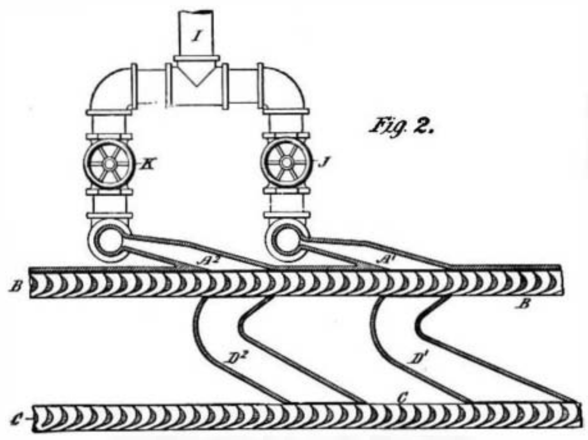
MODERN DEVELOPMENT OF THE STEAM TURBINE.

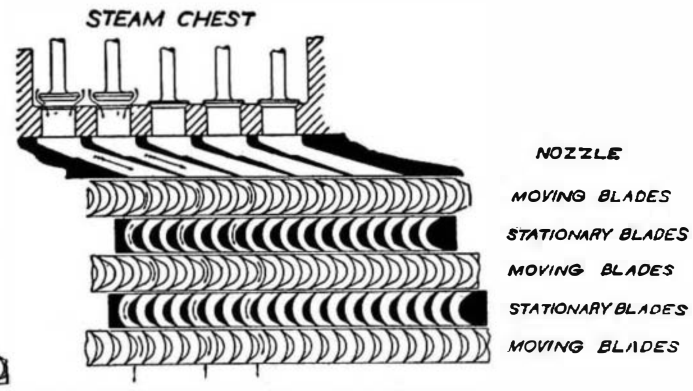
BY FRANK C. PERKINS.

Lately there has been a vast amount of work done both in this country and in Europe in connection with the development of steam turbines. That the most prominent engineers in England, Germany, Switzerland, France, and America have unbounded faith in the future of the steam turbine, particularly in connection with electrical power plants, is shown by the fact that the greatest electrical manufacturers in each of these countries have recently taken up this type of steam prime mover, and are now installing turbo-dynamos in sizes up to 5,000 kilowatts. It is not surprising that the steam turbine is meeting with such favor, when its high efficiency, its low cost, and the small space it occupies are compared with the high-power, slow-speed steam engines which are now directly connected to enormous fly-wheel alternators. It is frankly acknowledged by eminent steam and electrical engineers that there is a great probability that the immense compound and triple-expansion slow-speed engines, with their large revolving field alternators, which have been so extensively installed up to the present time, will soon become obsolete, their place being taken by the comparatively small steam turbo-alternators now being developed by the leading American and European manufacturers.

The Rateau steam turbine is being introduced in France by Sautter, Harle & Co., of Paris, and in Switzerland and elsewhere by the Maschinenfabrik Oerlikon, of Oerlikon, near Zurich. The steam turbine designed by Prof. Rateau consists of a number of Laval or Pelton wheels arranged in series on a shaft, each of which revolves in a separate chamber, and the whole forming a multiple-step impulse turbine, the steam being conveyed to the vanes on the wheels by distributing nozzles which are fixed, and the expansion taking place in the latter. There are two sizes of wheels in the turbine, one of a system of fifteen smaller wheels, and another of ten wheels which are larger in diameter. The steam leaves each of the chambers at but little lower pressure than that at which it enters, the impulse due to the velocity of the steam particles being imparted to the vanes, while there are no close fits, but still no great tendency to leakage. The Curtis steam turbine, which is being developed in America by the General Electric Company, also employs a series of impulse wheels for obtaining the necessary moderate speeds required. This turbine in a thoroughly practical and highly efficient state is said to be about ready to be placed upon the market, and its great simplicity, small size for a given output, and low cost in comparison with the large steam engines now in use, bespeak for it a great future. A horizontal type of the Curtis steam turbine has been in operation for some time at the power house of the General Electric Company, at Schenectady, and it is fair to suppose that its efficiency and general operation have been highly satisfactory, as a number of steam turbines are now being constructed by this company in their works in sizes up to 5,000 kilowatts. These turbines are of the vertically revolving type, the alternators being mounted on the top of the same. The floor space occupied by the 5,000 kilowatts unit, as well as the size of the alternator direct connected to the turbine, are so small as to cause wonder to the engineer when gazing at the same time at the 60-foot revolving field alternator, supplying only 3,500 kilowatts at 70 revolutions per minute.



