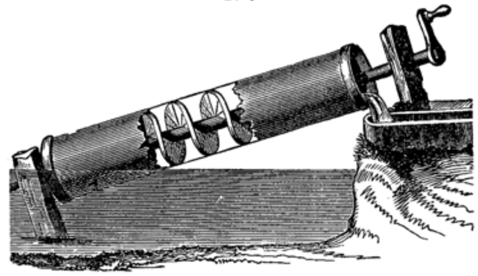
straight arch; ***H***, cambered arch; ***I***, groined arch; ***J***, fluing arch ; ***K***, skew arch; ***L***, trimmer arch; ***M***, relieving arch; ***H***, inverted arch.

ARBOR. The axle or spindle of a wheel or pinion; also the mandrel on which a circular object is turned on the lathe.

ARCHIMEDEAN SCREW. This consists of a screw-blade turned around a solid axis, similar to a winding staircase, and inclosed in a hollow cylinder. When placed in an inclined position with the lower end in the water, the latter is caught between the screw-blades, and, the cylinder being turned in the proper direction, the water will be raised and discharged at the upper end. This apparatus may be usefully employed in raising water to a limited height (10 or 15 feet or less). By its aid one man may raise 40 gallons of water 10 feet high in a minute — a larger amount of work than can generally be done with hand-pumps, owing to friction in the latter. Fig. 239.

239.



ARCHITRAVE. In carpentry, borders fixed around the opening of doorways or windows for ornament, and also to conceal the joint between frame and plastering. When the base of the architrave is not of equal thickness throughout, but stepped back in the centre, it is said to be "double-faced." Architraves are generally built up of parts glued together, tongued and grooved if large. They are also made by machinery in one piece.

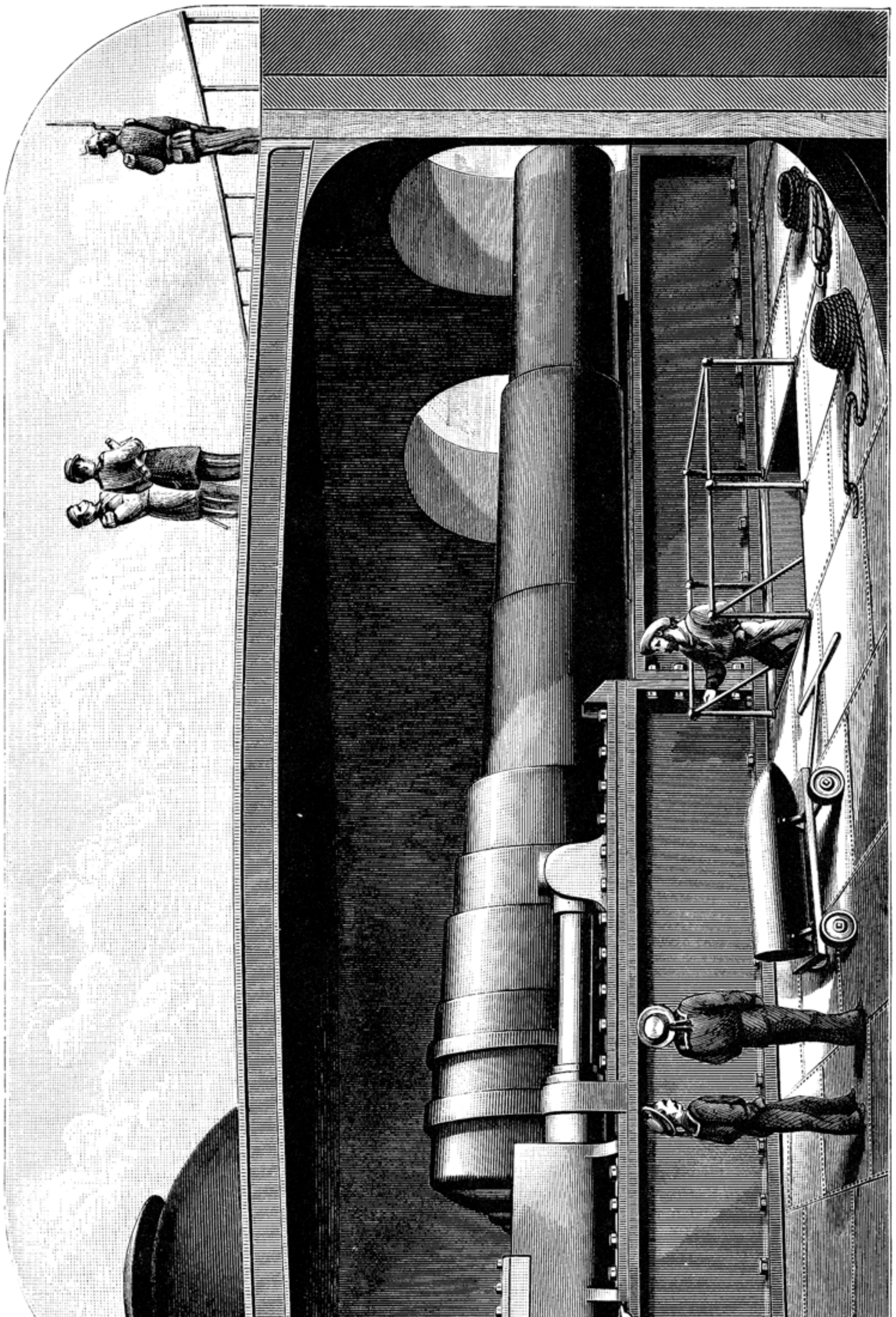
ARMATURE. See MAGNET.

