rails and carriers for transporting projectiles and cartridges. The sail area of the Pelayo is less than 6,000 square feet; she has two military masts of steel, with the few spars necessary for carrying the canvas and making signals; the tops of the masts are arranged for machine guns.

The engine power of the Pelayo is as follows: 1. Two independent sets of main engines, each driving a propeller, and each consisting of a pair of compound condensing engines, so coupled that they can be worked together or separately. 2. Two sets of auxiliary engines which drive the circulating and condensing pumps. 3. Twelve return flue boilers, registered for a working pressure of 82 lb. per square inch; these boilers are divided into groups of three, placed in separate chambers. The stokeholds are ventilated by four large fans, which can, in case of necessity, be employed to create a forced draught.

In addition to the main machinery there are a number of smaller engines for miscellaneous purposes. The more important of these are a servo-motor placed under the armed deck of the ship within reach of the captain's shelter, and connected with the large servo-motor which is placed aft, and which drives the steering gear; an engine coupled to the large capstan, two rotary steam pumps, each capable of lifting 500 tons of water an hour; a smaller pump, with a capacity of 30 tons an hour, various steam winches, the electric light plant, pumps for feeding the boilers, etc.

The official trials of the machinery were divided into three series. The first referred to the speed obtained with natural draught, and with the hatches of the stokeholds remaining open. A minimum speed of 15 knots was guaranteed, this speed to be the general mean of four runs on a course of 6.712 knots. The second trials were with a moderately accelerated draught; in these the pressure of air forced into the stokeholds was not to exceed 30 millimeters of water, and the object of the trial was not to ascertain what increase of speed could be obtained, but that all the machinery, etc., worked well under the modified condition. The third trials referred to the consumption of fuel.

The results obtained were considerably in excess of the guarantee, 16.20 knots, instead of 15 knots, having been obtained with natural draught. The coal consumption at 12 knot speed and per twenty-four hours was 45 tons, instead of the prescribed maximum of 70 tons. At the normal draught of water the Pelayo can carry 800 tons of coal, a supply sufficient, with a speed of 12 knots, to cover a distance of from 4,500 to 5,000 miles; reduced to a speed of 10 knots, the steaming capacity would be 7,500 miles. The contract between the Spanish government and the Forges et Chantiers de la Méditerranée was signed in 1884, and the Pelayo was launched in 1888. Considerable delay occurred before she was finally taken over, on account of her guns having been manufactured in Spain, the carriages, however, being all furnished by the Forges et Chantiers. The artillery trials proved as satisfactory as those of the hull and machinery had been, and on their conclusion the Pelayo was put in commission.

THE NAVIES OF EUROPE.

THE battleship fleets of the powers are their sea armies, the forces upon which alone any of them can logically depend for effectively and finally dealing with a maritime foe. The cruiser squadrons are their sea Uhlans and scouts—valuable for the protection of convoys, for the harassing of an enemy's outposts, communications, and even for the making of alarming, though not decisive, incursions into the hostile territory, but of only secondary significance toward the determination of the result of a campaign. Battleship fleets, therefore, should have, as their chief characteristic, offensive and defensive power; while cruiser fleets should, first of all, exhibit extreme mobility. I have compared the battleships with reference to their number, size and gun power. I must now compare the cruisers with reference primarily to their speed. It may be convenient, however, if, before doing so, I show how many cruisers (of each of the three classes into which the Navy List divides our own vessels of this type) the six powers severally will possess by the year 1894, when all the current programmes of construction will have been completed. Our cruisers, it should be explained, are in the Navy List classified, not according to their speed, but according to their size, and their offensive and defensive power, those of the first class, with few exceptions, having vertical armor on their sides, and thus forming a kind of connecting link between the heavily armored battleships and the light cruisers, which, if they carry armor at all, have it only in the shape of a protective deck at or about the level of the water line. The summary is as follows:

	1st Class. No. Tonnage.	2d Class. No. Tonnage.	3d Class. No. Tonnage.
Great Britain.....	23 162,200	48 178,540	54 114,545
France.....	12 65,584	13 64,330	35 64,835
Italy.....	—	7 23,680	14 30,274
Russia.....	8 53,239	9 29,400	14 29,650
Germany.....	1 5,200	6 24,640	19 40,120
Austria.....	3 11,800	2 6,760	12 21,620

