PART II. EIGHT PAGES.

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MISCELLANY AND ART.

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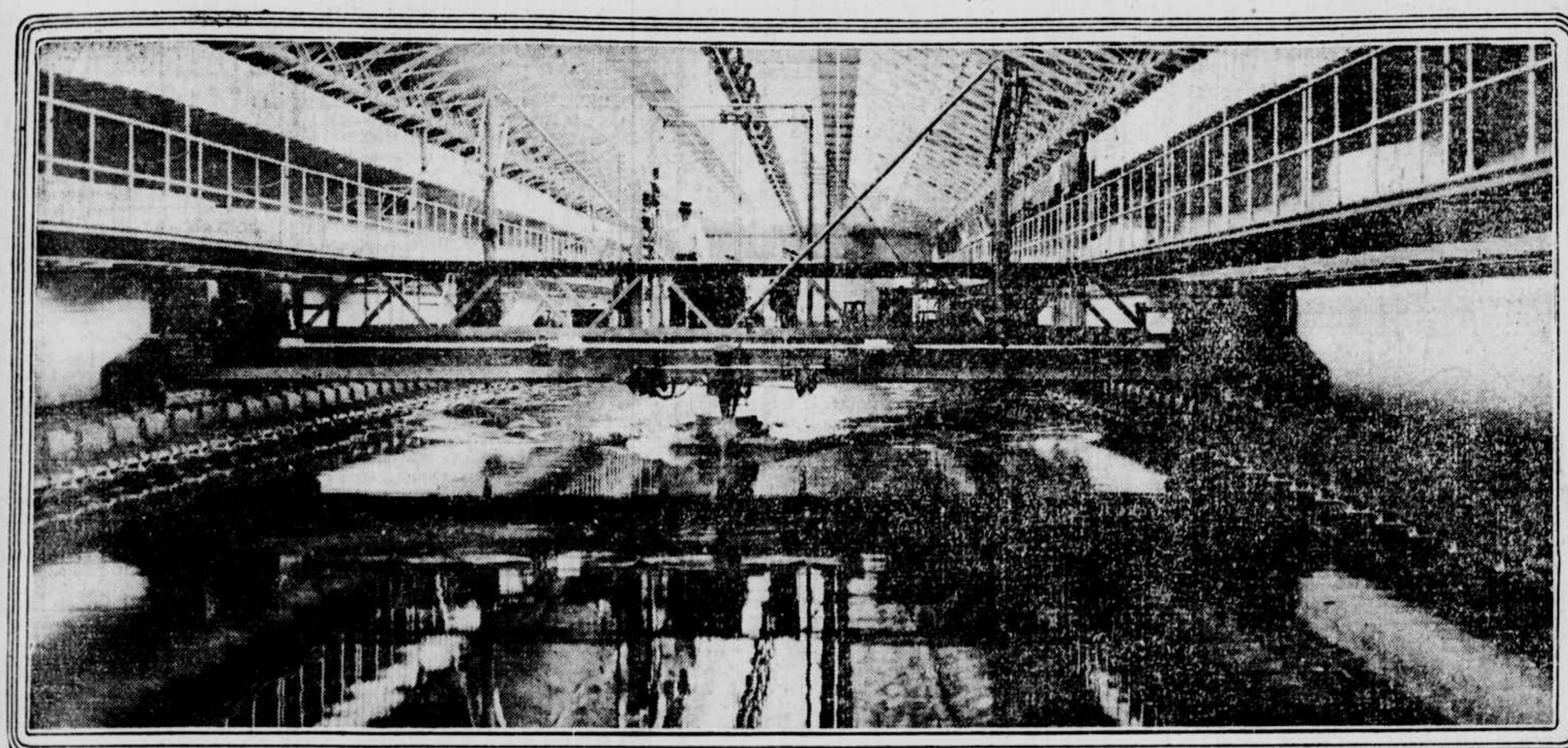
TINY WARSHIPS THAT PREDICT HOW BIG ONES WILL SPEED

On the Water of the Model Experimental Basin at the Washington Navy Yard Each New Vessel of Uncle Sam's Fleets Is Tested Before Construction by Means of a Toy Reproduction Possessing the Exact Lines and Proportions of the Large Craft's Plans.



The Towing Carriage in motion with a Model attached.