ARMING-PRESS. A machine used for embossing the back and sides of the cover of a book.

ARMOR. The problem for which a solution is sought in the cuirassing of ships of war, is, how best to protect them against the effects of the shock of the enormous projectiles which, thrown with an extraordinary energy from heavy guns of large calibre, will have to be resisted in future naval engagements, and against the convergent and simultaneous fire of other heavy guns but of smaller calibres. Up to 1862, experiments which involved the testing of plates ranging from a quarter of an inch to 8 inches in thickness, supported by various backings, yielded the following conclusions:

1. Good tough wrought-iron of high elasticity, but not necessarily of the highest ultimate tensile strength, is the best material for use in iron defenses;

2. Rolled iron, though not, perhaps, equal in resistance to the best hammered iron, has such great advantages as to cost, if used in simple forms, as to justify its use where



THE ARMSTRONG HUNDRED-TON GUN.

lightness is not of extreme importance;

3. In plates or bars of ordinary dimensions, the resistance to cannon-shot varies in a proportion approximating that of the squares of the thickness of the bars or plates;

4. Rigid backing is immensely superior to elastic backing, so far as the endurance of the front facing is concerned, but the elastic backing deadens the effect of a blow upon any structure behind;

5. The larger the masses and the fewer the joints, the stronger the structure, so long as the limits of uniform and perfect manufacture are observed;

6. Revolving iron shields are practicable and safe;

7. The qualities necessary in an armor-plate are softness combined with toughness, or better expressed by the word ductility. Apparently, the purer and better the iron is, the more this quality is perceptible; any impurity or alloy appears to harden the metal and produce brittleness. The presence of either sulphur or phosphorus in the fuel is specially to be guarded against, as productive of red-shortness and cold-shortness in the iron. The presence of more than 0.2 per cent. of carbon in the armor-plates also appears highly prejudicial.

In 1865 a series of experiments were made by the British Government, to determine the relative penetrating effects of two shot on an iron plate, provided they strike with the same work or energy, notwithstanding the one may be heavy with a low velocity, and the other light with a high velocity. From these tests the following practical conclusions were drawn when the projectiles are fired direct:

An unbacked wrought-iron plate will be perforated with equal facility by solid steel shot of similar form of head, and having the same diameter, provided they have the same *vis viva* on impact; and it is immaterial whether this *vis viva* be the result of a heavy shot and low velocity, or a light shot and high velocity within the usual limits of length, and so on, which occur in practice.

An unbacked iron plate will be penetrated by solid steel shot of the same form of head but different diameters, provided their striking *vis viva* varies as the diameter, nearly, that is, as the circumference of the shot;

and the resistance of unbacked wrought-iron plates to absolute penetration by solid steel shot and equal diameter varies as the square of their thickness nearly.

These experiments also proved that, although, in the case of cast-iron, a light projectile moving with a high velocity will indent iron plates to a greater depth than a heavier projectile with a low velocity but equal work, it is not as necessary that there should be a high velocity when the projectiles are of a hard material, such as steel and chilled iron; and this result is much in favor of rifled guns, by enabling them to prove effective with comparatively moderate charges.

If the plate is set at an angle, or the gun is fired obliquely at an up right plate, the shot has then a tendency to glance off and continue its motion in a new direction. The force with which the shot acting obliquely will strike is to that with which it would strike if acting directly as the sine of the angle of incidence is to unity. That is, the shot striking in a slanting direction may be supposed to have opposed to it a plate of a thickness equal to the diagonal formed by the line of direction.

From the foregoing it may be demonstrated that a 4.5-inch unbacked plate, when fired at direct, requires a force represented by 28 foot-tons per inch of shot's circumference to insure penetration. When placed at an angle of 38° with the ground, the force required is increased to 73.9 foot-tons. An experiment of this nature, where solid steel shot of 70 lbs. weight and 6.34 inches in diameter were fired against a 4.5-inch plate, set at an angle of 52° with the vertical, showed that a force of 52.7 foot-tons per inch of shot's circumference was not sufficient to insure perforation, although the plates were cracked and opened at the back.

Since the determination of these results, both the calibre of guns and the thickness of armorplates have greatly increased, and the latest trials — those of the 100-ton gun built for the Italian Government for use on the iron-clads ***Dandolo*** and ***Duilio*** — bring into remarkable relief the great superiority of steel as compared with iron plates, and at the same time yield results which could not be predicated upon those obtained with guns of smaller size.

The difficulties connected with the manufacture of iron plates of thicknesses greater than about 14 inches, and the consequent deterioration of the manufactured product, have hitherto led to a preference being given to armor built up of two plates, the thicker of which placed outside has sufficient strength to arrest, or nearly so, the heaviest projectiles at present forming the armaments of European navies (that is to say, calibres from 10 to 14 inches). The inner skin of the ship is thus protected by the second and thinner armor-plate, unless the shell should burst in the packing between the two plates, which would necessarily produce disastrous effects. The penetration of iron plates 14 inches in thickness requires an energy in the projectile of 230 foot-tons per inch of circumference; and only the heaviest calibre have hitherto been able to effect this, imparting, as they do, a striking energy of about this amount. So that, in the presence of 12-inch or 14-inch calibres, the adoption of this form of armor has been entirely justified.

