The price being determined, the real work begins. Needless to say, few, if any, shipowning firms, have at their disposal the necessary staff and plant for full investigation of the many points which absolutely must be determined for good and all, before even the material can be ordered; but as, on the other hand, many of the great shipbuilding firms have, the duty of making those investigations falls upon those who constitute the scientific staff of such firms, and I think we shall see that not only need no man on any such staff feel ashamed of his job, but that, on the contrary, any and every such unit in such combination should thank God for the brains that permit of his being considered fit to act such part.

It is human nature to be much like a horse, and the oldest of us sometimes thinks he is still the colt in the team, and doing all the work; but, in point of fact, it is the combination of men, each expert in his own particular way, or, may be, several ways, in combination, or rather, acting under the tactful guidance of that indispensable one—the "teamster," and to transpose that into nautical language, "No ship is so big that she can do with two skippers, and none so small that she can do without one."

Several departments get going at the same time, but we can only follow them one at a time. The general dimensions having been approximately fixed, I say "approximately fixed," because, as I shall try and shew presently, there is no greater mistake than to definitely fix dimensions, and make the design subordinate to those fixed dimensions; but I regret to say it is sometimes done by people who ought to know better; while in cases where the owners have had sense enough to leave the dimensions a little elastic, tank experiments and the deductions therefrom have, in many important ships, shewn the necessity of quite material modifications in dimensions, to be not only advisable, but even imperative. Usually, the dimensions having been approximately fixed as aforesaid, and a set of lines providing the requisite displacement got out, a model is made and tested, either in the private experimental tanks which form part of the modern shipbuilding equipment, or at the Government tank, and often both, in order to get independent and check results. Then other models, differing only in their factors, are set against one another, and that giving the best result selected.

It may be interesting to look for a few minutes at the factors that go to vary results, and assume that considerations of accommodation, draft to accommodate the ports to and from which the proposed vessel is to trade, docking facilities, and such-like have suggested, say, 700 feet in length by 75 feet beam, with a loaded draft of 32 feet,. a co-efficient of fineness of .65, and the model made accordingly and tried out with satisfactory results.

Now, in all probabllity, six models will be made, differing in beam, say, two feet at a time, but retaining the total displacement, or varying it only to suit the comparatively small changes in weight of hull structure such increases represent. It will be seen at once, that the dimensions being varied and the displacement being retained, gives opportunity for the designer to vary the placing of his displacement or under-water body, or, to use a more every-day phrase, it permits of his fining the vessel's ends, or filling them, in proportion as the midship body is increased or reduced.

Tank experiments have, in many cases, shewn differences in the resistance of models amounting to 10 per cent., which put into coal consumption of the finished ship, might easily represent 100 tons of coal per day; which, when in turn is converted into cost and bunker capacity, spells big figures.

The foregoing remarks are intended to shew that, however mathematically accurate, and however much past experience may have been put into a design—a first design—the tank, with its exceedingly delicate mechanism for accurately determining resistances, is of the utmost importance, and may be regarded as one of the shipbuilder's best friends, although when first adopted, some forty years ago, it was by many looked upon as quite superfluous, and even fanciful.

In the case of the two big Cunard liners, "Mauritania" and "Lusitania," the results of the many test tank experiments with 12-ft. models was not considered sufficient in view of the fact that they were in point of size and speed and power to be so much in excess of any of their predecessors, and it was determined, even at the great cost involved, to go the length of building a self-propelled launch in order to reduce the error as between model and finished ship to a minimum, and experiment in directions such as steadiness in both smooth and rough water, economy and speed, effect of wind, turning astern speeds, effect of wind pressure on deck erections, on stability, action of rudder, results of twin, triple and quadruple screws, effect of screws turning inwards and outwards, experiments with different forms of propellers, and other elements of the finished ship quite outside the province or capabilities of the towed model in a tank.

Accordingly a model was made, 47 feet 6 inches in length, and true in other respects to the selected model or finished design. Much of the data obtained is very properly kept secret by the builders, but amongst the results published, some are of so remarkable a character as to be little short of astonishing. It was ascertained, for example, that the wind pressures on the launch applied by law of comparison to the "Mauretania" would, in a breeze of 25 miles an hour, against her, call for 12 per cent. more power, and the same breeze behind her, a reduction of 4 per cent. in power, to maintain the same speed as in calm weather.

It was found that varying the position of the wing propellers in a fore and aft direction varied the power necessary for a given speed as much as 5000 I.H.P.

Twelve sets of propellers of different proportions were tested, involving upwards of 500 speed trials, and those finally selected, permitting as they did of higher revolutions and tending thus to greater efficiency of the turbines, were, contrary to general experience of turbine steamers, practically as efficient as the slow-running propellers of the ordinary twin-screw vessels of the same proportions.

Before leaving this subject finally, one may, I think, be excused for feeling an inclination to raise one's hat to the man who said "Let it be done," in the person of the chairman of Swan, Hunter and Wigham Richardson, the firm who built the "Mauretania."