CURTIS ELASTIC-FLUID TURBINE.



SECTION SHOWING FIXED AND MOVING BLADES.

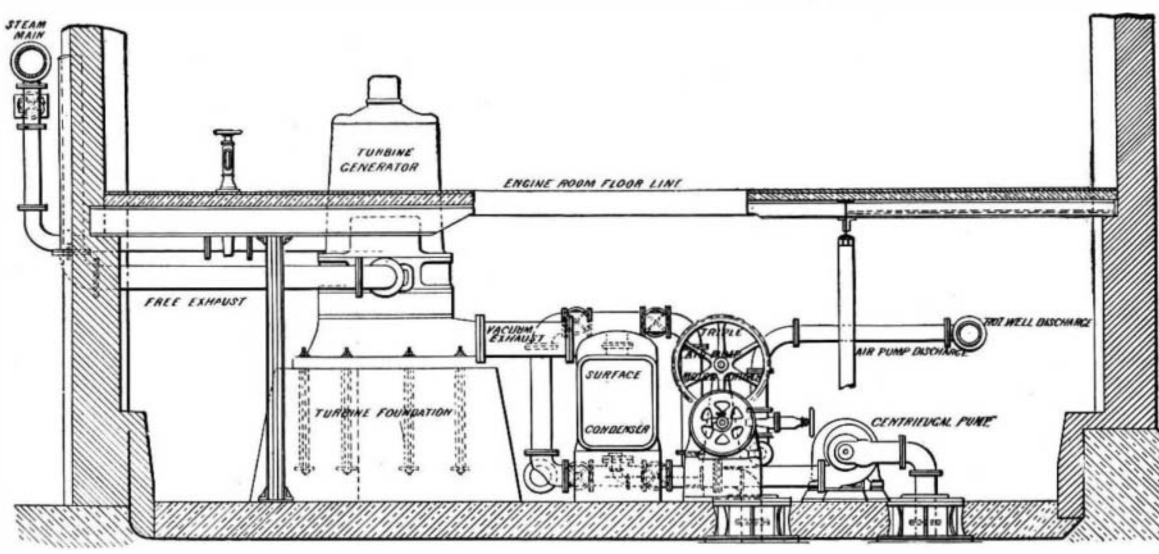
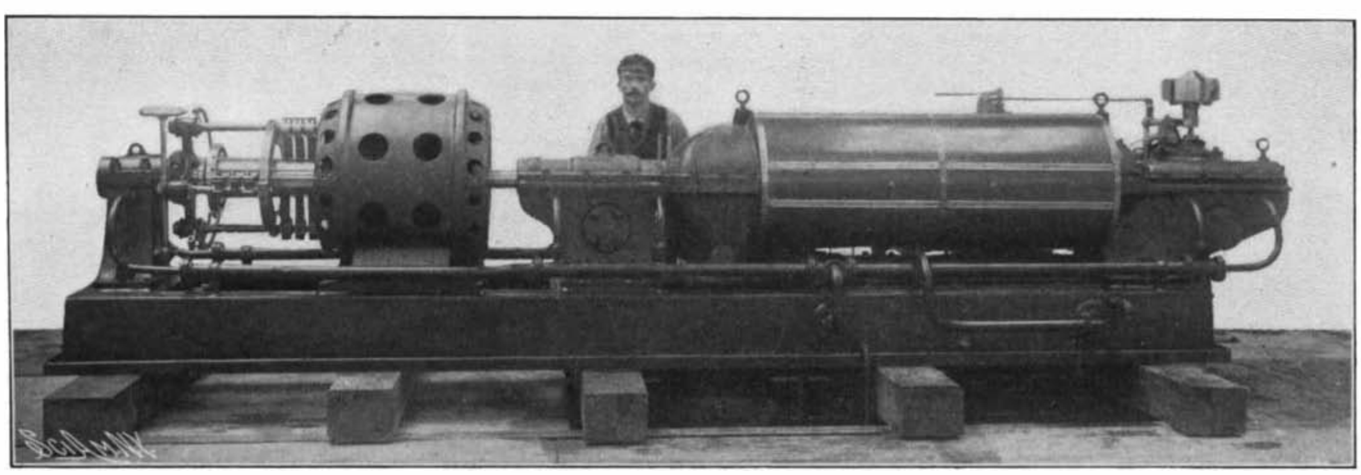