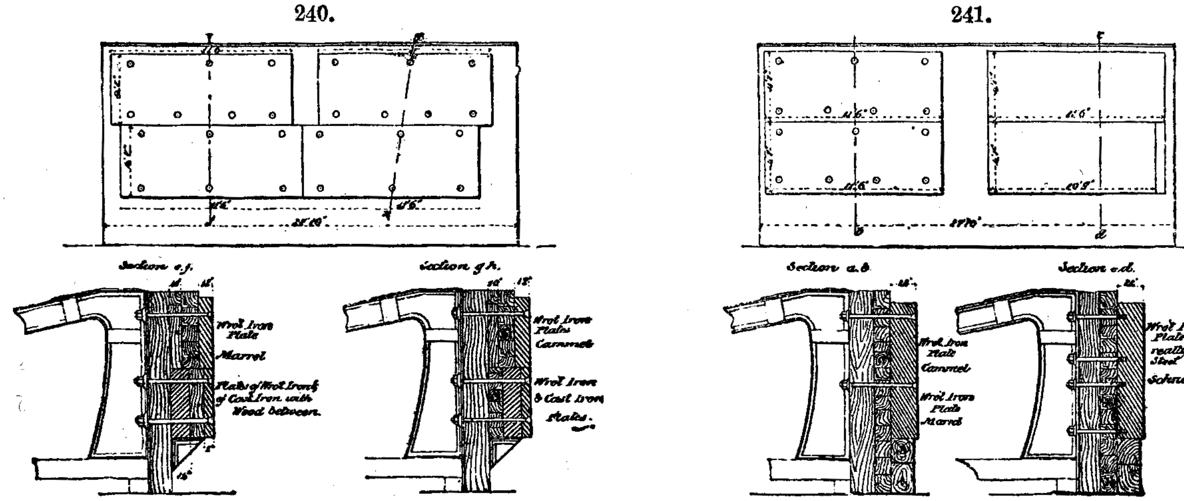
In the experiments conducted at Spezia against targets, the projectiles from the 100-ton gun developed a mean striking energy of 550 foot-tons, and those of the 18-ton and 25-ton guns an energy of 170 foot-tons per inch of circumference. The outer iron plate of the compound target at Spezia was 12 inches thick, to perforate which, according to Noble's formula, would require a somewhat less force; and other trials with the 18-tan gun entirely confirmed this theory, the projectiles possessing only the force actually required to pierce the outer plate; this force being thus absorbed, the shots were of course stopped without producing any further destructive effects upon the target. The projectiles fired with an energy of 230 foot-tons per inch of circumference, fired separately as well as simultaneously and converging, naturally produced effects very similar to those fired against the heavy 22-inch iron and the steel plates.

Invariably, however, totally different effects were produced by the projectiles from the 100-ton gun, which were fired, as has been already stated, with a velocity representing an average of 550 foot-tons per inch of circumference. The thickest iron plates forming the target should have been, according to Noble, easily pierced by the projectile endowed with such a striking force, and they were pierced completely. No reference need be made here to the compound target, which required only 275 foot-tons per inch to penetrate it; while the shot from the 100-ton gun, possessing twofold this force, had, as the experiments showed, a very large excess of power. On the other hand, the untouched steel plate, and the second one that had been injured by previous rounds, both completely stopped the projectiles from the 100-ton gun, and thus preserved the inner wall of the ship. The results of these rounds, and especially of that one fired against a fragment of the target much smaller than the original plate, and which, moreover, was only hanging to the backing, proves undoubtedly the superior resisting power of steel as compared with iron. Thus the same plate resisted one round from a 9.8-inch calibre gun, with a striking force of projectile of 162 foot-tons per inch of circumference; two simultaneous rounds from the 9.8-inch and 11-inch gun, with a striking force of about 170 foot-tons for each projectile, and one round from the 100-ton gun. After sustaining these three rounds, the backing was quite preserved without the skin of the ship sustaining serious injury. The pointed end of the projectile striking the iron plate acted like a wedge, rolled the fibres of the iron back laterally, and destroyed, by the vibration produced, the welding between the layers of iron forming the plate — an effect very visible at the Spezia trials; the projectile thus opens a way for itself, through what can only be considered as a series of plates in close juxtaposition, but with only imperfect adherence.

Steel plates, which are constructed of a compact metal, are homogeneous, of an equal and constant resistance in all directions, and present quite a different nature of resistance to the pointed head of the projectile, which, striking a compact mass, cannot penetrate with the same facility, and, finding no fibre it can throw back, it is broken up, and tends to act like a wedge. In consequence of the rupture of the point, the shot is stopped, producing an effect which, it is true, damages the plate, but, thanks to the uniform compactness of the metal of the plate, the penetrating effects of the projectile are destroyed. Iron plates, even of enormous thickness, must remain powerless to resist such formidable assaults; and it would therefore appear that steel alone is capable of opposing itself to shocks of these tremendous magnitudes.

The targets referred to are shown in Figs. 240-243 the plates being mounted on framing representing that of the ***Duilio*** and the ***Dandolo***. Figs. 240 and 241 are front elevations, showing the

240. 241.