The first class is composed of cruisers armored, or of upward of 7,000 tons displacement; the second class of vessels of from 3,000 to 7,000 tons; and the third of vessels of between 3,000 and about 1,300 tons. Each country has, besides, a number of sloops and gun vessels, but these are crafts which, as the tale of them could be increased at very short notice, and as they are, as a rule, little suited either for fighting or for running away, need not here be taken into consideration. The cruiser fleets proper, as I have summarized them, are, then, thus divided: Great Britain, 125 ships (of which twelve are armored on the sides), averaging 3,642 tons apiece; France, sixty-three ships (of which twelve are armored on the sides), averaging 3,099 tons apiece; Italy, twenty-one ships, of which none have side armor, averaging 2,569 tons apiece; Russia, thirty-one ships (of which eight are armored on the sides), averaging 3,622 tons apiece; Germany, twenty-six ships (of which one is armored on the sides), averaging 2,690 tons apiece; and Austria, seventeen ships (of which three are armored on the sides), averaging 2,363 tons apiece. Having thus cleared the way, I may examine the relative values of the cruiser fleets from the point of view of their mobility—namely, of the speed of the vessels composing them. For this purpose I accept the estimated extreme speed or the trial speed of each

craft. We may take it that, continuously steaming, each ship will do from three to five knots less.

	Above 20 knots	18 to 20 knots	16 to 18 knots	14 to 16 knots	12 to 14 knots	Under 12 knots
Great Britain.....	2	61	30	6	26	—
France.....	—	7	20	23	13	—
Italy.....	2	5	5	6	—	3
Russia.....	2	2	1	6	10	10
Germany.....	1	5	—	10	10	—
Austria.....	—	6	1	1	4	5

From this table it will appear that out of 150 cruisers having a nominal extreme speed of sixteen knots and over, Great Britain possesses, or will possess by 1894, ninety-three, as compared with fifty-seven possessed by the remaining five powers; and that, in fact, the majority of the cruisers owned by the other powers are slow craft, while the majority of hers are fast. It may be accepted, moreover, that most of the slow cruisers are old and comparatively valueless, while nearly all the fast ones are modern and armed with modern weapons, besides having a relatively wider radius of action. Multiplying the number of vessels of each degree of speed by their average speed in knots, and also by their average tonnage, is a process that gives us a fair idea of the aggregate cruiser strength of each nation. It is by such a process that materials have been obtained for the compilation of the six diagrams given herewith, which show the comparative cruiser force of the six powers.

Practically, the cruiser force of Great Britain is a little superior to that of the five remaining powers combined; but lest it be supposed by any that we have more cruisers than we need, it may be well to add that the duties which in time of war would be imposed upon our cruisers are immeasurably greater in every respect than the duties which would be imposed on those of all the other powers combined. For example, Great Britain and her colonies own, and have to protect, 12,000 merchant vessels, while France, Italy, Russia, Germany, and Austria together own only 6,600. Again we are an island power and all our external food supply must come to us by water, the routes across which we must therefore guard at the peril of national starvation. Finally, our empire rests upon every continent, and it is incumbent upon us to preserve free communication at all times with even the most distant parts of our inheritance. In these respects we differ from any of the other nations; and far from having too large a cruising fleet, we have in

THE NAVIES OF EUROPE—THEIR RELATIVE STRENGTH IN CRUISERS.

(The number of squares occupied by each diagram indicates the relative cruising power of each navy.)

fact altogether too small a one. This, I think, is easily demonstrable. We have, roughly speaking, 455,000 tons of cruisers to insure nearly 11,000,000 tons of merchant shipping. France, roughly speaking, has 195,000 tons of cruisers to insure only 985,000 tons of merchant shipping. If we had cruisers in proportion to those of France, we should have, not 455,000, but over 2,000,000 tons of them, or say 650 ships instead of our 125.

Besides the vessels which have been taken into account in the above estimates, each of the powers possesses a certain number of troopships, transports, storeships and yachts. These, as being non-fighting craft, do not properly form part of the various navies. There are also the small craft and a few miscellaneous vessels which do not lend themselves to classification, such as our torpedo ram Polyphemus, the torpedo depot ships, and the floating battery which has been adopted for stationary defense by Italy. There are, finally, the numerous coast defense vessels and the torpedo flotillas. These two last classes, taken together, will form the subject of my next letter.—*Daily Graphic*.

THE PHYSICS OF THE SCREW PROPELLER.