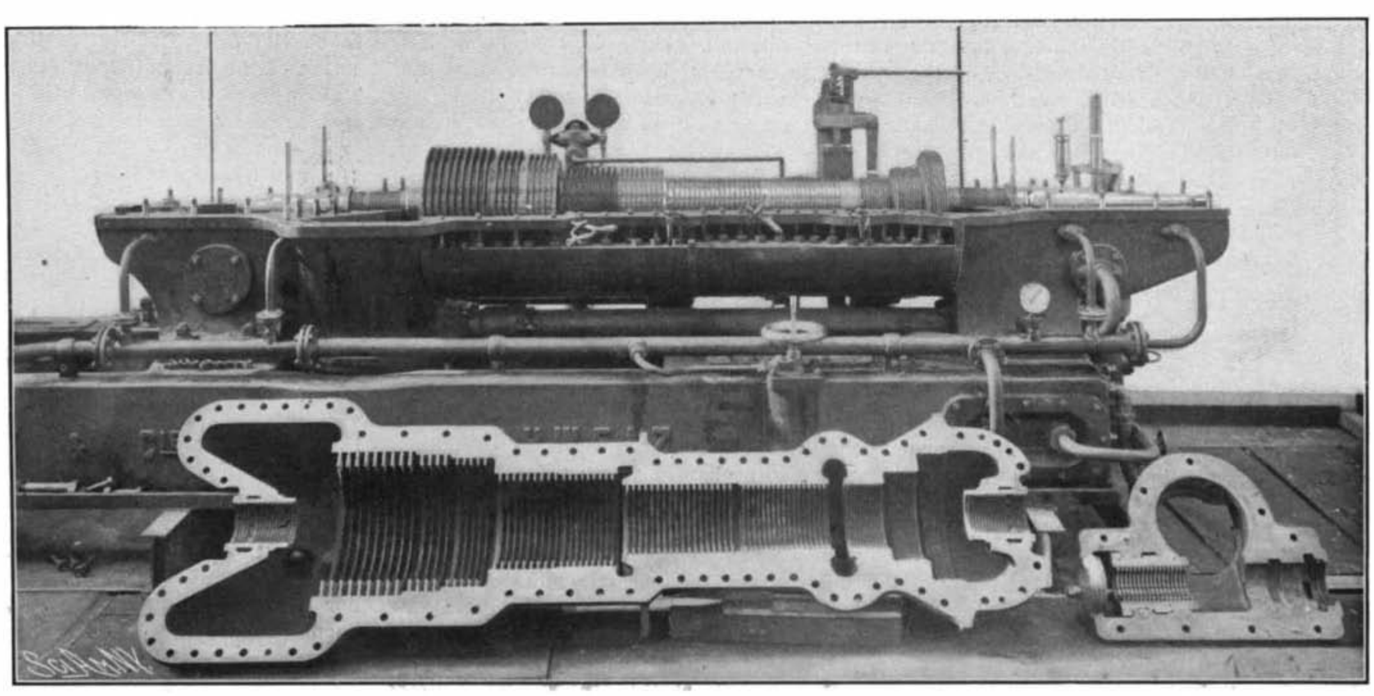
DIAGRAM SHOWING SMALL FLOOR SPACE OCCUPIED BY THE CURTIS VERTICAL TURBINE.

The buckets of these steam turbines are cut from the solid steel by a specially designed machine tool, instead of being fastened to the revolving part by mechanical means. The turbine was invented by Charles G. Curtis in 1896 and 1897. In the application of Mr. Curtis of August 4, 1896, he says: "The object I had in view is to produce an elastic-fluid turbine in which the steam is delivered simultaneously to an entire annular range of relating vanes. This I accomplish by the employment of an annular delivery-nozzle expanding or diverging in the direction of flow of the fluid and converting the pressure of the fluid largely into velocity before it strikes the first set of movable vanes. The movable vanes consist, preferably, of two or more sets mounted upon the periphery of the drum and separated by intermediate annular sets of stationary vanes which are mounted upon the shell. The annular working passage—i. e., the passage through the movable and stationary vanes between the discharge of the nozzle and the exhaust—is enlarged or expanded in the direction of flow of the fluid, so as to accommodate, without choking, the increased velocity as it progresses and also to compensate for and overcome the effects of frictional retardation and the tendency to reconvert velocity into pressure by eddy-currents, etc."