243. 242.

two wrought-iron plates of Cammell and Marrel respectively. The plates were each 11 feet 6 inches long by 4 feet 7 inches deep, and 22 inches thick. In the target constructed of the steel plates of Messrs. Schneider, the upper plate was 11 feet 6 inches and the lower one 10 feet 9 inches long, and each 4 feet 7 inches deep by 22 inches thick. The backing consisted of two thicknesses of timber, the front balks being arranged in horizontal layers and the rear vertically. The inner skin of each target consisted of two ¾-inch wrought-iron plates. Figs. 242 and 243 show sections through the centre of each plate. From these the methods of bolting through will be seen. A portion of the target, shown in the elevation at Fig. 240, consisted of one of Marrel's 12-inch wrought-iron plates of the same length and depth as before. Behind this was first a wood backing arranged horizontally, then another of Marrel's plates 10 inches thick, and then the vertical wood backing and skin. The lower part of this target was made up of a face-plate of wrought-iron 8 inches thick, backed with vertical timbers, behind which was a 14-inch chilled cast-iron plate, and to its rear the vertical timbers and iron skin-plates. The remainder of this target had at the upper part a 12-inch wrought-iron faceplate by Cammell, a thickness of horizontal timbering, and a 10-inch wrought-iron plate by the same maker, the whole being backed as before. The lower portion was made up of an 8-inch wrought-iron face-plate with a 14-inch cast-iron plate immediately behind it. The plates were backed with horizontal and vertical timbers and two ¾-inch wrought-iron plates as before. Sections of the targets shown in Fig. 241 are given in Fig. 242, and in each case it will be seen that the targets are further backed by framing representing that of the ships, the deck-beams; however, being bent downward toward the ground, and their ends being well strutted. Wrought-iron stringers were also introduced in the timber backing.

It will be seen from the Spezia trials that steel may stop shot which would penetrate iron. At the same time, steel is much more liable to be destroyed by splitting, and to snap its bolts. The statement may be put in this way:

> *The shot may be stopped by expending its work in fracturing steel when it would penetrate iron, because the steel, by transmitting the shock through its mass, absorbs it chiefly in making cracks in various directions, while soft iron does not transmit the blow, but receives the whole work on the immediate locality of the point of impact, and so must yield more easily.*

In order to keep intact the steel protection when the plate becomes disintegrated gradually under the blows of comparatively small shot, the adoption of an outside coating or binder of wrought-iron plates of great width and extent has been proposed, into which the bolts would hold, with massive steel plates behind it. It is claimed that much cracking and splitting of the steel might then take place without serious displacement of fragments. Tests of plates constructed in view of the foregoing have been made, the general results of which show a decided advantage in placing iron behind the steel. The "compound plates" tested by the Admiralty (Portsmouth, 1877)[1]* were of four types:

1. Cammell's sub-carbonized plate of solid steel, containing but 13 per cent. [1] of carbon. This split, although the test (impact of 250-lb. Palliser shot from 12-ton 9-inch muzzleloading rifle-gun at 30 feet range) was well withstood.

2. A combined iron and steel plate, composed of steel (0.64 per cent. carbon) 4 inches thick, backed by 5 inches of wrought-iron, was easily penetrated.

3. A sandwiched plate, composed of three-quarter inch of wrought-iron, 6½ inches of steel,

[1]*Engineering*,xxxiv, 625.

[1]***Note to the Electronic Edition:*** The "13" is the value actually in the original. It does not make sense and is, probably a typo. A more logically consistent value would be 0.13 percent.

and 1¾ inch of iron, likewise failed.

4. A plate of Whitworth compressed steel, in which hardened steel screw-plugs were inserted, cracked under the impact, the plugs tending to produce this effect.

It may be added that the whole question of armor-plating is (1878) undergoing revolution, and that no completely efficient system has ever yet been discovered. The problem, after all the enormous outlay spent in attempts toward its solution, has virtually narrowed itself down to whether it were better to adopt iron armor, which does not fissure, but allows the projectiles to penetrate; or steel armor, which successfully resists the penetration of the shot, but is itself broken up.

The Modern Types of Armored Vessels.

The ***Inflexible***, ***A***, Fig. 244.[1] The protected portion of the ship is confined to the citadel or battery, within whose walls are inclosed all the vital parts of the vessel. The vessel measures 110 feet in length, 75 feet in breadth, and is armored to the depth of 6 feet 5 inches below the water-line, and 9 feet 7 inches above it. The armored portion is included between the two shaded vertical bands in the figure. The sides of the citadel consist of an outer thickness of 12-inch armor-plating, strengthened by vertical angle-iron guides 11 inches wide and 3 feet apart, the space between them being filled in with teak backing. Behind these girders, in the wake of the water-line, is another thickness of 12-inch armor, backed by horizontal girders 6 inches wide, and supported by a second thickness of teak backing. Inside this are two thicknesses of 1-inch plating, to which the horizontal girders are secured; the whole of the armor-backing and plating being supported by and bolted to transverse frames 2 feet apart, and composed of plates and angle-irons. It will thus be seen that the total thickness of armor at the water-line strake is not less than 24 inches. The armor-belt, however, is not of uniform strength throughout, but varies in accordance with the importance of the protection required and the exposure to attack. Consequently, while the armor at the water-level is 24 inches in two thicknesses of 12 inches each, above the waterline it is 20 inches in two thicknesses of 12 inches and 8 inches, and below the water-line it is reduced to 16 inches in two thickness of 12-inches and 4 inches. The teak backing with which it is supported also varies inversely as the thickness of the. armor, being respectively 17 inches, 21 inches, and 25 inches in thickness, and forming, with the armor with which it is associated, a uniform wall 41 inches thick. The depth of armor below the load water-line is 6 feet 5 inches; but as the vessel will be sunk a foot on going into action, by letting water into its double bottom, the sides will thus have armor