By JOHN LOWE, Chief Engineer U. S. Navy.

It is a notable fact that in nearly every case of invention or discovery of permanent value to mankind, they have been introduced and made use of long before the physical laws under which they operate have been understood.

Most strikingly has this been the case with the screw propeller, for notwithstanding the many years it has been in use, and the splendid success it has met with, it is a fact that at this day the physical laws governing and limiting its operation are not yet understood.

Indeed, if search be made throughout the vast mass of literature which has been written upon this subject, there cannot be found as a culmination any rule or formula which can connect the dimensions, the velocity and the result in any satisfactory manner, nor has any of it proved of any practical value, save and excepting that written by Isherwood and by Froude in

detailing their experiments; and saving these experiments, all our knowledge has been obtained an item at a time, by costly attempt and failure.

Thus, for example, take the celebrated case of the old fashioned line of battle ship converted into a screw steamer, in which, whether the engines went one way or the other, the vessel always went astern, proving among other things that under proper conditions the screw will have neither thrust nor slip, but will act simply as a centrifugal pump.

In view of these facts, it is with considerable trepidation that the claim is hereby made for this paper that it declares and demonstrates, for the first time, the relations which must and which do exist between the thrust, the slip, the dimensions and the situation of the screw, when acting as a propeller.

There is a limiting set of conditions reached, depending upon the velocity, when a screw will cease to act solely as a propeller, but will commence to act also as a centrifugal pump, when the water is discharged both radially and axially.

These conditions are not considered in this paper, but the subject is limited to that of the screw when acting as a propeller.

The method of investigation pursued was first to discard and dismiss from the mind all previous knowledge of the subject, and thus to prepare the mind for the reception, not of the metaphysics, but of the physics of the screw propeller.

For this purpose, sixteen good examples of screws of all sizes were selected, in which the data observed and recorded were of a reliable character.

Now, then, one single assumption was made, to wit, that the thrust is some function of the slip, the dimensions, the velocity, and the situation of the screw.

The question then arose—which function? The answer was obtained by trying all possible functions of all the elements until such functions and a constant were found, which connected all the data, thereby making a direct appeal to nature and obtaining an answer.

It is a process analogous to that of opening a banker's safe after the combination of the lock has been forgotten, and is just about as laborious and perplexing.

The conclusion arrived at is expressed by the equation

$$T = K - d^2 R v^2 \theta \text{ in which}$$

T = Thrust of the propeller in pounds.

K = An experimental coefficient and constant.

π

$-d^2$ = Area of the screw's disk, d being diameter in feet.

R = Revolutions of the screw per second.

v = Velocity of the slip in feet per second.

θ = Athwartship area of the screw in square feet.

Not only is this question in perfect accord with the experimental facts obtained from Froude and from Isherwood, but it is also in perfect accord with abstract physics; because if v is the volume of any body, and γ the weight of one cubic unit, then the weight of that body will be γv .

If, now, g is the weight of one mass unit, then the number of such units or the mass will be

$$\frac{\gamma v}{g}$$

Now, then, if a pressure of t pounds, applied for one second, produces in this mass a velocity of one foot per second, then a pressure of $t v$ pounds will produce a velocity of v feet per second, and the total pressure will be

$$T = t v \frac{\gamma v}{g} \text{ pounds.}$$

These abstract truths are connected with the proposed formula by contemplating the minutest element of which θ is composed; it is a simple radial line, which in one revolution will sweep the area

$$\frac{\pi}{4} d^2;$$

and the area of

$$\frac{\pi}{4} R - d^2$$

per second; meanwhile setting in motion the water thus swept with the velocity of v feet per second.

In short, a cylinder v feet thick and of an area

$$\frac{\pi}{4} d^2 R$$

is the volume of water set in motion by this line in one second. Now, each and every line composing θ does the same thing, and, therefore, the total quantity of water which is set in motion in one second is

$$\frac{\pi}{4} R - d^2 v \theta;$$

of which, as previously explained, the mass is

$$\frac{\gamma R \pi}{g 4} d^2 v \theta;$$

and the thrust is

$$T = \frac{t \gamma \pi}{g 4} d^2 R v^2 \theta;$$

demonstrating the formula.