HAVE you ever stopped to think how it is possible for modern vessels to make the speed they do? Probably you have imagined the whole problem as something for the engine room to solve—in other words, merely a matter of just so much power churning the screws around in an increasing race. If you will ponder for a moment you will realize that this is a faulty conclusion, and the reason for your error is plain. Added power means bigger engines and a larger initial outlay for machinery. Bigger engines require more steam, and more steam can be supplied only by increasing boiler capacity. Boiler capacity costs money in two ways: First, for the boilers themselves, and second, for the fuel which must be burned in them to turn the water into steam.

This is an age of economy and efficiency, and these two vital factors to commercial or administrative success cannot be realized through extravagant mechanical effort or expenditure: each pound of coal and each developed horsepower must render as nearly as possible a maximum of effective service. Simply crowding a ship full of engines of immense mechanical energy will not meet these requirements. The real problem is to make each turn of the propeller drive the craft at the highest appropriate speed, and a vessel of any prescribed form can be forced through the water economically only to a definite limit. Up to that limit the supporting fluid offers a minimum resistance, let us say, but when the ship tries to advance faster the water suddenly increases its opposition, and the struggling engines waste their energy in producing large waves without moving the craft ahead proportionately to the added power exerted.

NEPTUNE PLAYS FAVORITES.

In brief, the water is kindly in its encouragement to speed toward some ship shapes and very antagonistic to others trying to travel at the same rate. This is not a matter of recent discovery; the fact has been known for centuries. But the need of means to determine the best form for each kind of vessel and its chosen duty has had its birth only within the last few decades, and particularly so within the last twenty years.

A little bit of history will not be out of place, because it is but fair that the genius of the late Dr. William Froude, of England, should be recognized. In 1871 the British Admiralty had under consideration the building of a number of improved ships of war, and to facilitate matters the naval authorities instituted a committee on design, and Dr. Froude became one of its members.

The practical men of that body were sensibly alive to the difficulties of the work cut out for them, and they were equally aware of the limitations peculiar to the mathematical methods and the rule-of-thumb order of procedure then commonly employed in approximating the speed possibilities of different ship-forms as well as that of determining the probable engine power needful. The naval architect and the marine engineer up to then had groped their ways along and did a good many things just so because their fathers and grandfathers did likewise before them. The building of steamships had not then a great variety of conditions to meet nor had commercial competition or military supremacy exacted very much. But in 1871 the British Admiralty felt the need of radical betterment, and the puzzle was how to gratify this demand. Here is where a revolutionary work of science had its inception, and the authorities were peculiarly fortunate in having Dr. Froude's aid.

DR. FROUDE'S EXPERIMENTS.

Somewhat earlier Dr. Froude, in his own garden, at Torquay, had engaged in a series of private experiments of a practical character primarily free from all mathematical considerations. He was anxious to fathom the physical laws involved in the movement of a ship through the water, and he went at his investigations in a novel way. By towing thin planes covered with coatings of various sorts and also small models of vessels of different forms, that astute Englishman was able to establish certain facts of starting significance. With this information as a starting point he was able to go ahead with confidence and then to attach to these discoveries their true mathematical values.

If you stop to think for a moment you will appreciate that the many different movements of the water in touch with and surrounding a vessel under way have all to do with the speed of her progress, and you will also grasp the appalling task involved in trying to resolve these by mathematics into a single force which the engines are to struggle with. Now, Dr. Froude knew this, too, and he set out to reach his answers by physical means which were to deal with results and not room with involved or abstruse intermediate mathematical problems. His experiments showed him that the predetermining of the engine power needed to drive a full sized, self-propelled ship was a matter essentially exterior to the craft; in fact, the question was that of discovering the measure of propulsive energy lost through wave making and the overcoming of friction between the water and the submerged surface of the vessel's hull.

Thus by reversing the older order of affairs and by working from the outside inward to the propelling engines Dr. Froude proved that the puzzle was open to practical solution. But this was not all. He showed that the needful information could be had in advance of the building of a full sized craft by the towing of a miniature of the proposed vessel, and he evolved what is now called "Froude's law" or the "law of comparison." That patriotic Englishman laid before his government the fruit of his private researches and sensibly urged the authorities, inasmuch as they contemplated spending large sums of money in new ships, to verify his conclusions by towing a full sized ship upon a model of which he had previously experimented. The ship was not to use her own engines, and the towline was to be tied to a sort of gigantic scales on the other and active vessel. The "pull" on the tow rope would represent the true or total resistance to be overcome should the passive craft take up the work of her own propulsion.