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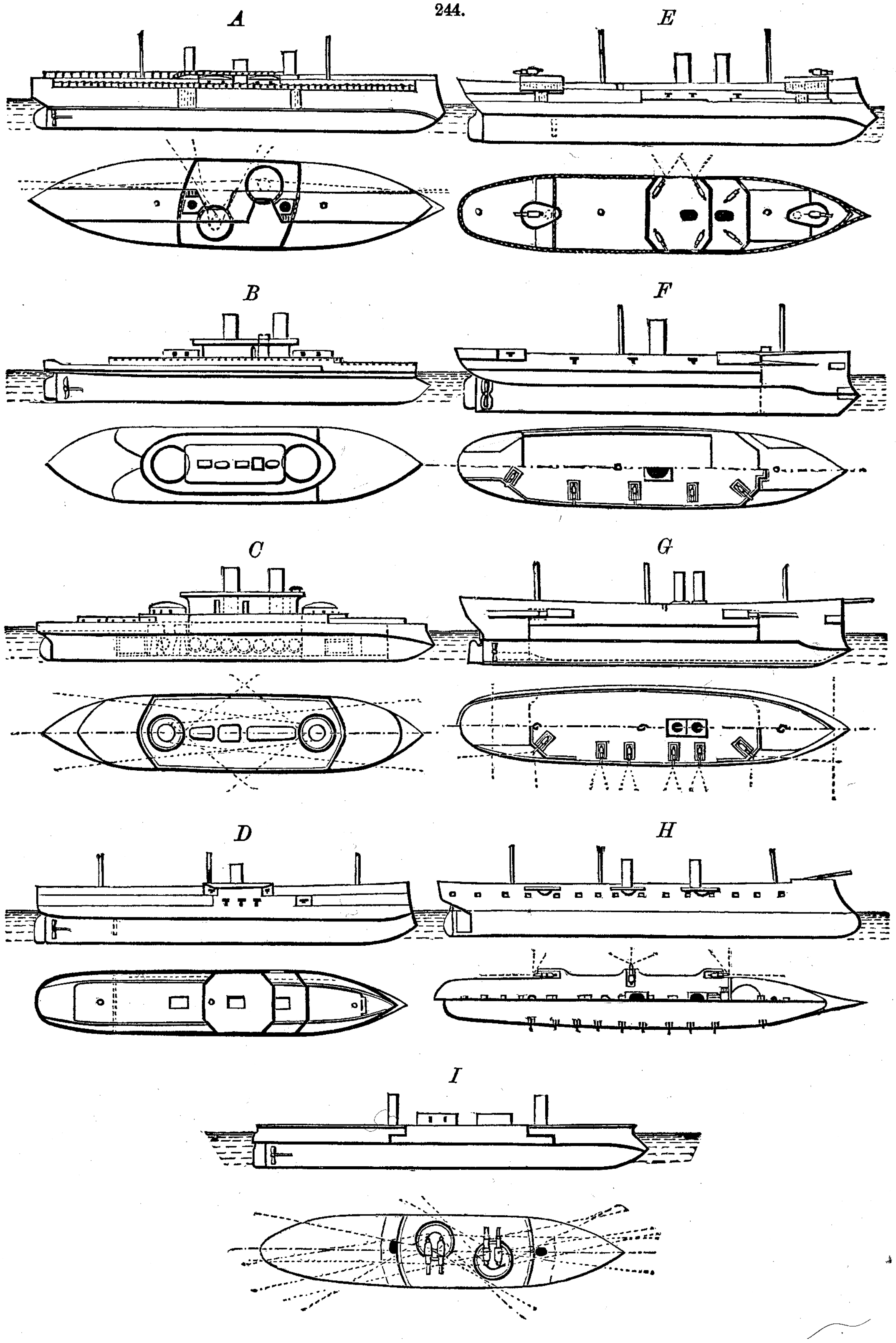
[1]*Note to the Electronic Edition:* The overall length of the ship, given as 110 feet, is **NOT** logical. That is much too short in relation to the given breadth. It's plausible that it's the length of the "armored citadel" of the ship, simply an egregious error. A quick web search at the present time (2005/01/22) lists lengths for the ship of 320-344 feet (which may reflect the difference between overall and waterline lengths.)

244.



protection to the depth of 7 feet 5 inches below the fighting-line. The outside armor is fastened by bolts 4 inches in diameter, secured with nuts and elastic washers on the inside. The shelf-plate on which the armor rests is formed of I-inch steel plates, with angle-iron on the outer edge 5 inches by 33 inches by nine-tenths of an inch. The armor on the fore bulkhead of the citadel is exactly the same in every respect as that on the sides, but the armor of the rear bulkhead is somewhat thinner, being of the respective gradations of 22, 18, and 14 inches, and forming, with the teak backing, which is 16, 20, and 24 inches, a uniform thickness of 38 inches. It may also be useful to mention that before and abaft the citadel the frames are formed of 7-inch and 4-inch angle-irons, covered with $^9/_{16}$-inch plates. The total weight of the armor, exclusive of deck, is 2,250 tons, and the total weight of armor, inclusive of deck, is 3,155 tons.

The most singular feature in the design of the ship is the situation of the turrets. All turrets are placed on the middle line — an arrangement which, though advantageous in some respects, possesses this signal disadvantage, that in double-turreted monitors only one-half of the guns can be brought to bear on the enemy — which rise up on either side of the ship *en échelon* within the walls of the citadel, the forward turret being on the port-side and the after turret on the starboard-side, while the superstructures are built up along a fore-and-aft line of the deck. By these means the whole of the four guns can be discharged simultaneously at a ship right ahead or right astern, or on either beam, or in pairs, toward any point of the compass. The walls of the turrets, which last have an internal diameter of 28 feet, are formed of a single thickness of 18 inches, with backing of the same thickness, and an inner plating of 1 inch in two equal thicknesses.

The ***Thunderer***, ***B***, Fig. 244. Here the height of the side-armor above and below water is shown. The position of the armored deck is indicated by the line along the upper edge of the side-armor.

