RECENT ADVANCES IN THE ART OF BATTLESHIP DESIGN.[1]

BY

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In October, 1905, Great Britain laid the keel of a battleship materially larger than any before constructed and differing much from its immediate predecessors, notably in the fact that the heavy turret guns, instead of comprising two calibres, were all of the heaviest calibre—12 inches—and there was no intermediate battery of 6-inch calibre, the only calibre carried being 12 inches in the main battery and 3 inches in the secondary battery or torpedo defense battery. This vessel, named the Dreadnought, being constructed with unprecedented rapidity and under circumstances of unusual and, for Great Britain, unprecedented secrecy, was, largely for this reason, the best advertised ship in the world. It has been the fashion since to call large battleships Dreadnoughts, though in England, where the fashion originated, the expression super-Dreadnought is much used now, and doubtless we shall soon hear of super-super-Dreadnoughts.

While the Dreadnought herself has been thrown in the shade by the later vessels, some of which are more than fifty per cent. larger, she ushered in an era of world-wide competition in battleship building and rapid increase of size and power of individual ships.

Table I below shows the effective battleship tonnage on January 1, 1912, of the eight leading naval powers, divided between completed battleships of the pre-Dreadnought type and vessels of the Dreadnought type, built and building. For the purpose of this classification vessels having a main battery of all big guns, 11 inches or more in calibre, are classed as of the Dreadnought type. None of the eight nations of Table I is building battleships of any other type. Vessels over twenty years old are not included, so Table I shows approximately the battleship tonnage completed or laid down from 1891 to about 1906 as compared with that completed or laid down from about 1906.

[1] Presented at the stated meeting held Wednesday, February 21, 1912.

TABLE I.

Effective Battleship Tonnage.

Nations.	Pre-Dreadnought type built. Tons of displacement.	Dreadnought type built and building. Tons of displacement.
Great Britain	617,500	483,350
Germany	252,712	359,120
United States	334,146	221,650
France	286,005	92,368
Japan	191,698	41,600
Russia	122,250	158,000
Italy	97,500	85,620
Austria	74,613	80,000

Table I brings out clearly the world-wide "speeding up" in battleship building of the last few years. The figures for Great Britain and Germany make it clear why some people in Great Britain consider that country to have made a colossal blunder when she forced the pace by building a new and more powerful type of battleship. The result, of course, is to relatively reduce in value earlier battleships, as to which we see, in the second column of Table I, England had a much greater superiority over Germany than indicated in the third column for battleships of Dreadnought type. Incidentally, Table I makes it clear why the United States is just yielding the place of the second naval power to Germany. Of completed battleships the United States even yet has more tons than Germany, but the latter country is building so many more tons that the United States will never regain second place unless there is a marked change of policy on the part of one country or of both.

Of course, the customary gauging of naval power by tonnage is not an exact method of determining fighting power, but there is no accepted method by which we can determine this except, perhaps, actual war. Even tonnage statistics are not strictly comparable. We know that we use two kinds of tons in this country, the short ton and the long ton. For measuring displacement of battleships there are virtually as many different kinds of tons in use as there are nations.

A freight steamer may be able to carry in cargo double the weight of her hull and machinery. Her displacement then may vary 200 per cent. from her empty displacement. A battleship has a much larger proportion of fixed weight, but carries a large removable or variable load in her coal, ammunition, stores, and water. Such weights may amount to eighteen or twenty per cent. of the empty weight of a large battleship. It is the practice to include arbitrary amounts of consumable weights when fixing the legend displacement of a battleship, and, as the practice in this respect of the various nations varies, the designed or official displacement of a given battleship would be different in each country.

In most countries the designed displacement of a battleship corresponds to a condition in which she carries a rather small proportion of her capacity of consumable weights. That was also the practice in the United States until about three years ago, when a much larger proportion of consumable weights was included in the designed displacement. A 20,000-ton vessel under our previous practice, which was close to the average foreign practice, would be, say, a 21,500-ton vessel under our present practice.

There is another little peculiarity about warship tonnage as customarily stated. The displacement of a battleship is the designed displacement and never changes. We have never had much experience of vessels materially exceeding their designed displacement—I believe no vessel of war built on the designs of the Navy Department since 1903 has exceeded her designed displacement by a single ton—but I know of cases of vessels such as the Dreadnought herself which notoriously exceeded their designed displacement when completed, yet are carried on all lists at the displacement of their original design.

Of course, the question of the proportion of consumable weights to be included in the official displacement of a battleship is largely one of expediency. Whatever the practice in this respect, the designer, in fixing position of armor and such matters, must, of course, consider all conditions of loading.

If the official displacement of a battleship is fixed rather light, she will make a slightly better speed on trial—the difference is very slight indeed for large battleships—and if existing tonnage is minimized, the chance of legislative authorization of more is improved. If, on the other hand, the official displacement is fixed rather heavy, since consumable weights which make her heavy are not included in cost of construction, the battleship will be cheaper per ton of displacement.

OFFENSIVE POWER.

A battleship, as you know, is a very complicated matter, a complete design being evolved by art as well as by science from many conflicting considerations. Perhaps the most salient characteristics bearing directly upon war efficiency are offensive power, speed and endurance, and defensive power.

There are many other essential characteristics, such as habitability, strength of structure, stability in intact and damaged condition, seaworthiness, etc., but for present purposes we must largely take these for granted.

In making Table I we adopt as the dividing line between the Dreadnought type and pre-Dreadnought types the characteristic of carrying a main battery of all big guns 11 inches or more in calibre. The Dreadnought was by no means a wholly novel type. The name has been borne in succession by a number of British men-of-war, and, curiously enough, when we compare the Dreadnought of 1905 with her immediate predecessor completed in 1875 (just thirty years before the Dreadnought of the present day was laid down) we find that the Dreadnought of 1875, like her successor, was, when completed, the largest, fastest, most powerful, and most heavily armored British battleship. Her main battery was uniform in calibre, consisting of four muzzle-loading rifles of 12.5 inches calibre, mounted in turrets. She carried also six rapid-fire guns—called then quick-firing—of 2½ inches calibre. The Dreadnought of 1905 carried a main battery uniform in calibre consisting of ten breech-loading rifles of 12 inches calibre, mounted in turrets. She carried also twenty-seven rapid-firing guns of 3-inch calibre. Each of these Dreadnoughts had an armor belt extending from end to end; its thickness amidships was 11 inches in each case.