Without burdening the reader with the whole story, it suffices to say that the experiments with H. M. S. Greyhound brilliantly confirmed Dr. Froude's claims, and thus was laid the foundation of a science which has revolutionized the art of ship designing. Prior to that time vessels were built and finished only to disappoint both their constructors and their owners, and this meant the sacrifice of much money. Dr. Froude showed how these needless sacrifices could be avoided and success made certain by the testing of inexpensive models in advance of any work on the proposed big craft.

MODEL EXPERIMENT BASIN.

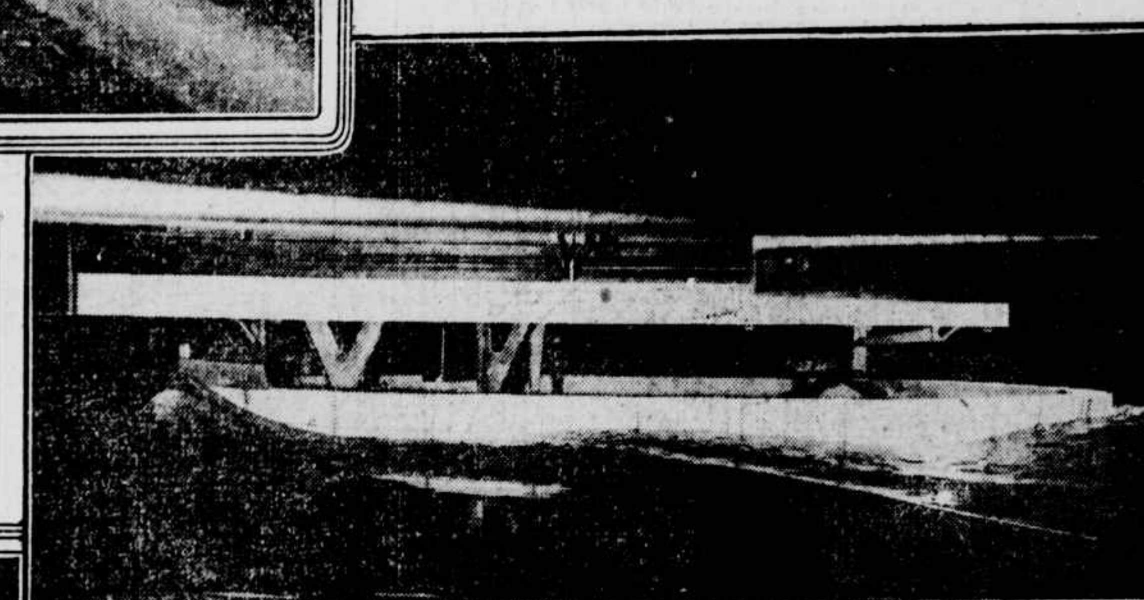
Down at the navy yard in Washington the government has what is officially known as the United States model experimental basin, which was established there in the latter 90's. Before then, year after year the Navy Department asked Congress for the necessary funds to erect the plant, but our unscientific legislators looked upon the whole project as a sort of technical hobby, and they could see no relation between small models and full sized vessels. They thought our designers were doing well enough, and they did not realize that their economy, in the end, would be like saving at the spigot and wasting at the bung. In short, some of those Solons actually thought the basin was a covert effort to obtain a luxurious swimming pool for the officials at the yard. These circumstances are cited merely that the public may the better realize to what really valuable and vital ends the model tank—as it is commonly called—has actually lent itself.

Before we describe the model basin let us follow the evolution of the experimental design and the making of the models that are to be towed. Congress always expects when it makes an appropriation for a ship that it shall be equal to if not better than any of the same size and kind abroad; and our national legislature approximately limits this size or displacement as well as the total cost. The designers of the Navy Department, then, must do their best to make good within the limits and the requirements imposed upon them. A naval vessel is primarily a fighting ship and must be fittingly armed and armored, but she must also have a wide range of economical speed and be capable of answering the physical and the political needs of our seaboard.

MEETING MANY REQUIREMENTS.

