise, or whether the increased cost of producing Krupp plates warrants the increase of price named. It can only state that it is the price asked, and from the best information obtainable it is less than is being paid abroad or in the United States for armor made by the Krupp process.

PRICES PAID ABROAD FOR ARMOR.

The Department has considerable information as to prices now paid abroad for armor, obtained from official and unofficial sources; some of it confidential.

GOVERNMENT ARMOR FACTORY.

The question of the establishment of a Government armor plant being a national measure of great importance may well be left to Congress.

The report of the armor factory board, transmitted to Congress on December 6, 1897, and contained in House Document No. 95, Fifty-fifth Congress, second session, contains a comprehensive report, with specifications and estimates for such an establishment.

The board estimated that the cost of a plant having a capacity to manufacture 6,000 tons per year of nickel-steel, face-hardened, and reforged armor would be, exclusive of land for a site and of freight on building material, or expense for piling foundations, but including an open-hearth department for the production of nickel-steel ingots, $3,747,912.11.

Owing to the marked increase in the cost of structural material, especially of steel, since the date of the board's report, it is probable that such estimate should be increased not less than 30 per cent, bringing it up to $4,872,285.74.

The cost of a plant to produce Krupp armor would not materially differ from one to make Harveyed armor, as all the principal features are common to both; but the output of Krupp armor would undoubtedly be less than that of Harveyed armor—perhaps 5,000 instead of 6,000 tons.

The board concludes its report with the following remarks:

In accordance with your views that the Congress would wish from the board a statement in the rough of the practicability of putting up an armor plant, we respectfully submit the following considerations:

1. An armor factory comprises essentially a collection of special furnaces, heavy machine tools and appliances that are not needed in any other class of work, and a class of labor specially skilled in the business.

2. A Government armor factory not connected with an establishment engaged in other branches of the steel industry would depend for its success and economic administration upon a constant demand for an output nearly approaching its full capacity.

3. If the Government should establish an armor factory the efficient and economic maintenance or working of that factory would necessarily depend upon a constant yearly appropriation for ships to be provided with armor, because the armor produced at any time must be specially designed for and fitted to those ships. Any failure to appropriate for such ships in any one year would require the cessation of work and the laying off, indefinitely, of the skilled experts and laborers that had been trained to this industry. A resumption of work at a later period would require the training, at a considerable expense, of a new set of men. In the meantime the progress of the art would perhaps have been such that difficult and radical changes would be required, which under continuous working might have been gradually and easily made. * * *

The Department does not feel called upon to discuss in this memorandum the advisability or otherwise of establishing a Government armor factory. All that the Department desires is that the building of armored ships for the Navy shall not be impeded by lack of armor of the best quality when it is required.

In no case should a Government factory be regarded as a possible source of supply of armor for the Maine, Ohio, and Missouri.

FOREIGN GOVERNMENT ARMOR WORKS.

The only government armor factories of which the Department has any knowledge is the Russian plant at Kolpino, near St. Petersburg, known as the Tjora Iron Works; but from the fact that to-day Russia is purchasing armor for her naval vessels in the United States and in Europe, the inference is that the works above referred to can not or do not meet the Government requirements.

In France, at the naval establishment known as the Forges de la Chaussade, at Guerigny, near Nevers, deck armor is made, the greatest

thickness being 4 inches. This establishment has no steel-making plant, the ingots being purchased from private firms, and it can not be classed as an armor factory in the generally understood sense of the term.

Japan has established a plant which is not yet in operation, known as the Imperial Iron Foundry, at Yawatamura, in the province of Chickuzen, at which plates are to be made 6 inches thick, weighing up to about 6 tons. No doubt, if this proves successful, still heavier plates will in time be manufactured.

PRIVATE ARMOR FACTORIES.

From the best information obtainable the following is believed to be a correct list of all private armor works of any importance:

Great Britain:
- Vickers Sons & Maxim, Sheffield, England.
- Sir John Brown & Co., Sheffield, England.
- Cammell, Sheffield, England.
- Beardmore, Glasgow, Scotland.

France:
- Marrel Freres, a Rive de Gier.
- Schneider & Co., Le Creusot.
- La Compagnie de Chatillon-Commentry, Montlucon.
- La Compagnie Anonyme des Forges, Paris.
- La Compagnie des Hauts Fourneaux, St. Chamond.
- St. Etienne Steel Works, St. Etienne. (Deck armor only.)

Germany:
- Fried Krupp, Essen.
- Dilligen Works, Dilligen.
- Gruson Works, Buckau. (Armored turrets.)

Austria:
- Witkowitz Iron Works, Witkowitz, Moravia.

Italy:
- Terni Steel Works, Terni.

United States:
- The Bethlehem Steel Company, South Bethlehem, Pa.
- The Carnegie Steel Company, Pittsburg, Pa.