Compare then how we may, the twin-screw, reciprocating-engined, 14-knot, 10,800-ton Dreadnought of 1875 shows remarkable similarity of type to the four-screw, turbined, 18,000-ton, 21½-knot Dreadnought of thirty years later. One naturally asks how it happens that in 1905, when making a marked advance in battleships, there was recurrence to the type of 1875, particularly as regards battery. The reasons, I think, are two-fold. In the first place, in thirty years the process of evolution had nearly completed its cycle and the battery was approaching again the type of a generation before. There are on a battleship but two really satisfactory locations for turrets carrying heavy guns. One is forward of the machinery spaces in the centre line of the ship, and the other is aft of the machinery spaces, also in the centre line of the ship. So we find successors to the Dreadnought of 1875 in the English Navy mounting usually four heavy guns in these locations. But there was a steady evolution from the half dozen 2½-inch quick-firing guns of the old Dreadnought. The secondary battery grew into an auxiliary battery plus a secondary battery, so that in fifteen years, or about 1890, we find British battleships carrying four heavy or main battery guns as before, but instead of a few puny quick-firing guns they carried ten or a dozen 6-inch guns, protected behind armor, in addition to smaller guns still.

These 6-inch guns, combined with four heavy 12-inch guns, remained the standard, one may say, for some ten years or so. In the King Edward class, designed about 1901, we find a change. Their immediate predecessors carried four 12-inch guns, twelve 6-inch guns behind armor and sixteen 3-inch guns unprotected. The King Edwards carried four 12-inch, four 9.2-inch in turrets, ten 6-inch behind armor and twelve 3-inch unprotected. This was the first appearance of the 9.2-inch gun upon the British battleship. The next British class—the Lord Nelsons—laid down in 1904, abandoned the 6-inch gun. The Lord Nelson carried four 12-inch, ten 9.2-inch in turrets, and fifteen 3-inch unprotected. Here, then, we have two sizes of heavy turret guns, and it is quite reasonable to suppose that in time the 9.2-inch guns would have grown larger until by natural evolution the all-big-gun one-calibre ship would have appeared.

But there was a second factor which accelerated the slow process of evolution. For thirty years, to my knowledge, it has been a truism of the ordnance officer that the gun is a weapon of precision. Indeed, the precision of heavy guns is astonishing. Twelve-inch shells fired from a modern high-powered gun and leaving the gun in exactly the same direction with exactly the same velocity may be expected in still air to strike a target 10,000 yards, or say 5⅔ miles, away within a very few feet of each other. But, strangely enough, up to some ten years or so ago no navy appears to have realized the possibilities of the gun, or, at any rate, to have developed accuracy of shooting to an extent approaching anywhere near the inherent possibilities of precision of the gun. I think it may be justly claimed that the shooting of the United States Navy has always been as good as that of any other nation. In the Spanish-American war the shooting of the United States vessels was obviously far superior to that of the Spaniards, but, even so, the percentage of shots that hit was painfully small, and it is only the hits that count. But about the year 1900 there began a movement for improvement. It originated in the British Navy, but their first improvements were very soon adopted in the United States Navy, and both made rapid and remarkable progress. Telescopic sights were adopted and perfected. Formerly the gun sighter had to look simultaneously at his rear sight, his front sight, and the target. With the telescopic sight he has simply to look at the target. Cross wires in the telescope which to the gun sighter seem to be in the plane of the target show the point of the target where the shot will strike if the sighting is correct. Methods were devised for increasing the rapidity of loading and for facilitating training and elevating guns so that, regardless of the motion of the ship, the gun could be kept always pointed on the target and could be fired as fast as loaded. Guns, of course, were fitted with sight bars adjustable for the various ranges and also to allow for wind, etc., but it was soon found that there were variables present which no sight bar could take account of. For instance, after a gun had been warmed up by firing a number of shots it would not shoot quite the same as when cold. Two charges from different lots of powder would not shoot alike. Charges from the same lot of powder, if of different temperatures when loaded, would not shoot alike. Careful and systematic endeavors were made to eliminate or reduce to rule the above and other variables liable to produce erratic shooting, and it was found in the end that the most hits were made if the sight bar was corrected as necessary from observations of previous shots. Hence the development of observation stations as high up as possible, so that the "spotters," as they are called, can follow the fall of shell at extreme ranges. Elaborate systems of communication were also developed, so that the fire control officers at the spotting stations could readily communicate necessary instructions to all guns.

Now it was found very early in the evolution of methods of fire control that the problem was very much complicated when it was attempted to handle simultaneously two different calibres of guns. Also, the largest guns were much more accurate at the longest ranges. Hence there arose a demand from gunnery officers for uniformity of calibre of heavy guns just about the time when, by a process of natural evolution, we were approaching this type. Accordingly we find the British Dreadnought and the American Michigan, which was designed very soon afterwards, carrying 12-inch guns and 3-inch guns only, the intermediate calibres, which were 7 inches and 8 inches in America and 6 inches and 9.2 inches in Great Britain, having disappeared.