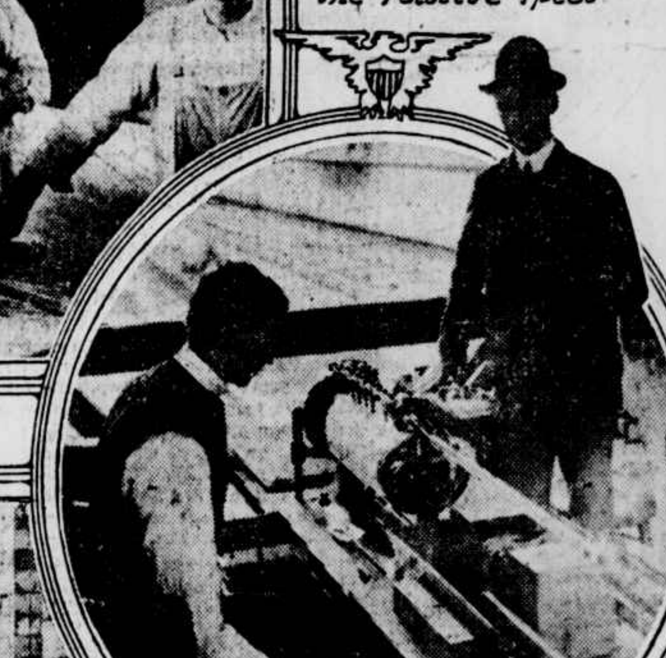
You don't know it, but these conditions call for a great deal of study, and fortunately the accumulated data of ships already in service help the designer in a general way to plan the broad characteristics of the new craft. Every needless ton put in machinery is a sacrifice of just so much protection in the way of armor, or so much less fuel in reserve, or so much less ammunition for the guns in the hour of battle. Therefore the naval constructor tries to evolve a form of hull which will meet all of the military requirements while demanding the least engine power for the service expected of it.

Let us assume that the designers have worked out a preliminary form of hull which reasonably promises—based upon experience—to meet the present requirements. These plans are sent down to the head of the model basin, Naval Constructor D. W. Taylor, who is known the world over because of his rare professional equipment for this work. The "lines" of the new ship are laid upon a big glass-covered table, and by means of a pantograph these lines are mechanically reproduced to suit the uniform scale upon which all models are made at the basin. The pencil of the pantograph draws cross sections of the hull at different points fore and aft, just as if you sliced the intended ship as you would a loaf of bread. This pencilling is done on heavy paper, and this is carefully cut to the lines to serve as patterns in fashioning one stage of the wooden model. The various sections, made of thin pine, are then set up on an erecting table with proper intervals between them, and over these sections are fastened long strips of pliant, half-round moulding.



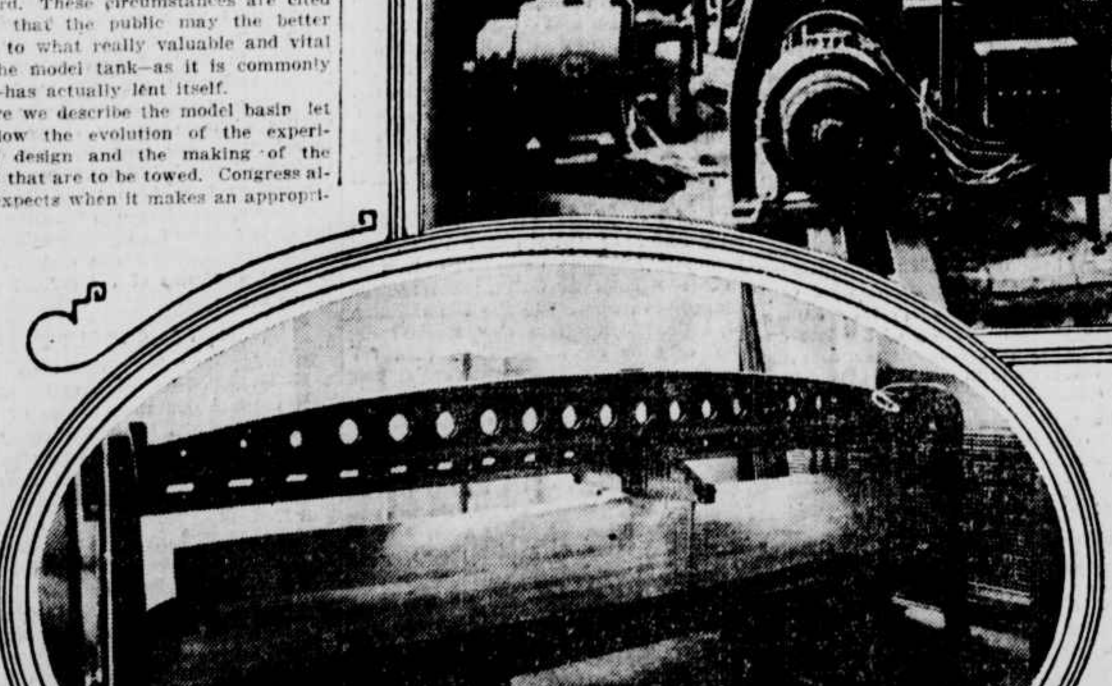
A miniature battleship being tested. The big ship will exactly reproduce the wave formation at the relative speed

The finished model ready to go to the towing basin



The Recording Mechanisms and the Switchboard on the Towing Carriage—

The machine that makes the model. The "former below and the model in the making above.