The ***Dreadnought***, ***C***, Fig. 244. The citadel is 184 feet in length, and the height between-decks is 7 feet 6 inches. It is armored with solid plates 11 inches thick, except at the ends and abreast the bases of the turrets, where the thickness is increased to 13 and 14 inches. The armor-belt, which is carried entirely around the vessel, is 11 inches thick on the water-line, tapering to 8 inches at 5 feet below water, where it stops. It also tapers above water, fore and aft of the citadel as well as toward the ends. This armor-belt, fore and aft the fighting part of the ship, rises only 4 feet above water, and is intended solely to protect the vital portion of the hull. The turret-deck is plated with two courses of 1½ and 1 inch iron respectively, and the main berth-deck below is also plated with the same thickness of metal fore and aft of the citadel.

The turrets rise through the citadel-deck to a height of 12 feet from the base or revolving deck-platform inclosed by the citadel. The diameter of each turret inside of framing is 27 feet 4 inches, the depth of the framing being 10 inches. They are built up with two courses of plates and two courses of teak, in the following manner: first, the shell or wall consists of two ¾-inch plates, bolted together and riveted to the framing; on the exterior of this shell is a teak backing 6 inches thick; on this backing armor-plates 7 inches thick are secured; next, teak backing 9 inches thick is fastened on; finally, armor-plates outside of all, 7 inches thick — all securely bolted together. The plates were rolled at Sheffield, and curved to templates, drilled and prepared for their places.

The ***Alexandra***, ***D***, Fig. 244. The sills of the main-deck ports are 9 feet and those of the upper-deck ports more than 17 feet above the water. The water-line is protected by a belt having a maximum thickness of 12 inches, and it will be seen that the armor forward is carried down over the ram, both to strengthen the latter, and to guard the vital parts of the ship from injury by a raking fire from ahead, at times when waves or pitching action might expose the bow. The machinery, magazines, etc., are similarly protected against a raking fire from abaft by an armed bulkhead 5 inches thick. The batteries are protected by armor only 8 inches thick below and 6 inches above; the total weight of armor and backing is 2,350 tons.

The ***Téméraire***, ***E***, Fig. 244. This vessel carries her upper-deck armament in two fixed open-top turrets, the forward one protected by 10-inch, the after one by 8-inch armor. Like all belted ships, the Téméraire has weak places in her water-line; but amidships, over the most vital parts, she has 11-inch armor (against 12-inch in the Alexandra), reduced very slightly above and below. At the bow, to guard against exposure to raking fire in pitching, the armor is carried down over the point of the ram, and similar protection is gained for the magazines, etc., against raking fire from aft, by an armored bulkhead across the hold (shown in the sketches); this is plated with 5-inch armor. The deck at the level of the top of the belt outside the main-deck battery is 1½ inch thick. The hull, which has the usual double bottom, and is divided into very numerous water-tight compartments, is built on the well-known bracket-frame system, and it is sheathed externally with wood covered with zinc. The weight of the armor and backing is about 2,300 tons, or nearly the same as in the Alexandra.

The ***Shannon***, ***F***, Fig. 244. There are several interesting peculiarities in the construction of this vessel. The guns which are to fight upon the broadside are on an open deck, and all without protection of armor. The armor is limited to a belt extending around the vessel at the water-line; this belt is not tapered toward the bow, as is usual, but ends abruptly 60 feet short of it, at an armored bulkhead 9 inches thick, which extends across the vessel at this point, and descends 5 feet under water. Forward of this bulkhead the armor takes the form of a submerged deck 5 feet below water, running forward and sloping to 10 feet at the stem. The plating of this deck is 3 inches thick. The deck aft of this armor-bulkhead is of iron 1½ inch thick, covered by wood; the hatches passing through it are protected by shell-proof gratings. The armor-bulkhead already referred to — that across the bow of the vessel, 60 feet from the stem — rises to a height of 20 feet above the water-level to the top of the forecastle; and it here turns at the sides, extending aft and embracing the forecastle with arms 26 feet long on both sides. It thus guards both decks against raking fires from ahead, and creates an armored forecastle, open at the rear, and carrying two 18-ton bow-guns. Within this armored forecastle are the instruments for communicating with the engine-room, the helm, and the battery. In other respects the ship is unarmored.

The armor-belt referred to is 9 feet deep, 5 feet of which are under water and 4 feet above water. It is put on in 12-foot lengths, and extends from 4 inches under the counter to 60 feet from the stem. The thickness at the water-line is 9 inches, tapering below as well as above the water.

The ***Nelson*** and ***Northampton***, ***G***, Fig. 244. In these vessels the protecting armor consists of a belt on the water-line of about 181 feet in length amidships; this belt is 9 feet deep, 4 feet above water and 5 feet under water. It is put on in two strakes; the upper plates are 9 inches thick on a 10-inch backing of teak, and the lower plates are tapered to 6 inches thick, supported by a teak backing 13 inches thick. Extending across the ship at each end of this armor-belt there is an armor-bulkhead; it starts at the bottom of the armor-belt, 5 feet under water, and extends to the upper deck, having in all a depth of 22 feet. Its thickness is 9 inches above water, tapering to 6 inches at the bottom. Between the main and upper decks these bulkheads are shaped to form corner ports at the fore and after ends of the battery. Between the armor-bulkheads, and at the upper level of the armor-belt, the lower deck is formed throughout of 2-inch plates, by means of which protection is afforded to the machinery, boilers, magazines, etc. A peculiar feature is the horizontal armor as here applied. For about 57 feet at the fore-end there is an armor-deck. This deck is 2 inches thick, and it is 5 feet under water at the junction with the armor-bulkhead, but inclines deeper toward the stem, and terminates forward in the ram. There is likewise an horizontal armor-deck of the same thickness and depth under water, extending from the after armored bulkhead to the stern. These submerged armor-decks are intended to protect the lower part of the ship fore and aft of the armored bulkheads, especially the steering-gear provided for emergencies.