It is interesting to note that at once the process of evolution again began. The small guns were called the torpedo defense battery and were supposed to be of use only against torpedo vessels. But in England the 3-inch guns of the Dreadnought were replaced by 4-inch guns on her successors, and it is currently reported that the most recently laid down English battleship is to carry a torpedo defense battery of 6-inch guns. In the United States the 3-inch guns of the Michigan were followed by the 5-inch guns of the Delaware, and on later vessels there is carried an improved type of 5-inch gun about as powerful as the 6-inch gun of ten years ago. Other nations which took up the Dreadnought type later never abandoned the 6-inch gun. Hence we may say that, broadly speaking, on the average the type of battery of to-day is again that of ten or fifteen years ago, consisting of a number of heavy guns in turrets and a number of 6-inch guns in broadside. The differences are that on the much larger ships two or three times as many heavy guns are carried and the 6-inch guns are not so well protected, being regarded by many designers as useful against torpedo craft only. With the increase in size of torpedo craft and in range of the torpedo we may anticipate a demand for torpedo defense guns which will put torpedo vessels out of action at longer ranges, and probably for larger calibres which are more accurate at the longer ranges. The art of fire control has not stood still, and the problem of the control of a mixed battery is not so difficult as it was some years ago. While the only thing that may be safely prophesied is that present types will be developed into others, it seems reasonably certain that the evolution of the torpedo defense battery of to-day will be along one of two lines.

The torpedo defense battery will be made larger in calibre, given more protection, and relied upon for use in action against battleships, so that we will return to a mixed battery type, or the main battery will be relied upon for torpedo defense work and the torpedo defense battery will disappear.

In concluding what I shall say about armament I would invite your attention to Fig. 1, indicating by skeleton deck plans the main battery distribution of the most recent battleships of the principal naval powers. Broadly speaking, the heavy turret guns monopolize the commanding positions and the small guns have to be given what is left. Most nations, the United States among them, locate the torpedo defense guns below the heavy guns. They are thus better protected and easily supplied with ammunition, but are objectionably close to the water. Great Britain has hitherto located torpedo defense guns at the level of and above the heavy guns. It is much more difficult to carry 6-inch guns thus than 4-inch guns, and if it is a fact that England has come to 6-inch torpedo defense guns it is very probable that the change in calibre will be associated with a change in disposition.

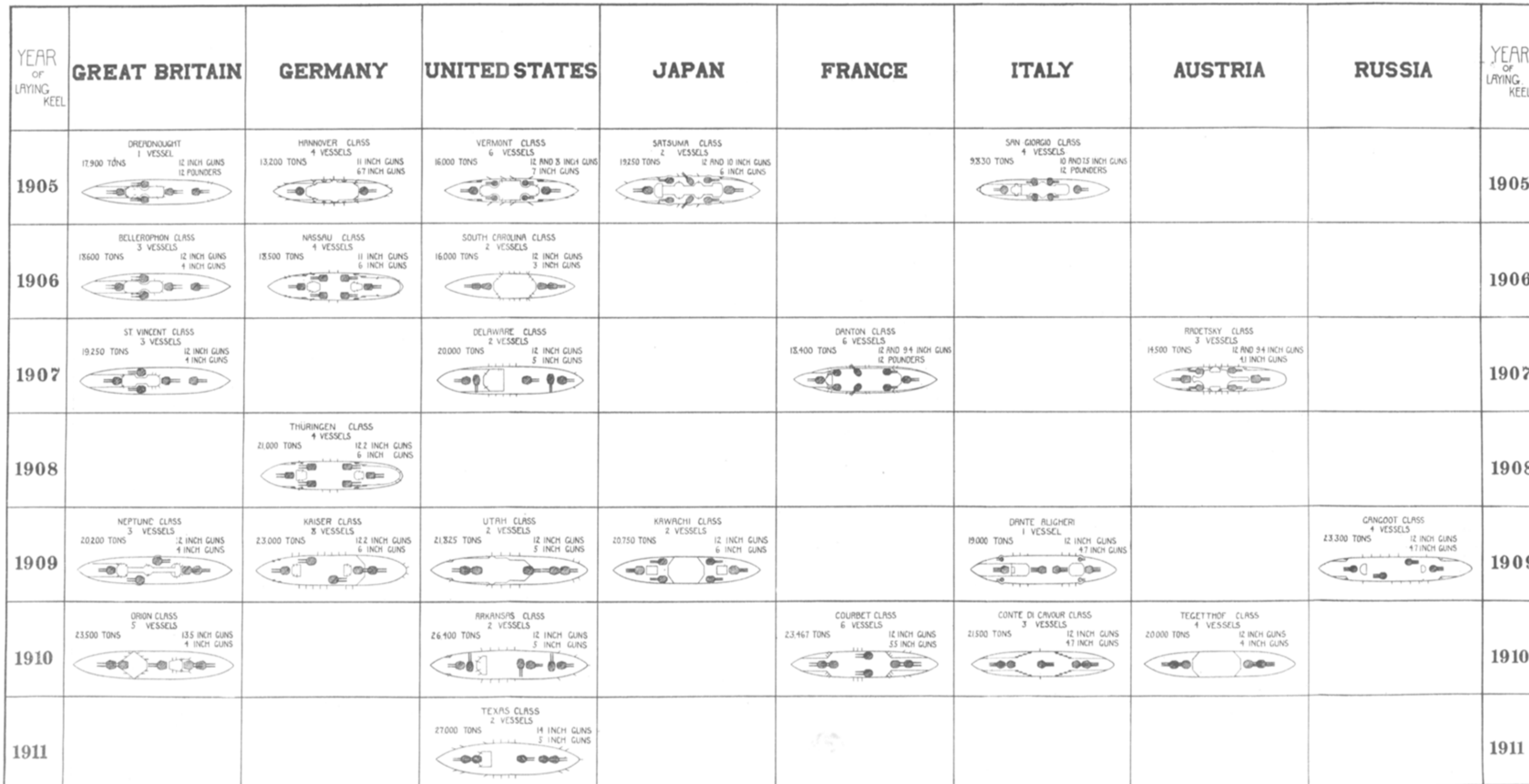
As to the heavy guns, the disposition, as shown in Fig. 1, is most varied. I have already mentioned that the only satisfactory locations for turrets carrying heavy guns are forward and aft in the centre line. Broadside fire is paramount under present conditions, as it is generally admitted that ships will fight broadside to broadside rather than end on.

A centre line mounting is the only one that permits a gun to be used with equal effect on each broadside. A gun mounted in the centre line forward can also be used forward and one so mounted aft can be used aft. A gun mounted in the centre line near the middle of the ship can be used, as a rule, for broadside fire only, and generally for rather a limited range only. Having in view the necessities of the machinery, it is difficult to provide satisfactory ammunition stowage for guns mounted near the middle of length of a ship.