AMOUNT OF ARMOR LIKELY TO BE CARRIED BY NEW SHIPS.

The question has been asked whether vessels will carry a less quantity of Krupp armor, because of its superiority, than of Harveyed armor. The reply is that they will not.

The general tendency is to decrease somewhat the weight of armored protection carried by vessels, not because of better armor, but because the demands for increased weight for coal, machinery, armament, and large supply of ammunition, render it imperative.

The object will be, as heretofore, to give the vessels as much weight of armor as their displacement and other weights to be carried will admit of, and the vessel, therefore, that carries the best armor will be the best protected, the weight of armor being the same.

The vessels of the *Indiana* class carry armor to the extent of 27 per cent of their displacement; the *Kearsarge* class, 25 per cent; the *Iowa* class 23 per cent; the *Alabama* class, 22 per cent; and the *Maine* class, 20 per cent.

RELATIVE AMOUNT OF HARVEYED AND KRUPP ARMOR NECESSARY TO OBTAIN EQUAL PROTECTION, AND RELATIVE COST.

As an illustration of the relative amount of Harveyed or Krupp armor that would be necessary to give equal protection, and the relative cost, the following cases are cited:

For the vessels of the *Alabama* class Harveyed armor to the amount

of 2,529 tons has been contracted for, at a cost of $411.20 per ton, costing $1,039,924 for each vessel (assuming that the Government will ultimately pay the royalty of $11.20 per ton, which it has agreed to do, under certain conditions).

Were armor made by the Krupp process to be used for these vessels and an equal amount of protection retained, a reduction in weight could be made to the amount of 497 tons; that is, the vessels would each carry 2,032 tons of armor instead of 2,529 tons. This reduction would be made on the following basis:

As now designed, each vessel carries 1,747 tons of heavy armor (that is, of over 6 inches in thickness), which could be reduced 25 per cent in weight (that is, in thickness), amounting to 437 tons; they each also carry 600 tons of light armor (that is, of 6 inches or less in thickness), which could be reduced 10 per cent in weight, amounting to 60 tons; a total reduction of 497 tons, as above stated.

Of the total amount thus required, namely, 2,032 tons for each vessel (if Krupp armor were used), 182 tons would be Harveyed in any case, as it consists of very thin plates, such as turret tops and doors, sighting hoods, etc., which could not be advantageously made by the Krupp process.

The amount required would therefore be—

1,850 tons Krupp, at $545 per ton, costing	$1,008,250
182 tons Harveyed, at $411.20 per ton, costing	74,838
2,032 tons, costing	1,083,088

The above sum ($1,083,088) is $43,164 more than the present contract price for all Harveyed armor (namely, $1,039,924).

Thus it will appear that to retain the same amount of protection on the *Alabama* class, by using Krupp instead of Harveyed armor, the increased cost would amount to $43,164; but were it contemplated, as it should be, to give these vessels the best protection obtainable on the weight allotted for armor, the account would be—

2,347 tons Krupp, at $545, costing	$1,279,115
182 tons Harveyed, at $411.20, costing	74,838
2,529 tons, costing	1,353,953

or $314,029 per vessel more than the present contract price for Harveyed armor (namely, $1,039,924).

To summarize:

Present contract, all Harveyed, 2,529 tons, costing	$1,039,924
Same protection, using Krupp, 2,032 tons, costing	1,083,088
Best protection, using Krupp, 2,529 tons, costing	1,353,953

In the foregoing statement it will be noted that a reduction of only 10 per cent is made in the weight of thin armor, if Krupp is used, whereas in the thick plates a reduction of 25 per cent in weight is made. This is due to the fact that it will not do to reduce to too great an extent the thickness of thin plates, no matter how good their quality may be, as there would be too much danger of their breaking up under the impact of a heavy projectile. A certain mass is necessary to absorb the energy of the projectile and to resist its crushing effects. The thin armor is relatively as good as the thick, but for the reasons stated it is not considered expedient to reduce it more than 10 per cent, no matter how good it may be.

The armor being already contracted for for the *Alabama* class, the foregoing is merely given as an illustration.

As regards the *Maine* class (vessels now under construction, and for which armor has not yet been ordered) the case is somewhat different.

These vessels are to have a speed of 18 knots and are to carry 2,000 tons of coal, whereas the *Alabama* class have a speed of 16 knots and carry 1,200 tons of coal. The *Alabama* class are allotted 22 per cent of their displacement for armor, i. e., 2,529 tons, whereas the *Maine* class are allotted 20 per cent of their displacement for armor, i. e., 2,492 tons.

The *Maine* class are 20 feet longer than the *Alabama* class, requiring armor to cover a greater surface, though there is a less quantity of it to do so. The maximum thickness of the belt armor on the *Alabama* is 16½ inches, while the same armor on the *Maine* will be 11 inches; hence the importance of using on the latter the best quality that can be procured.