The elastic-fluid turbines patented by Mr. Curtis, under date of September, 1897, are adapted to be used either as condensing or non-condensing engines, by utilizing the elastic fluid at different ratios of expansion. In one of these designs, his turbine is divided into two parts, mounted upon a common shaft, one of such parts being adapted to convert into vis



PARSONS 100 K. W. CONTINUOUS-CURRENT TURBO-DYNAMO; 220 VOLTS; 3,500 REVOLUTIONS.



A PARSONS TURBO-DYNAMO WITH UPPER CASING REMOVED.

viva the pressure of elastic-fluid from the initial pressure down to approximately atmospheric pressure, and to transform it into mechanical power, and the other part is adapted to convert into *vis viva* the pressure of the elastic fluid from atmospheric pressure down to the pressure of a vacuum-exhaust, and to transform the same into mechanical power.

The Massachusetts electric companies are to install Curtis turbines and generators built by the General Electric Company in units of 500 kilowatts and 2,000 kilowatts with a total output of more than 30,000 horse power in their new power stations. The 3,000 horse power Curtis vertical turbines to be installed operate at a speed of 750 revolutions per minute, the steam pressure at the nozzle being 175 pounds per square inch. The alternators mounted upon the top of the steam turbines and directly connected generate a three-phase current of a frequency of 25 cycles and a pressure of 13,000 volts. The 1,000 horse power turbines operate at a speed of 1,800 revolutions per minute and have a total height of about 12½ feet, including the generator, while the diameter at the base is 7 2-3 feet. The alternators driven by the Curtis turbines at the Newport Station are three-phase machines and generate a current of 2,500 volts pressure, the capacity being 500 kilowatts. The diagram on the preceding page shows the general outline and small floor space occupied by the vertical turbines and alternators. The total height from the bottom of the foundation is about 18 feet, the foundation being 5½ feet high and 11 feet in diameter at the base. It is of brick construction and 9 feet in diameter at the top while it rests upon a cement bed 1½ feet thick. The Newport Station is designed to have four steam turbo-alternators of 1,000 horse power each, which will be supplied with steam from Aultman & Taylor water-tube boilers. The steam enters the top of the turbines and exhausts from the bottom through a pipe 1 foot in diameter. The plant will be utilized as an electric railway power house as well as for supplying current for lighting.

The large 2,000 kilowatt General Electric turbo-alternators weigh about 95 tons each and have a total height of nearly 20 feet, the diameter at the base being 12 feet. These machines, generating a three-phase alternating current of high potential, are capable of taking care of an overload double their normal output for a short time, and the turning moment is far superior to that of the ordinary slow-speed fly-wheel engine generator. These machines are to be installed at power stations owned by the Massachusetts Electric Companies at Danvers, Mass., Quincy Point, and Fall River, each having a capacity of about 10,000 horse power. The current will be utilized for operating several hundred miles of electric railway on the Boston and Northern and Old Colony Divisions, now taken care of by a score of small power stations.

The saving of space in a large power station using the vertical type of steam turbo-alternators will without doubt be even greater than when the long horizontal turbo-alternators are employed. A comparison of the space required by a 100,000 horse power plant using the General Electric turbines and the immense vertical and horizontal compound and triple expansion slow-speed engines and revolving field alternators of large diameter, will go a great way toward the adoption of these new high-speed units. This is especially true in power stations where the cost of land is very high, and the other savings of the steam turbine, such as oil, labor, and repairs, should make the brilliant future of this new and yet old prime mover a fact. From all accounts the efficiency is also equal to or greater than the best reciprocating engine, especially when the highest superheated steam is used.

The Parsons steam turbine is being developed and introduced in America by the Westinghouse Electric and Manufacturing Company, and in England by the British Westinghouse Company as well as by C. A. Parsons & Co., while in Switzerland it is being manufactured by Brown, Boveri & Co., of Baden (Aargau).

In America a number of 300-kilowatt steam turbines have been in successful operation for some time in the power plant of the Westinghouse Air Brake Company. These machines operate at a speed of 3,600 revolutions per minute, and are directly connected to bipolar alternators, having a frequency of 60 cycles per second. Among the many other installations of the Westinghouse-Parsons steam turbo-alternators may be mentioned those at the power plant of the Hartford Electric Light Company. These consist of 2,500 horse power Parsons turbines directly connected to Westinghouse 1,500-kilowatt 60-cycle 2-phase alternators. These are six-pole machines supplying a current of 2,400 volts, and operating at a speed of 1,200 revolutions per minute. The weight of the revolving part is 14 tons, while the total weight of the unit is 90 tons, and its length nearly 34 feet.