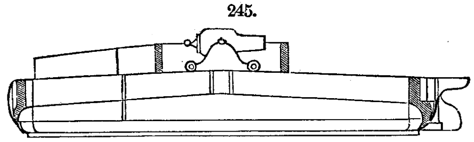
The ***Duquesne*** (French), ***H***, Fig. 244. This vessel is a cruiser of the rapid type, and is designed for 17 knots per hour at sea. The frames, bulkheads, beams, and all interior parts, also masts, are composed of steel; but the outside plating of the hull is entirely of iron, and the bottom is sheathed with 2 layers of teak planks, in all 7 inches thick, and coppered, put on in a similar manner to the system of the English, except that, to insulate the iron from the copper, thick layers of marine glue have been placed between the iron hull and the teak planks, also between the teak and copper.

The ***Dandolo*** (Italian), ***I***, Fig. 244. There is a central armored citadel or compartment, 107 feet in length and 58 feet in breadth, which descends to 5 feet 11 inches below the load water-line. It protects the machinery and boilers, the magazines and shell-rooms, and a portion of the machinery for working the turrets and guns. Forward and aft of this citadel, the decks, which are 4 feet 9 inches under water, are defended by horizontal armor. Over this citadel is built a second central armored compartment, which incloses the bases of the turrets and the remaining portion of the mechanism employed in loading and working the guns. Lastly, above this second compartment rise the two turrets. The turrets are placed at each end of the central armored citadel — not in an even line with each other, but diagonally at opposite corners of it, with the centres at the distance of 7 feet 8 inches from the longitudinal centre-line of the vessel, so that one turret is on the starboard side and the other on the port side. The effect of this arrangement is to render possible the discharge of three guns simultaneously in a direction parallel with the keel. Only the central portion of the ship and the two turrets will be protected by vertical armor.

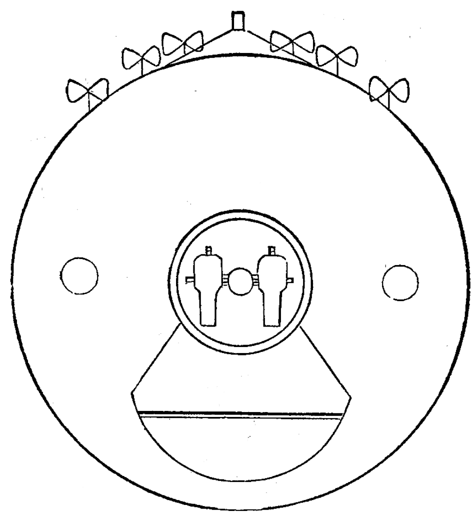
As regards the armor of the central portion of the vessel, the thickness at the water-line is 22 inches. The decks are protected by horizontal armor of iron and steel, the former being under the latter. The armor of the turrets will be composed of solid plates 19 inches in thickness, resting upon teak backing.

Admiral Popoff and *Novgorod* (Russian), Figs. 245 and 245A: Circular iron-clads or *Popoffkas*. These vessels are circular only in one sense; i. e., their horizontal sections only are circular, or, in other words, they have circular water-lines. The departure from a circle is a small extension or protuberance at the stern for the purpose of facilitating the arrangement and working of the rudder and steering apparatus. It follows as a consequence from the circular form of water-line, that all the radial sections are alike; the bottom of the vessel is an extended plane surface, which is connected with the edge of the deck by a quadrant of a small circle. With this form of section great displacement is obtained on moderate draught of water. The deck of the circular ship is formed in section with such curvature as to give in a ship of 100 feet in diameter a round-up of about 4 feet.

245.



245 A.



Types of Armor Plating— Laminated Armor.— In American iron-clads this type of armor has been largely used. It consists of consecutive plates averaging 1 inch in thickness, but backed, as in some of our monitors, by armor-stringers or plank-armor of small breadth and moderate thickness. Experiments made by the English Admiralty proved this laminated armor to be far inferior to solid armor in power of resistance, and that no amount of strengthening can compensate for the defects of the system. The resistance of single armor-plates, shown by direct experiment for all thicknesses up to .5½ inches to vary as the square of the thickness, does not obtain for laminated armor. For example, a 4-inch solid plate would be 16 times as strong as a 1-inch plate, but would not be four times as strong as four 1-inch plates riveted together, although it would be much stronger than the laminated structure. From actual experiment, it also appears that projectiles arrested by a 4-inch solid plate easily penetrated 6 inches of laminated plates.