As exemplified by the diagram of the Michigan in Fig. 1, it has been the practice in the United States Dreadnoughts to carry two heavy turrets at each end, thus having four turrets in the most satisfactory location. Additional turrets are located in the centre line.

With two turrets at the end one must fire over the other. As this American arrangement has had the flattery of imitation by nearly all foreign nations, the history of its adoption may be

Fig. 1
BATTERIES OF BATTLESHIPS LAID DOWN IN 1905
AND SUBSEQUENT YEARS



of interest. It was first seriously proposed and advocated by the Bureau of Construction and Repair in 1895 in connection with the Kearsarge design. It was proposed then to locate an 8-inch turret behind and firing over a 13-inch lower turret. The gunnery experts of the day claimed that under such conditions the lower turret would be uninhabitable. The idea lingered, however, and about 1904–5 a thorough test was made upon the recommendation of Chief Constructor Capps. After preliminary experiments at the Proving Ground a crucial test was made on the monitor Florida. A 12-inch gun was removed from her turret and mounted so as to fire over it. Simple changes were made in the turret roof and the 12-inch gun was fired over it a number of times. The tests were progressive, the turret being occupied, I believe, first by four-footed animals, then by midshipmen, and so on up to rear-admirals. With the turret top of proper thickness and tightly closed it was found perfectly feasible to occupy and work the lower turret when the upper turret is firing—a thing which will seldom be done, by the way—never in broadside firing.

Fig. 1 shows clearly that the latest battleships of nearly all nations have adopted this disposition.

It is seen from Fig. 1 that heavy turrets that are not placed near the ends in the centre line are disposed according to three methods.

1. On the broadside firing on one side only.

2. On the broadside firing through a large arc on one side and a restricted arc on the other.

3. In the centre line firing equally on each broadside.

The first arrangement has the serious drawback that a turret so mounted can be used on one broadside only. It is seen that the United States never adopted it for the heaviest guns, and England and Germany have abandoned it.

The second arrangement has the disadvantage that the arc of fire across the deck is usually very restricted—and more restricted, as a rule, upon the actual ship than upon the design. It has also the disadvantages, common to all large broadside turrets, that the opening in the deck for the barbette below the turret is a source of weakness of structure difficult to make good, and that the magazines below are much more liable to be exploded by torpedoes or mines than in the central location.

With this broadside arrangement we find generally one turret on each side near the middle of the ship. On paper such turrets are generally indicated as firing from right ahead to right astern. As a matter of fact, it is not practicable in most cases to fire right ahead or right astern without serious damage to the ship from the blast.

The third arrangement has the advantage from nearly all points of view, except that when two turrets are used and it is necessary to raise one in order to permit train across the deck, it is slightly heavier than the broadside arrangements.

We see from Fig. 1 that at a comparatively short time after the adoption of the all-big-gun type of ship many nations increased the size of these big guns. England went from 12 inches to 13½ inches in the Orion, laid down in 1909. The United States went from 12 inches to 14 inches in the Texas, laid down in 1911. Germany went from 11 inches to 12.2 inches in the Thüringen, laid down in 1908, and there are rumors in the papers that she is about to increase again her big-gun calibre, and that other nations who have not surpassed 12 inches are about to do so.

The introduction of a new calibre of heavy guns into a navy is a large undertaking and results in permanent complications as regards manufacture and supply of ammunition. I regard it as doubtful if the calibre of 14 inches now used by the United States will be exceeded in the near future by any nation. Looking backward, it may be recalled that eight out of our first nine battleships carried 13-inch guns of rather low power and that in 1899 we made a reduction of bore, adopting the 12-inch calibre—of high-power type.

Before leaving the question of offensive power I will touch very briefly upon the torpedo battery of battleships. The torpedo is a weapon which cannot be ignored, but, being at best complicated, easily deranged, and erratic, it has never shown in practice capabilities claimed for it by its advocates. It is primarily the weapon of the torpedo craft, but battleships carry them too—from two to six submerged torpedo tubes being carried by the latest battleships. Torpedoes have been improved during the last few years, and with their increase in size and range they would now be a very formidable addition to the battleship's offensive power were it not for the fact that the increase in fighting range due to improvement in gunnery has been relatively even greater than the increased range of the torpedo.

The torpedo battery of battleships will continue to be a strong incentive to induce battleships to do their fighting at ranges beyond that of the torpedo, and naturally to prevent any recrudescence of ramming tactics in battleship actions. Ramming tactics became obsolete as soon as the torpedo became a dangerous weapon, more than a quarter of a century ago.

SPEED AND ENDURANCE.

The question of the proper speed for a battleship is one concerning which designers differ more, perhaps, in theory than in practice. Italy is the only nation which has consistently for many years attached great value to high-speed battleships. With the exception of Italy, we may almost say that the standard battleship speed at the time of the Dreadnought design was about nineteen knots; the great majority of battleships were designed for that speed within half a knot above or below. The designed speed of the Dreadnought class was twenty-one knots, and most of the nations in their latest ships aim at battleship speeds above twenty knots.

The maximum speed of a battleship is, in the public eye and in tables of data, a constant quantity. We find it always stated as the maximum speed attained or alleged to be attained on trial. As a matter of fact, there is no characteristic of the battleship so variable and indefinite as the actual maximum speed which it can show at any given time. The wind and the sea will materially affect speed, their influence, of course, being transitory. Foulness of bottom due to the length of time out of dock may readily reduce the maximum speed two knots or so below what might be otherwise attained. The condition of the machinery, the efficiency of personnel, the chapter of accidents all affect speed and render it variable and uncertain.

The possible speed of a fleet is, of course, the maximum speed of the slowest vessel in it, and hence the speed of a fleet is apt to be very much less than the maximum on trial of any individual member of the fleet, since a large fleet is almost certain to have one or more lame ducks.