Among the important plants in England in which Parsons steam turbines have been in successful operation for some time, should be mentioned the four 75-kilowatt units in the original Fourth Banks Station, each of which operates a 2,000-volt single-phase alternator, having a frequency of 80 cycles per second. The satisfactory operation of these sets resulted in the installation of a number of other turbo-generators in this plant having a total capacity of 3,000 kilowatts. These machines were of various sizes up to 500 kilowatts each, the dynamos being of both direct and alternating current types. In the new Close works of the Newcastle and District Electric Lighting Company, several turbo-dynamos, having a capacity of 1,000 kilowatts each, have been installed, while provision is made for increasing the capacity to 12,000 kilowatts. These 1,000-kilowatt Parsons turbines operate at a speed of 1,800 revolutions per minute, and are directly connected to two continuous-current generators supplying direct current at 500 volts pressure.

The sizes of the steam turbine unit have been rapidly increasing, and many are now being constructed both in this country and in Europe for an output of 5,000 kilowatts each. The British Westinghouse Electric Manufacturing Company are now building and installing a number of these large units, driving three-phase alternators, which supply current at 10,000 volts pressure. These machines will be utilized in the electric generating station of the Metropolitan Railway of London, the current being transmitted to various substations, and there changed by rotary converters to a continuous current for use on the railway motors.

The Brown-Boveri-Parsons steam turbines and dynamos have been quite largely installed in Europe and range in size from 100 kilowatts to 2,000 kilowatts. One of the smaller units consists of a 100-kilowatt continuous-current dynamo directly connected to a Parsons turbine operating at a speed of 3,500 revolutions per minute. The generator supplies a direct current of 220 volts and is very similar to ordinary direct-current machines, except that a small number of poles are employed, and the diameter of the machine is small, while the armature is much longer than with ordinary direct-current types. It has been found difficult to construct a machine which will not spark at variable loads, on account of the small number of poles and high speed required. The Swiss engineers, however, have overcome this difficulty by employing a compensating winding which counteracts the magnetic field produced by the armature winding.

In a comparison of a 400 horse power steam turbine and a compound steam engine of about the same output, it was found that the steam consumption per kilowatt hour was 10.5, with an output of 400 brake horse power for the steam turbine, while the steam consumption per kilowatt hour was 12.25 kilogrammes with the steam engine, the output being 420 brake horse power. The steam engine operated at a speed of 150 revolutions, and had an efficiency of 86 per cent, the output in kilowatts being 284, while with the steam turbine at full load, the output was 270 horse power. The curves and data of this test also show that the steam turbine when operating at half load, or 200 horse power, had a steam consumption of 11.4 kilogrammes per kilowatt hour, while the compound steam engine, with an output of 211 brake horse power, had a steam consumption of 13.3 kilogrammes per kilowatt hour. In a similar test, comparing a 600 horse power compound steam engine with a steam turbine of the same capacity, operating an alternator of 400 kilowatts capacity and 2,000 volts, it was found that the steam engine had a steam consumption of 13.4 kilogrammes per kilowatt hour, the output being 670 horse power and the speed 125 revolutions per minute. The steam turbine operating at a speed of 3,000 revolutions per minute, with a pressure of 7.5 atmospheres, had a steam consumption of 10.5 kilogrammes per kilowatt hour, the output being 600 horse power. The steam consumption of the compound engine at half load, or 305 horse power, was found to be 16.2 kilogrammes per kilowatt hour, while the steam turbine had a steam consumption of 12.8 kilogrammes per kilowatt hour, the load being 300 horse power. The curves of the comparison of steam consumption of the turbine alternator and generator driven by reciprocating engines show that the steam consumption at practically all loads was greatly in favor of the steam turbine, while the actual steam consumption for the steam turbine was in nearly every case lower than that guaranteed by the Swiss engineers.

The amount of oil used in lubricating a steam turbine is very much less than that needed for ordinary steam engines, as the bearings are practically the only portion of the outfit which require lubrication. The actual cost of the oil for even the largest units is guaranteed to be so small by the best makers of steam turbines, as compared with the oil required for the high power steam engines, as to be hardly worth mentioning.