The armor plan for the *Maine* class is based upon the assumption that armor made by the Krupp process will be used, but even should it not be, the same arrangement as to thickness and distribution will be adhered to, as it is considered preferable to any other.

The armor plan for the *Maine* contemplates—

Thick plates, Krupp..... 1,496 tons Thin plates, Krupp..... 814 tons	at $545 per ton, costing.....	$1,258,950
Thin plates, Harveyed..... 182 tons, at $411.20 per ton, costing....		74,838
2,492 tons, costing.....		1,333,788

The above gives the best protection obtainable.

To obtain the same protection using Harveyed armor exclusively, the armor plan would be—

1,496 tons thick plates, increased by 25 per cent, or by 374 tons, equals..	1,870 tons.
814 tons thin plates, increased by 25 per cent, or by 203 tons, equals..	1,017 tons.
182 tons thin plates, remaining the same in either case, equals.....	182 tons.
2,492 tons all Krupp.	All Harveyed..... 3,069 tons.

Three thousand and sixty-nine tons Harveyed armor at $411.20 equals $1,261,972, or $71,816 less than if all Krupp armor were used, but the weight to be carried would be 577 tons greater, which is not admissible.

If the same weight of armor be used, as the plans now contemplate—that is, 2,492 tons—and Harveyed armor be used exclusively, the cost at $411.20 per ton will be $1,024,710, or $309,078 less than the plan contemplated—that is, all Krupp—but the vessels will not have the best protection on the weight allowed for protection.

Summary, armor for *Maine* class, present plan contemplates—

2,310 tons Krupp, at $545, equals.....	$1,258,950
182 tons Harveyed, at $411.20, equals.....	74,838
2,492 tons, costing.....	1,333,788

Same protection, all Harveyed—

3,069 tons, at $411.20, costing.....	$1,261,972

Not admissible on account of increased weight.

Same weight as now contemplated, all Harveyed—

2,492 tons, at $411.20, costing.....	$1,024,710

Under this arrangement the ship does not receive the best protection on allowed weights.

It will be observed that in estimating the additional weight necessary to obtain equal protection with Harveyed as with Krupp armor, 25 per

cent is added to the thin as well as to the thick plates; whereas in the case of the *Alabama* class only 10 per cent was allowed on thin plates in changing from Harveyed to Krupp armor. The difference is that in the case of the *Alabama* class there was a reduction in thickness which was deemed inadmissible beyond a certain point; while in the latter case there is an increase of thickness, which may be permitted, and is desirable if it can be made within weights allowable.

It is not intended to show by the above that the use of Krupp armor is only a little more expensive than Harveyed; it is only so if the same protection is obtained. It is considerably greater if the best protection practicable is obtained.

ARMOR CONTRACTS TO DATE.

The following is a list of all armor contracted for, and the cost of the same:

	Tons.	Cost.
Bethlehem Steel Co., contract of June, 1887	6,891	$4,168,000
Bethlehem Steel Co., contract of March, 1893	3,882	2,510,000
Bethlehem Steel Co., contract of June, 1896	2,800	1,534,272
Bethlehem Steel Co., contract of July 1898 (estimated)	3,965	1,586,000
Bethlehem Steel Co., contract of October, 1899 (estimated)	1,142	456,800
Total	18,680	10,255,072
Carnegie Steel Co., contract of 1890	6,054	3,475,000
Carnegie Steel Co., contract of 1893	3,120	2,094,000
Carnegie Steel Co., contract of 1896	3,073	1,697,808
Carnegie Steel Co., contract of 1898 (estimated)	3,712	1,484,800
Carnegie Steel Co., contract of 1899 (estimated)	1,134	453,600
Total	17,093	9,205,208

A grand total of 35,773 tons, at a cost of $19,460,280.

Average cost per ton.

	Cost per ton.
Bethlehem Steel Co., contract of 1887	$604.85
Bethlehem Steel Co., contract of 1893	646.41
Bethlehem Steel Co., contract of 1896	547.96
Bethlehem Steel Co., contract of 1898	400.00
Bethlehem Steel Co., contract of 1899	400.00
Carnegie Steel Co., contract of 1890	574.00
Carnegie Steel Co., contract of 1893	671.13
Carnegie Steel Co., contract of 1896	552.50
Carnegie Steel Co., contract of 1898	400.00
Carnegie Steel Co., contract of 1899	400.00
General average per ton	543.99

The highest price per ton was $671.13, and the lowest price $400 per ton.

Armor carried by United States vessels.