To the popular mind, particularly in America, speed seems to appeal in a peculiar fashion. Superiority of speed seems to imply somehow superior fighting qualities, just as quickness in a pugilist is associated with fighting ability.

As a matter of fact, speed appears to be of more value strategically—that is to say, during the moves previous to actual contact—than tactically—that is to say, during actual battle. A number of years ago investigations at the United States Naval War College led our experts to the conclusion that, as regards battleships, superior speed was not of great advantage for the probable conditions of actual battle unless superiority was very marked, say three or four knots.

In those days, moreover, the probable fighting ranges in battle were taken to be 2,000 yards or so. The fighting range has now grown to 10,000 yards or more. Bearing this in mind, it is obvious that the relative superiority given by three or four knots advantage of speed when fighting at 2,000 yards would require an advantage of probably eight to twelve knots when fighting at 10,000 yards. Without pursuing this line further, I think it may be safely stated that for battleships the main advantage of speed is the ability it confers to refuse action, which is a polite expression for running away. The next advantage of speed is the ability it confers to force action, or to catch an enemy who is running away.

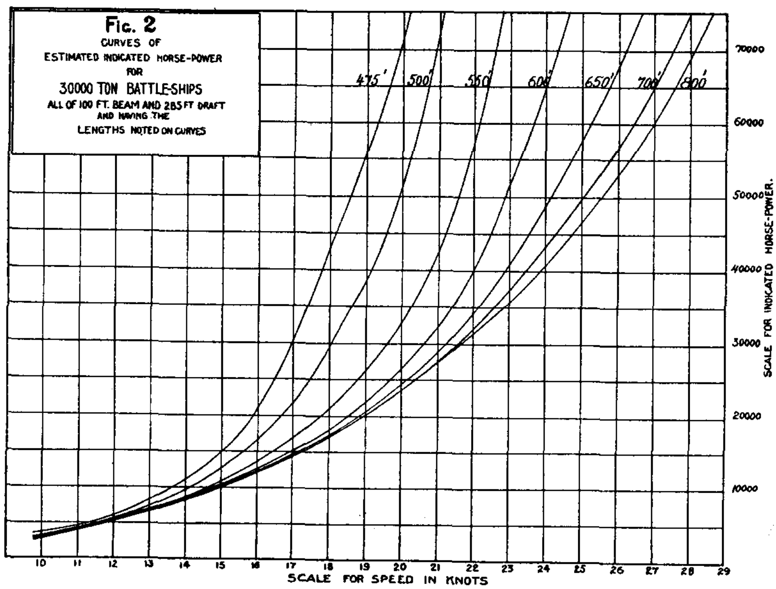
Once battle is joined battleship speed is of comparatively minor value.

The penalties of speed, or the sacrifices which must be made to attain speed, are very large indeed. One might think, at first sight, that it would simply be a question of giving up so much weight of armor or armament and putting it into machinery. This, however, is very far from being the case. The indirect sacrifice, particularly as regards protection, necessary to obtain speed is much greater than the direct sacrifice. This is mainly because high speed is necessarily associated with great length. This fact is illustrated by Fig. 2, which shows the estimated curves of horsepower for a series of 30,000-ton battleships, all of the same beam—100 feet—with the same draft—28½ feet. The influence of length upon speed, sometimes enormous and always important, is obvious from the diagram.

If we assume that in each case we could put a maximum of 70,000 horsepower into the vessel, which is somewhere near the truth, we see that if she were made 500 feet long the speed would be twenty-one knots, whereas if she were made 800 feet long the speed would be twenty-eight knots.

It is doubtful if sufficient length and space could be given to machinery in a 500-foot vessel to enable 70,000 horsepower to be developed; probably it would not be possible to drive such a vessel over twenty knots, owing to limitation of space for machinery.

However, assuming, for the present, that we could get 70,000 horsepower into each vessel, the weight of machinery would be approximately the same, regardless of the length of the vessel; but to build a 30,000-ton vessel 800 feet long would take a very much greater weight of hull than to build a 30,000-ton vessel 500



feet long. This additional weight of hull would have to come from the armor or armament, the 30,000 tons of displacement being fixed. Moreover, the thickness of armor protection for a given weight which could be placed on an 800-foot vessel would be very much less than for the same weight applied to a 500-foot vessel.

It is evident, then, that the penalty paid for speed besides the direct weight necessary to provide for machinery is the additional weight of hull necessary to provide a vessel of the length and form to enable it to be driven at the higher speed, and, superposed upon this, the diminution of the armor thickness, or the restriction of the proportion of the area of the ship protected by armor resulting from the greater length to be protected. The solution of the problem of speed is then obviously a compromise between conflicting considerations, as is the case of so many other problems of warship design. For the latest United States battleships the designed speeds have varied from twenty and a half knots to twenty-one knots, trial speeds usually being a little better by half a knot or so.

It will be seen from Table II that these speeds are close to the average of those chosen by foreign nations.

The question of endurance of vessels of war, or the distance which they can steam with designed fuel capacity, is one which is very difficult to reduce to absolute rule.

In the first place, a battleship will seldom make the same run twice with the same coal consumption. There are too many variable factors; the skill of personnel, condition of machinery, condition of bottom, and weather conditions are all variables which enter into the question of endurance. There is hardly any quantity, moreover, which is so apt to be misrepresented as that of endurance and so constantly exaggerated. A trial is made under most favorable conditions, the coal consumption being reduced to the minimum, and the endurance is stated to be that obtained by dividing the coal capacity by the consumption of the main engines, the trial being perhaps of a few hours' duration only. With such methods it is easy to obtain an endurance 50 or 100 per cent. greater than will be shown by the vessels in actual service under average conditions.

The matter of endurance has been brought more prominently to the front during the last few years by reason of the almost universal adoption of turbines for the propelling machinery of battleships. These have the unfortunate feature that if designed to give the best speed or the best results at or near the top speed, while giving better results for these conditions than reciprocating engines, they are very much less efficient than the reciprocating engines at ordinary cruising speeds. Now if the greatest endurance is aimed at, it is necessary to steam at quite a low speed, below ten knots, in fact, but ordinarily endurances are figured on the basis of a ten-knot speed.