Marking the waterlines on the model

This structure when completed is called the "former," and is then transferred to a special machine which has two platforms, one above the other. On the lower one the "former" is placed, and on the upper one there is a rough approximate made of a mass of pine planks held together by waterproof glue. Again a pantographic mechanism is called into service. The lower arm terminates in a simple wheel, which rolls over the surface of the "former" and translates its motion to the upper arm, which is equipped with cutters. These knives revolve at high speed and eat into the wood of the upper mass of planks and roughly reproduce the shape of the "former" below.

After enough of the wood has been thus removed the knives are supplanted by disks of sandpaper, and these finish off the model's surface to a nicety. The machine does not complete the model so far as the shaping of the refined parts of the bow and the stern. This work is done by experts, and they also place the various structural projections which support the propeller shafts, the rudder and other features, like the bilge, keels, etc., which play an important part in modifying the speed of a vessel. The model is then painted and varnished, and after that it is put in a special apparatus which traces upon the smooth surface a succession of horizontal lines, which indicate the different waterlines from the keel up to a height some distance above the full load line. The purpose of these upper lines is to indicate the crests and hollows of the natural waves formed by the model when running at high speeds. The positions of these wave formations indicate graphically whether or not the model is being pushed beyond its economical maximum velocity. Photographs are taken of the model when in motion. Everything is now ready for the transfer of the work to the towing basin.

As we have previously said, all models are made the same length, i. e., twenty feet, no matter what is to be the size of the regular craft. This length of model is desirable because it is so big that it reduces the factor of error which may exist in translating the model performance to that of the full sized ship. In other words, it lessens the gap and makes for increased accuracy. In this particular our tank has set a noteworthy example to other experimental basins. As a part of the experimental tank, there is what is known as the balancing basin, where the model is loaded with bags of shot until it settles in the water to the desired draft. With this preparation finished, the miniature battleship, let us say, is then attached to the towing carriage or platform. This platform spans the model basin from side to side and has a run of three hundred feet from end to end of tank. The towing carriage is propelled by four electric motors, which are arranged so as to give this vehicle a very smooth motion. It can actually be run at a speed of twenty knots an hour, but the scale upon which the models are built does not require them to be towed at even half this rate. You must understand that the speed of the model bears a relation to the speed of the full sized ship, which is governed by a certain mathematical ratio which we need not go into here.

The model is so attached to the towing carriage that it pulls against a spring much after the fashion of the scales we have so often seen hanging at the tail of the iceman's cart, and this drag is recorded in pounds upon a sheet of paper enveloping a revolving cylinder.

This registering instrument also marks the speed of the carriage, and, incidentally, that of the model. After a number of runs have been made at different speeds, the data are reduced to diagrams or curves which the designer studies. If these curves show an undesirable pull at the particular speed desired, then the model must be modified and this altered miniature in its turn tested. This is repeated until the results are satisfactory. Of course, this does not go on indefinitely, because the designer is drawing upon his experience and the accumulated data about many other vessels, perhaps, of a kindred sort.

If, however, as in the case of the first of our scout cruisers, the craft is essentially novel, then the task is a harder one, but at best it is the surest and by far the cheapest way of obtaining satisfaction in the full-sized craft. At the same time, thin planes—similar to those employed by Dr. Froude originally—are separately towed to ascertain the amount of resistance due to the friction of the water in contact with the bottom of the craft independent of the shape of the model. These planes are just as long as the battleship in miniature and have the same area of wetted or submerged surface. With this twofold information available, the designer knows how to proceed, and the cost of it all is only a few hundred dollars.

The taxpayer naturally asks for a concrete example of good done or economy effected by our governmental model basin. When our "scouts" of the Salem class were undertaken, they represented an entirely new problem.

Using the best judgment and information available, these vessels of 4,000 tons displacement, intended to make twenty-

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