Name of vessel.	Class.	Displacement.	Armor carried.	Per cent of displacement given to armor.
		Tons.	*Tons.*	
Amphitrite	Monitor	3,990	664.15	16
Monadnock	do	3,990	674.96	16
Terror	do	3,990	628.61	16
Puritan	do	6,060	1,126.46	19
Texas	Second-class battle ship	6,315	1,064.77	17
Maine (old)	do	6,682	1,221	18
Monterey	Coast-defense ship	4,084	706.49	17
Katahdin	Ram	2,155	775.07	36
New York	First-class cruiser	8,200	517.46	6
Brooklyn	do	9,215	702.02	8
Oregon	Battle ship	10,288	2,766.54	27
Massachusetts	do	10,288	2,773.53	27
Indiana	do	10,288	2,746.15	27
Iowa	do	11,340	2,603.17	23
Kearsarge	do	11,525	2,830.49	25
Kentucky	do	11,525	2,830.49	25
Alabama	do	11,525	*a* 2,558.76	22
Illinois	do	11,525	*a* 2,558.76	22
Wisconsin	do	11,525	*a* 2,558.76	22
Maine (new)	do	12,500	*a* 2,492	20
Ohio	do	12,500	*a* 2,492	20
Missouri	do	12,500	*a* 2,492	20
Arkansas	Monitor	3,214	*a* 541.44	17
Florida	do	3,214	*a* 541.44	17
Connecticut	do	3,214	*a* 541.44	17
Wyoming	do	3,214	*a* 541.44	17

a Estimated.

WHAT THE DEPARTMENT SUGGESTS TO CONGRESS TO DO IN THE MATTER OF ARMOR.

First. Enable the Department to procure the best quality of armor that can be made in the United States for battle ships *Maine*, *Ohio*, and *Missouri*.

Second. Make the necessary provision at an early date.

Third. Remove the restriction contained in the act of March 3, 1899, limiting the price of armor for the six armored vessels authorized by said act to $300 per ton, including royalty.

Fourth. Remove the proviso contained in the act of March 3, 1899, which directs that none of the armored vessels authorized by said act shall be contracted for until the armor therefor is contracted for.

In any case, the Department trusts that some final solution of the armor situation may be arrived at, in order that the building of armored vessels may be proceeded with, it being evident that until some settlement of this vexed question is reached no shipbuilding programme can be satisfactorily carried on.

Ship and armor contracts.

Name of vessel.	Act of authorization.	Date of contract for hull and machinery.	Contractor.	Keel laid.	Date of contract completion.	Date of act authorizing armor.	Limit of cost of armor per ton.	Date of armor contract.	Tons of armor contracted for.	Armor contractor.	Elapsed time between contract of ship and of armor.
											Months.
Kearsarge *a*	Mar. 2, 1895	Jan. 2, 1896	Newport News Co.	Jan. 30, 1896	Mar. 24, 1898	Mar. 2, 1895	No limit.	June 1, 1896	2,830	Bethlehem	6
Kentucky *a*	do	do	do	do	do	do	*b* $550.33	do	2,830	Carnegie	6
Alabama *a*	June 10, 1896	Sept. 24, 1896	Cramp & Sons	Dec. 1, 1896	Sept. 24, 1899	May 4, 1898	*c* 400.00	June 9, 1898	2,559	Bethlehem	20½
Illinois *a*	do	Sept. 26, 1896	Newport News Co.	Feb. 10, 1897	Sept. 26, 1899	do	400.00	June 3, 1898 June 9, 1898	1,406 1,153	do Carnegie	20½ 20½
Wisconsin *a*	do	Sept. 19, 1896	Union Iron Works	Feb. 9, 1897	Sept. 19, 1899	do	400.00	June 3, 1898	2,559	do	20½
Maine *a*	May 4, 1898	Oct. 1, 1898	Cramp & Sons	Feb. 15, 1899	June 1, 1901	Mar. 3, 1899	400.00	(*d*)	(*d*)		
Ohio *a*	do	Oct. 5, 1898	Union Iron Works	May 19, 1899	June 5, 1901	do	400.00	(*d*)	(*d*)		
Missouri *a*	do	Oct. 11, 1898	Newport News Co.	Not laid	June 11, 1901	do	400.00	(*d*)	(*d*)		
Arkansas *e*	do	do	do	do	do	do	400.00	Aug. 3, 1899	538	Carnegie	10
Connecticut *e*	do	Oct. 19, 1898	Bath Iron Works	Apr. 17, 1899	Jan. 19, 1901	do	400.00	do	538	do	10
Florida *e*	do	Oct. 11, 1898	Lewis Nixon	Jan. 23, 1899	Oct. 11, 1900	do	400.00	Oct. 4, 1899	541.44	Bethlehem	10
Wyoming *e*	do	Oct. 5, 1898	Union Iron Works	Apr. 11, 1899	Jan. 5, 1901	do	400.00	do	541.44	do	10

a Battle ships. *b* Average cost. *c* Per ton. *d* 36.86 tons of armor, at $400 per ton, were contracted for in August and October, 1899. *e* Monitors.

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