Now, if this quantity set in motion operated in vacuo, it would be easy to get the value of t from our text books; but the water in question moves in, and is resisted by, other water; and thus the value of t must be found experimentally. The consolidated constant

$$K = \frac{t \gamma}{g}$$

is taken provisionally from the example of the U. S. steamer Dolphin, and found to be

$$K = 0.22135. \text{ Log } K = \bar{1}.3450829.$$

We have then demonstrated the formula to be

$$T = K R \pi \frac{d^2}{4} - v^2 \theta$$

and that it expresses the relations existing between all the elements of the screw propeller.

Not only is this the case, but as a corollary it is to be proved that by its use the screw propeller becomes a correct instrument for the measurement of the speed of the vessel in all ordinary cases.

Because Isherwood has shown how the thrust of the screw may be obtained from the performance of the engines; therefore, T may be regarded as a known quantity, and the equation may be solved for v.

The pitch of the screw being P, its usual speed is RP, and the speed of the ship is S = (RP - v) in feet per second, which may be reduced to knots per hour.

Now, all this is true or it is untrue, and practice is the crucible to try it by. For this purpose the following table exhibits a comparison between experimental and calculated quantities, and is intended, without comment, to settle the question:

Name of Vessel.	Observed Quantities.						Calculated Quantities.	
	Diameter of the Screw.	Revolutions per Minute.	Pitch.	Thrust.	Slip of the Screw.	Speed of the Ship.	Slip of the Screw.	Speed of the Ship.
	ft.		ft.	lb.	per ct.	knots	per ct.	knots
Trenton.....	19.5	53	26.5	84.77	43613	10.22	12.61	12.40
Newark.....	14.5	127	18.97	40	58757	20.3	19	10.98
Dolphin.....	14.25	127	24.08	48.56	30534	13.77	15.36	12.77
S'n Francisco	13.5	124.8	18.75	44.55	67551	15.45	20.604	20.456
Concord.....	10.5	153.34	13.02	21.45	27692	16.8	15.42	16.662
Siesta.....	4.58	221.5	8	6.59	2093	23	13.45	14.58

The object of this paper is accomplished above, and the paper should now close. There are, however, one or two words left to be said upon the general subject.

It will be remembered by all who have measured propellers that no two points upon any blade are of the same pitch, and that the pitch assigned to any propeller is a mere nominal figure expressing the mean of all the observed pitches. Bearing this in mind, let us recall the remarkable example of the Iris, a vessel which was at first considerably over-screwed, and which, in consequence, upon trial, disappointed expectations as to speed. It will be remembered that afterward the screws of this vessel were reduced nearly one-half, and the expected speed was then much more than realized.

It will also be remembered that Mr. Wright's comment upon these performances was that nothing in the theory which required a balance between friction and slip could account for the difference in the performances of these screws.

My own opinion, briefly expressed, is this: That the great difference between all the pitches was the cause of the discrepancy. The inferior pitches actually operated adversely. A reduction of the area reduced also the amount of these adverse influences, and the ship then behaved better. But if these pitches had been reduced to uniformity by machining the propeller, then the adverse influences would not have been present. Mr. Froude's theory would have been justified, and possibly the largest screw would have been the best; in short, a question of workmanship is involved, which, in the struggle after high results, cannot much longer be ignored.

At any rate, the cause of the vast amount of power absorbed by the largest screw has not been otherwise explained, and if the difference in pitches is not the cause, then the question arises: What is the cause?

THE RAVELLI HELICOIDAL WINDLASS.

MR. RAVELLI has undertaken to modify the ordinary arrangements adopted for endless screw gearings with a view of extending the applications of them to cases in which the non-reciprocity of the gearing constitutes an essential advantage. It is with this object in view that he employs helices of close pitch, at the risk of increasing the loss of work due to friction.

In the annex of class 52 of the Universal Exposition, there was exhibited a windlass of the capstan type,

RAVELLI'S HELICOIDAL WINDLASS.

which was very powerful and served as a demonstration of Mr. Ravelli's system.

Our engraving gives a perspective view of this apparatus, which consists simply of a strong iron frame, of a bevel gearing, whose pinion is keyed to the winch shaft, and of a pair of helicoidal gearings. Upon the shaft that connects the two bevel wheels is keyed a

drum provided with depressions for the reception of the chain to which the load to be lifted is attached.

The endless screw has several threads, but the latter do not, as usual, run around the entire circumference. If there are four threads, each of them embraces but a quarter, and if there are six, each embraces but a sixth. Upon the whole, this endless screw constitutes a sort of a disk upon the circumference of which are arranged a variable number of pins that are slightly inclined with respect to the bases of the disk. At every fraction of a revolution corresponding to the number of the pins

what is left attacks not only the stone but the saw itself, which is thus quickly put out of service.