The net work done in driving a ship over a distance is proportional to the resistance and to the distance over which the resistance is overcome. For a constant distance the net work is proportional to the resistance, and if the resistance decreases indefinitely with speed the net work will also so decrease. But with any type of machinery the ratio between the net and gross

TABLE II.

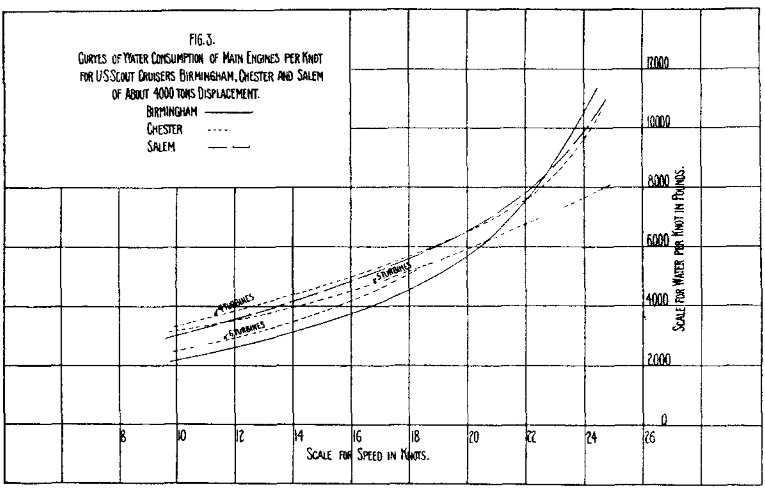
Designed Speeds and Armor Thickness of Recent Battleships of Various Nations. (From Jane's Warships.)

Nations.	Vessels.	No. in class.	Year of laying down first of class.	Designed speed, knots.	Thickness of armor belt, maximum.
					Inches.
Great Britain.	Monarch Class	5	1910	21	12
	Orion Class	3	1909	21	12
	Colossus Class	2	1909	21	12
	St. Vincent Class	3	1907	21	9¾
Germany	Kaiser Class	8	1909	20	11¾
	Thüringen Class	4	1908	20	10¾
	Nassau Class	4	1906	19.5	9¾
United States.	New York Class	2	1911	21	12
	Arkansas Class	2	1910	20.5	11
	Utah Class	2	1909	20.75	11
Japan	Kawachi Class	2	1909	20	12
	Aki Class	1	1905	20.5	9
	Satsuma Class	1	1905	20	9
France	Jean Burt Class	6	1910	21	10¾
	Danton Class	6	1907	19.4	10
Italy	Conte di Cavour Class	3	1910	22.5	..
	Dante Alighieri Class	1	1909	23	..
Austria	Tegetthof Class	4	1910	21	11
	Radetzky Class	3	1907	20	9
Russia	Gangoot Class	4	1909	23	11
	Imperator Class	2	1903	18	8½

work will decrease at low speeds as the speed decreases, so there will be some low speed at which the gross work done in steaming a given distance will be a minimum. In practice the speed for minimum gross work or maximum endurance is inconveniently small, but in most cases the endurance at the convenient speed of ten knots is almost as great as the maximum possible endurance.

The reduced economy of the turbines is associated not only with the economy of the turbine proper, but with the reduced efficiency of the type of propeller, which must be adopted to give the best all-round results for the turbine, hence the only fair basis of comparison is one involving all of the factors.

I have attempted to make such a comparison between the scouts Birmingham, Chester, and Salem, tried two or three years ago. The Birmingham was fitted with reciprocating engines, and the Chester and Salem with turbine engines of different types. The curves of Fig. 3 show the pounds of water used by the main



turbines per knot for various speeds. The Chester, being fitted with various combinations, required three curves.

The basis of pounds of water used per knot was adopted in order to eliminate as nearly as possible the effect of type of boiler, efficiency of firing, etc.

I will invite attention to two facts brought out by Fig. 3. In the first place, the curves are still falling off at the speed of ten knots, so that if these vessels were to steam the maximum possible distance, time being not important, it would be policy, as already indicated, to adopt a speed even below ten knots.

In the second place, the Birmingham, with reciprocating engines, shows markedly better economy at the low speeds and worse at the high speeds.

Incidentally it may be remarked that the maximum trial speed of the Birmingham was materially below that of the two turbine vessels.

Although turbines have been adopted by practically all nations, including ourselves, for battleships, the superior economy of the reciprocating engines at cruising speeds caused us to return to them for the Texas and New York, now under construction, and contracted for a little over a year ago. Of our two battleships just contracted for, the Nevada and Oklahoma, one will have reciprocating engines and the other turbines arranged so as to promise better economy than hitherto.

Many devices have been proposed for obtaining the advantages of the turbines at high speeds and good economy at low speeds.

To gain the maximum steam economy for the turbine it should revolve much faster at high speeds than has been the practice, while the propeller of maximum economy should revolve much more slowly. When directly connected each hampers the other.

Among the methods to increase the economy of turbine-driven ships, I may note the following:

1. Gearing the turbine shaft to the propeller shaft. Then the turbine can run as fast as desired and the propeller shaft as slowly as desired within the limitations of the gearing. This method has been used abroad on merchant vessels with claims of success, and is being tried on a United States collier.

2. Indirect electrical drive—turbine of maximum economy driving electric generators, which in turn drive electric motors on the shafts.

This method is being tried on a United States collier under construction. It is heavier and more complicated than the simple gearing, but is more flexible than the gearing method and can be used for powers larger than would be undertaken with gearing at present.

3. Small reciprocating engines, to be clutched in at cruising speed and thrown out at high speeds, which exhaust to the turbines. This method is being tried on a United States torpedo

boat destroyer under construction, and shore tests of the apparatus indicate marked gain in economy.

As might be expected, each method tried has difficulties and objections peculiar to it, but steady progress is being made, and probably it will not be long before a satisfactory solution will be evolved. It appears to me that at present for vessels carrying the whole or a large proportion of their fuel supply in the form of oil, as do our most recent battleships, the ideal solution would be to fit Diesel engines, or the equivalent, driving generators, which in turn drive motors upon the shafts; this installation, however, to be of low power, adapted to drive the ship about ten knots only. For higher speeds turbines and boilers would be relied upon.