The governor on the Parsons steam turbine, as constructed by the Swiss engineers, is very close in its regulation. The effect of the Parsons governor is to change the duration of the periodic puffs of steam. According to the tests of a 400-kilowatt turbine alternator, it was found that the sudden dropping from three-quarter load to no load caused a variation of but about 2½ per cent in the speed. The variation in voltage when this alternator was supplying about 200 kilowatts and suddenly was operated at no load was only about 80 volts in 2,000, the speed being increased only about 30 revolutions, with a normal speed of 3,000 revolutions per minute.

LAUNCH OF THE "RELIANCE."

Contemporaneously with the publication of our special Yachting and Automobile number, the new cup defender "Reliance" was having her first taste of salt water, and the new challenger "Shamrock III." was engaged in one of her most successful trials against "Shamrock I." In the issue referred to, we so fully described the design and construction of "Reliance," that it is not necessary to do much more now than point out how completely the photographs of the boat which we herewith publish agree with that account of the yacht.

The events of the yachting seasons of 1901 and 1902, and the performance of certain very successful racing craft in those two years, notably the cup yacht "Independence," and the sister boats "Neola" and "Weetamoe," which more than saved their time on the Herreshoff 70-footers last year, rendered it pretty certain in the judgment of the yachting "sharps" that, when the folding doors of the Herreshoff building shed were opened, there would pass out through them a vessel of very extreme type. Consequently the exaggerated proportions of the forward and after overhangs of the new boat, as shown in our illustrations, caused no surprise, even though they are the work of such cautious and conservative builders as the Bristol firm.

In view of the rather demonstrative merriment which greeted the appearance of "Independence," with her hard turned bilges, her blunt forward and after waterline, and her huge overhangs, each some 25 feet in length, it must have been something of a shock to the critics to witness, sliding down the ways on which the wholesome models of "Columbia" and "Constitution" made their first bow to the public, a boat which so far out-Heroded Herod, that her overhangs divide up nearly 60 feet of the overall length of the yacht between them.

At the same time it must be admitted that, with all her exaggerated proportions, the boat bears a strong family likeness to the modern Herreshoff boats; and there is no denying that in drawing out her lines to such extreme length, Herreshoff has produced an extremely handsome craft. As we explained in our previous issue, the hard turn of the midship sections at the bilges is softened out gradually as the forward and after ends of the waterline are reached, with the result that the overhangs themselves are very symmetrical and show a sweetness of modeling which goes far to redeem their disproportionate length. The deckline does not flow toward the bow and stern with so flat a curve as has been customary in earlier Herreshoff boats, with the result that when the yacht is heeled, she will take a very long bearing, and there will be no hard spot or shoulder to pile up the water when the vessel is driven at high speed—as happened in the case of "Shamrock II.," and even more noticeably in "Independence." The great beam of "Reliance," and the fact that her waterline is full, proves that her wetted surface will be very large; and while the small deadrise and long flat floor will give her great initial stability, they will render it somewhat difficult to get her to heel to her sailing lines in light winds. These characteristics combined will render her relatively less speedy in light weather, particularly if there is a troubled cross sea running. But with every added pound in the pressure of the wind, and every added angle of heel, the boat, to our thinking, will show great increase in speed, and even in spite of the excellent work which is being done by "Shamrock III.," on the other side, she should prove to be the fastest 90-footer afloat.

One of the most striking features in the boat is the long drawn-out bow which projects nearly thirty feet beyond the waterline. Only a small proportion of it can be utilized for gaining sailing length; for "Independence" at thirty degrees heel only added five feet of length forward, and she was even flatter than "Reliance." Driving into a head sea, she will take the seas a little earlier but not so much earlier as to compensate, one would think, for the carrying of so much added bow weight at a height of eight or nine feet above the water. Many yachtsmen will wonder why the bow was not made shorter relatively to the stern; for in a low, long stern such as that of "Reliance," every foot of length can be utilized. "Reliance," however, is regarded even by her designer as something of an experiment, and only the actual test in a jump of a sea off Newport or Sandy Hook can determine the value of such an extreme bow.

When the new craft was fairly afloat, it looked as though she might sit a little low in the water when her spars, sails, anchor, crew, etc., which will weigh about 19¼ tons, were put aboard; and although her full waterlines give her great buoyancy, it is not probable that much, if anything, can be gained by a shortened waterline when she comes to be measured.