Among the tentatives made in view of substituting for the ordinary saw a suitable blade adapted for mechanical work, it is necessary to hold before all to the method which consists in providing the teeth with diamonds. Up to the present the results obtained in this direction have not been very satisfactory. This is due less to the efficiency of the process than to the means employed for realizing it. The setting of the diamond has always left something to be desired from the stand-

FIG. 3.

CIRCULAR STONE SAW.

FIG. 1.—Elevation. FIG. 2.—Transverse Section. FIG. 3.—Plan.

one of them abandons the tooth of the gearing while the following pin and tooth engage.

In order to diminish passive resistances, the teeth do not rub against the inclined planes formed by the pins, but roll over them. To this effect, they consist of truncated cone spindles loose upon journals set firmly into the felly of the gearing. The wear of these spindles is slow, because they are numerous and engage at relatively wide intervals of time.

The power of this machine is very great, although no recourse is had to a differential mechanism nor to tackle. Stoppage is secured under full load, either in the raising or lowering of weights, without the intervention of any stop-work or brake. No flying back of the winch is to be feared, and this gives every security to the workman.

Mr. Ravelli has devised a certain number of variants of these gearings especially for models of small dimensions. If it is necessary to transmit motion in several directions, it is possible, owing to the wide diameter of the helix disk, to arrange bevel gearings in proper positions upon its circumference.—*Revue Industrielle*.

AN IMPROVED CIRCULAR STONE SAW.

THE mechanical sawing of stones, and particularly of hard stones and marbles, is, in various ways, the object of interesting studies. A perfect solution of this question is a thing to be desired by a large number of

point of solidity. So, in blades having an alternating motion that have been provided therewith, a loosening of the diamond soon occurred, followed by its complete extraction.

Although the selection of a blade is of great importance, an advantageous arrangement of the machine is also an important factor in the quality and production of the work.

It has hitherto been desired to exaggerate the simplicity of the mechanism, so that there has been devised a machine as a whole of too primitive a construction, which required expensive maneuvers to bring the blocks under the saw, and which did not permit of obtaining varied sawings cheaply.

Messrs. D'Espine Achard & Co. have taken up the study of this important problem. The experience that they have acquired upon this subject, and long researches followed by numerous trials, have led them to devise and have patented some types of stone-sawing machines which satisfy the following desiderata recognized as necessary in practice.

These machines permit of sawing blocks of large dimensions, with a forward motion of the saw from twenty to fifty times more rapid than with the old sand processes, and without requiring long and expensive maneuvers. The surfaces cut are smooth and polished, and the block may be easily cut in all directions, and this, in many cases, does away with the ulterior aid of the stone cutter. Finally, the diamonds of the teeth act always in the same direction, and consequently are not subject to shocks in their sockets.

In the figures that accompany this article we represent a small model of this sawing machine, which, like the larger models, is based upon the use of a circular saw, whose periphery is armed with small diamonds which constitute the toothing, and the process of setting of which has been patented by Mr. Kohler. The following is a succinct description of it. A small bar of soft steel is taken, and after it has been bent into the form of a very narrow U, a small diamond is inserted between its branches. These latter are afterward soldered while hot, and so expanded as to constitute a disk in which the diamond is inclosed without the interposition of any soldering material.

In the manufacture of these disks special arrangements are taken to have the position of the diamond, exposed by a proper finishing, vary from one to the other. In the disk of the saw as many cavities are formed as the saw is to have teeth, and each of these is formed according to two diameters upon the half thickness, for the reception of the disk. The mounting is then finished by a soldering of tin.

Between each of the cavities hollows are made in the saw, so that the diamonds may cut well into the stone. We shall now describe the arrangements devised by the manufacturers for the use of the saw thus constructed.

Figs. 1, 2, and 3 represent the machine adapted for the sawing of blocks of small dimensions, the carriage of which is relatively easy. As may be seen, the diamond-set disk, A, is fixed projectingly at the extremity of a shaft, B, resting upon the two pillow blocks of a solid cast iron cross piece, N, which is carried by the frame, P, upon which it is capable of sliding vertically.

The saw disk, plentifully watered by ajutages, is held between guides that can be regulated at will, and are