Such an arrangement would be slightly heavy as regards weight, but would have the advantage that the endurance would be doubled at cruising speed and an entirely independent means of propulsion would be provided, giving reasonable insurance against breakdowns. It would also be a step towards the generally anticipated use of the oil engine only for propulsion.

Such an installation would involve some difficult engineering problems, but I know of no reason why they could not be satisfactorily solved.

PROTECTION.

Let us now consider briefly the question of the protection of battleships.

In this connection we need to consider attack by gun fire, by torpedoes, by mines, and by explosives dropped from aëroplanes. The principal things to be protected are the buoyancy of the battleship, her stability, her vitals below water, such as engines, boilers, steam pipes, magazines, and steering gear; her armament; and the personnel directing the operation of the vessel.

As regards gun fire, we rely for protection almost entirely upon armor, whether vertical armor on the sides or horizontal or sloping armor in the shape of a protective deck. It is evident that if the ship were composed of a very large number of small watertight compartments it would take a number of shots to destroy her buoyancy and stability, since each shot would reach but a limited number of the compartments. This principle of subdivision is relied upon to some small extent for protection against gun fire, but, as already stated, our main protection must be armor.

An ideal system of protection against gun fire would be one where the sides are covered with impenetrable armor from a point below the water line, as low as will ever be attacked by shell, to a point sufficiently high above the water line to insure that the ship would always retain her buoyancy and stability.

If, at this upper level, there were worked a level impenetrable deck we would have protection of buoyancy, stability, and vitals.

To complete this conception we should have, rising from this upper level, impenetrable armor superstructures carrying impenetrable turrets, impenetrable conning towers, etc. Needless to say, this ideal is not attained in practice. The demand for offensive power and speed in battleships is so great that defensive power in many cases falls far short of the ideal and in no case actually reaches it.

Full information as to actual armor protection of the battleships of the various nations is very difficult to obtain. Half a dozen battleships of the same size, carrying the same total weight or armor, would distribute it somewhat differently. However, as a rough gauge of armor protection we may use the maximum thickness of the main belt. This is given in Table II for a number of the most recent ships of various nations, the latest ship in each case coming first.

It will be observed that there is a tendency in nearly every nation to increase armor protection, judging by the maximum side armor thickness given. Another fact noticeable from the table is the comparatively close agreement of a number of nations in the maximum side-armor thickness of their most recent ships. This is 12 inches in Great Britain, Japan, and the United States, 11¾ inches in Germany, 11 inches in Austria and Russia, and 10¾ inches in France. There is no information as to the Italian ships, but, considering their speed, it is not likely that their armor is very heavy.

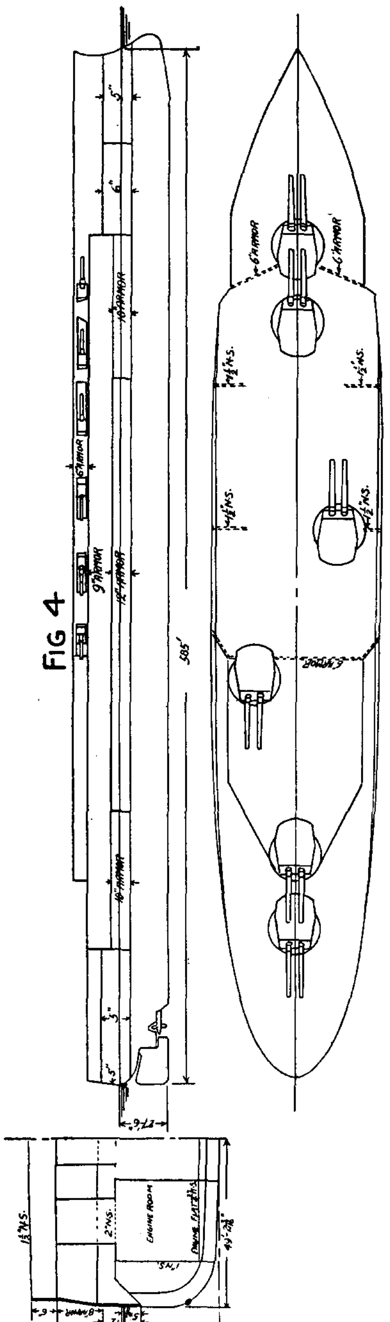
For many years there have been two opposing classes of thought as regards armor protection. On the one side we find the greatest importance given to the side armor with the idea of keeping the shell out of the ship as long as possible; on the other side we find great importance given to the horizontal armor, or sloping armor, the idea being that the shell would not do much damage provided it does not reach the vitals. Hence, we find material variations in the relative weights devoted to protective decks and side armor.

As illustrating current ideas of armor protection I invite attention to Fig. 4, giving the approximate distribution of armor upon some of the best protected of the most recent battleships; namely, the Argentine Republic battleships Rivadavia and Moreno, building in American shipyards upon American designs. It is seen that we have first a 12-inch belt extending over the midship portion of the vessel and tapering slightly forward and aft until we pass the last heavy gun position, where it drops abruptly to a thickness of five or six inches. Above this belt is a uniform thickness of nine inches of armor extending to the upper deck and protecting the bases of turrets, smokestacks, engine hatches, etc. The barbettes and turrets rise above this level, their protection being about equivalent to that of the main belt. We also have conning towers projecting above this level.

The main protective deck, with a flat portion above the water line and sloping to the bottom of the side belt, is 2-inch nickel steel, and at a high level we have also 6-inch armor protecting the 12- to 6-inch guns. There are, in addition, a number of 4-inch guns mounted without protection on top of turrets and elsewhere. Below water we have a heavy bulkhead worked about 10 feet within the side, intended primarily for protection against torpedoes.