Elastic-Backed Armor. — It has already been noted that a rigid backing for armor is in all respects preferable to an elastic one; and this conclusion is substantiated by experiments upon a large variety of types of armor, using a number of different substances as support. Millboard in thicknesses of 15 inches, tissues of wire ropes 14 inches thick, India-rubber and pine, India-rubber and oak (1 inch rubber and 20 inches oak, afterward 4 inches of rubber and same thickness of wood), have all been tried, and have failed. A similar result was obtained with a target of four 1-inch wrought-iron plates, and four sheets of rubber 1 inch thick, backed by 20 inches of solid oak; and it was conclusively settled, by comparative tests, that India-rubber serves no useful purpose in causing (as was supposed might be the case) the shot to recoil. A large iron boiler 10 feet in diameter was packed with wool at Shoeburyness, in 1864, and subjected to the shot of a 68-pounder and a 111-pounder Armstrong gun at 100 yards range. The shot passed through 11 feet of wool, the iron caisson, and buried themselves in 12 feet of solid earth. Five bales of hog-hair, backed by 4-inch plank, aggregating a thickness of 3 feet 3½ inches, have been easily pierced by a 38-pound rifle-shot. The advantages of wood backing are not so much that it adds material strength or resistance to the armor-plate, but — 1. It distributes the blow. 2. It is a soft cushion, to deaden the vibration and save the fastenings. 3. It catches the splinters. 4. It still holds the large disks, that may be broken out of a plate, firmly enough to resist shells. A solid backing of wood of from 2 to 4½ times the thickness of the iron unquestionably adds to the resistance, and, when divided into a cellular form by iron edge-pieces or girders, as in the Chalmers target, offers great support, and prevents the distortion of the plates by buckling.

The Armor of American Iron-clads may be briefly summarized as follows: The original monitor had her hull protected by 5 layers of 1-inch plate, diminishing first to 4 inches and then to 3 inches in thickness below the water-line. Her turret was built of 8 layers of 1-inch iron. The Passaic class of monitors have armor of the same thickness as the first monitor, with 39 inches of wood backing. The Canonicus class have 5 layers of 1-inch plates, supported by 2 armor-stringers let into 27 inches of wood backing. Their turrets have 11 layers of 1-inch plates. The Miantonomoh and the Monadnock, which are wood-built, are protected much like the Canonicus. The Puritan and the Dictator have 6 layers of 1-inch plates on their sides, with 42 inches of wood backing. Their turrets are 15 inches thick, made up of two drums, with segments of wrought-iron hoops 5 inches thick, placed between the drums, which are composed of layers of 1-inch plates. In the Kalamazoo class the total thickness of hull-armor is 6 inches, made up of 2 layers of 3-inch plates, backed by 30 inches of oak, still further strengthened near the water-line with 3 armor-stringers 8 inches square, let into the backing, and only a few inches apart. This is by far the most formidable armor carried by any of our monitors; and while there are in some places 14 inches of iron, there is no part of it nearly so strong as it would be with that thickness of solid plates. The turrets of the Kalamazoo are 15 inches thick, like those of the Dictator, but none of them have any backing or wood about them. The rapid diminution in thickness of armor on these vessels is a serious defect, leaving no ground for comparison with corresponding English ships. The Dictator, for instance, 2½ feet below the water-line, has but two 1-inch plates, and at 3 feet only one. Though generally unfit far cruisers, the monitors are well adapted to coast and harbor defense.

Works for Reference. — "A Treatise on Ordnance and Armor," A. L. Holley, 1865; "Report of Secretary of the Navy on Armored Vessels," Washington, 1864; Capt. Noble's "Report on the Penetration, etc., of Armor-Plates," 1876; "System of Naval Defenses," Eads, 1868; "Our Iron-clad Ships," and "Shipbuilding in Iron and Steel," by E. J. Reed, London, 1869; "Reports of the Committee Appointed by the Lords Commissioners of the Admiralty to Examine the Designs upon Ships-of-War which have recently been Constructed," London, 1872; "La Marine cuirassée," by M. P. Dislère, Paris, 1873; and "Reports of the Secretary of the Navy" — Report of Chief-Engineer J W. King, U. S. N., on European Ships-of-War, etc., Senate Ex. Does., No. 27, Washington, 1877 (from which copious extracts are embodied in the foregoing).

ARMOR, SUBMARINE. See DIVING.

ARRIS. The angle formed by the meeting of two surfaces not in the same plane. A piece of square-timber sawed diagonally is said to be cut arriswise. The term is applied to tiles laid diagonally.

ARRIS-PIECES. The portions of a built mast between the hoops.

ARTESIAN WELL. See WELL-BORING.

ARTIFICIAL STONE. See CONCRETE.

ARTILLERY. See ORDNANCE.

ASBESTOS. A mineral fibre composed of silicate of magnesia, silicate of lime, and protoxide of iron and manganese. Mineralogically, the name is given to the fibrous varieties of tremolite, actinolite, and other species of hornblende, excepting such as contain alumina, and also to the corresponding mineral pyroxene. It exists in vast quantities in the United States, in various parts of Great Britain, Hungary, Italy, Corsica, and the Tyrol. To various kinds of asbestos have been applied the names "mountain leather," "mountain cork," "amianthus," and "chrysolite," and certain other minerals having characteristics resembling those of asbestos are described as asbestoid, asbestiform, and as lamellar-fibrous. The chief characteristics of the mineral upon which its value depends are its indestructibility by fire and its insolubility (except for a few varieties) in acids; secondly, its peculiar fibrous quality. The material is obtained from the mines, in forms ranging from bundles of soft, silky fibres to hard blocks. The blocks may be broken up and separated into fibres, which, like those naturally obtained in that state, are extremely flexible, admit of great extension in the direction of their length without cracking, are greasy to the touch, and very strong. The fibre obtained in New York and Vermont varies in length from 2 to 4 inches, and resembles unbleached flax when found near the surface, but when taken at a great depth it is pure white.

One of the first applications of this mineral was the manufacture of incombustible cloth, the fabric being woven of asbestos and vegetable fibre. The latter was employed on account of the shortness of the asbestos fibre. The vegetable substance was afterward burned out, leaving the incombustible texture. Another early utilization was in lamp-wicks, for which purpose it is still used