The question of protection against torpedoes is one which is by no means solved. The usual practice has been to make compartments as small and as numerous as possible where torpedo explosions were liable to occur, and the larger the size of ship the less the danger that a single torpedo would put her out of action.

In the war between Japan and Russia there were some very striking examples of the deadly effect of submarine mines carrying large charges of high explosives. During that war the torpedoes did not score many hits, and, when they did score a hit, did not accomplish the damage which had been anticipated by torpedo enthusiasts. But since then the speed, accuracy, and weight of explosives carried by torpedoes have all been increased, and there has been developed the torpedo gun, or a torpedo carrying in a " gun " a shell charged with high explosives, FIG 4



Distribution of arms upon Argentina battleships.

which is fired, when the torpedo strikes, with a velocity sufficient to penetrate the ordinary ship through and through.

This device will probably be almost as effective against a ship protected with torpedo nets as against one not so protected.

The question of further protection against torpedoes has been talked of for years, and there is more and more tendency to fit such protection. It has usually been fitted as upon the Rivadavia, but there are advocates of fitting it externally in the shape of external armor far down on the ship.

There is little reasonable doubt that battleships of the near future will carry materially greater protection against torpedoes than those of the recent past.

As regards attack from aëroplanes, which, so far as can be anticipated at present, will come entirely in the form of explosives dropped from the aëroplanes, protection is not yet a difficult matter. Any bomb so dropped cannot be expected to have much penetrative power, and from present aëroplanes must have comparatively small weight. It would be possible to fit nets or light shelters above vital spots which would explode the bomb before it reached a dangerous position. With the rapid development of aëroplanes, however, their attack may become very serious within a comparatively few years through increase of carrying capacity.

It will have been observed that in speaking of protection against torpedoes I intimated that present protection was not satisfactory as regards the most recent forms of attacks by this weapon. The situation as regards attack by gun fire is also not satisfactory. It may be readily inferred from the varying thicknesses, etc., of the armor on the Rivadavia that the designer had at his disposal an inadequate weight of armor and has to ponder almost ceaselessly as to its distribution, giving, of course, the greater weight where there is the greater danger. He is in the position of the tailor who must cut his coat to suit his cloth, but finds his cloth quite inadequate to make a proper coat of any fashion.

The recent increase in calibre of heavy guns in this country and England has emphasized the fact that the attack by gun fire is markedly ahead of the defense by armor. In "Fighting Ships for 1911," by Jane, the penetration of the new British 13½-inch gun in Krupp armor is given as 26 inches at 3,000 yards and 22 inches at 5,000 yards.

While ranges of 3,000 yards and 5,000 yards have become very short for fighting within the last few years, the penetration of this gun at 10,000 yards would probably be 15 or 16 inches of armor, and, except in favorable weather, it would hardly be possible to carry on the fight at greater ranges than 10,000 yards, owing to difficulty of vision.

Bearing in mind that the heaviest armor carried by any British ship mounting 13½-inch guns is but 12 inches, we may say that these ships can penetrate their own sides as far as it is possible to see. The same conclusions will apply to the 14-inch gun mounted on the American ships, and, indeed, we may say almost the same thing of the more powerful of the 12-inch guns whose use is practically universal.

As may be inferred from Table II, there is a tendency to increase armor thickness as the size of ships increases, and in the most recent United States ships this has been carried materially further than indicated in the table; but increases hitherto made can hardly be regarded as adequate, and it must be admitted that at the moment the gun is superior to the armor. Whether the armor will again forge ahead by superior combination of old elements, the development of still further improved armor, or the devotion to armor of a larger proportion of the displacement, it is impossible to say, but there is great need for improvement in protection, and it would seem fairly safe to prophesy that for some years to come we may expect to see the protection developed relatively more rapidly than the attack. I think that is certainly the proper and much-needed line of development. An alternative is to give up the fight and practically abandon armor.

In this connection I would invite attention to some extracts from a paper by Admiral Bacon before the British Institute of Naval Architects in the spring of 1910. He says:

> The problem of building a ship which can not be sunk by the explosion of a torpedo is one that has exercised the skill of naval architects, and the design of a ship which will not be incapacitated by such attack has hitherto baffled all solution.
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> As regards retention of the present thickness of armor protection, this is a matter which may before long undergo considerable modification, and the armor problem of the future appears to resolve itself into the answer to the following question:

Supposing the guns of the enemy can with certainty pierce armor protection at reasonable fighting range, what is the most economical thickness of armor to adopt? Very many considerations are involved in the answer to the question, such as the position and thickness of horizontal armor, but, considering the enormous sacrifice in weight now made to carry thick armor protection, it is a matter that before long may undergo bold and radical revision.

Developments since the paper of Admiral Bacon appear to indicate that the bold and radical revision in armor protection has not come as yet, though now overdue. If the protection does not soon relatively increase, the only thing to do will be to abandon protection, just as the knights in the Middle Ages threw away their armor after gunpowder weapons were developed, and to evolve entirely novel types of ships. Personally, however, I think that the armor maker and the naval designer will not give up the fight and that protection will gain on attack.

In this connection, while slightly apart from my topic, I might say a word or two about the fast armored cruisers, or "battle cruisers," now being built abroad. These vessels illustrate completely what I have said about the indirect effect of speed upon protection. They are as large as, or larger than, battleships, and their length is materially greater than that of the battleships, while their armor protection is very much less. They carry heavy guns, as heavy as battleships, although not so numerous, and presumably would have to fight battleships at times. Their protection is so very slight, however, that against modern heavy guns they are practically on a par with the old protected cruisers, and the value of an enormous ship which will be put out of action immediately upon sighting the enemy appears at most problematic. They undoubtedly have their use for other purposes than the line of battle, such as scouting, but the value of any ship for scouting is likely to be largely reduced in the very near future by the development of aëroplanes.

The very name "battle cruiser" is a contradiction in terms, and the type is far from fixed. The weight which they carry in the form of protection is largely wasted, since it affords wholly inadequate protection, and if this type is further developed along logical lines we may expect to see a great increase of size with protection brought up to that of the battleship or an abandonment of protection along the lines forecasted by Admiral Bacon.