Turning now to another section of the investigation and designing staff, whose work is going on simultaneously with that just described, the all-important question of strength has to be most carefully considered.

Time was, and not so long ago, when vessels were built not exactly by rule of thumb, but their scantlings were determined mainly by mere size. Tables of quantities and scantlings were prepared by the various classification societies—Lloyds Register, Bureau Veritas, British Corporation, German Lloyds, and others; and while these were the outcome of the collective experience of very many able men, and while by deduction from past experience, scantlings were fixed for vessels of size not yet put into practice, there came a time when that method appeared scarcely satisfactory, and it became evident to the really advanced men in the shipbuilding trade that a more scientific method should be adopted and used, of course, in conjunction with the experience of the past.

Close investigations have been progressing now for some years as to the stresses going on in actual ships at sea, and, to the credit be it said of those making such investigations, their results have been made known, and valuable data collected accordingly.

It is now generally conceded that the stresses a vessel is subjected to in a seaway are much too complicated to lend themselves to purely mathematical treatment. Past experience must be the guiding factor; but by comparing a ship with a girder it is possible to calculate the stresses that would come upon it under given conditions. Hence it becomes in turn possible for the designer to estimate the changes in stresses due to change in form, and modify the scantlings to meet the altered conditions.

It has been found that the distribution of weights is very irregular, some being very much concentrated, and others very well distributed. (Figure 9.) The form

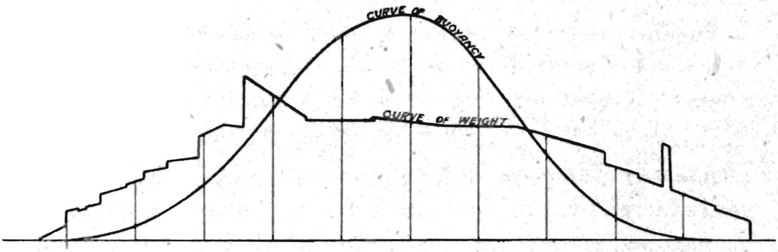

Fig. 9

of the ship must be fair, and therefore regulating the buoyancy to suit the weights is out of the question; the alternative is to regulate the strength of the structure at and about such variations, which is now commonly done, as distinguished from the old method of uniformly graduating the scantlings from half or three-fifths length towards the ends.

The diagrams here shewn (Figure 10) will give a good idea of the general form of what is now known as equivalent girder. They are those of such well-known ships as the names under indicate, and bring us very nearly up-to-date in shipbuilding advance. They do not, however, help to solve this very important question of local strengthening, so curves of stresses occurring under all the likely positions of wave crests relative to the ship's length, and apportioning the structure to meet the maximum as shewn thereby, is in common practice. That this has proved very satisfactory has been cor-

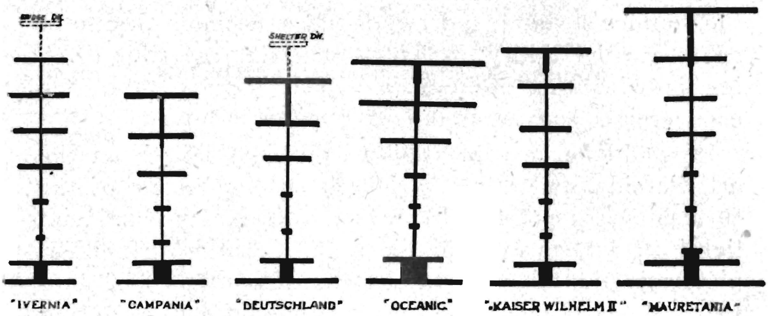

Fig. 10

dially endorsed by the classification societies, who are necessarily in close touch with the big builders, and with the happy results that those two, in some ways opposite, interests work together in harmony.

The inclination, of course, is for the builders to regard Lloyds, for example, as being somewhat conservative; while Lloyds take care that scantlings are not cut too fine. It may be well here to remark that even in the largest ships, weighing, without cargo, passengers, coal or water, otherwise equipped weight, as it is usually termed, say, up to 40,000 tons, the question of weight is carefully watched; and, of course, making provision for strength to meet all exigencies, not a ton that can be saved is put into the structure. In many cases of modern ships this question of weight has been studied to the extent of substituting high tension steel for mild steel in certain parts, particularly at and about the top member of the girder; and though of a somewhat denser character, a saving of from 10 to 18 per cent. on the parts so substituted has been allowed without any reduction of strength whatever.

This point is made mainly to illustrate the care that is taken, and that engineering, in the proper acceptation of the term, is playing its part in almost every detail of the modern ship.

Taking out quantities, detailing the orders for the material, calls for the attention of another section of the builder's staff; and, while it is not our desire to deprecate the ability of that section, our care this evening is with the engineering aspect rather than the commercial.

It would be very pleasant to dwell at length on the artistic side, and dilate at length on the beauty of the furnishing, carpeting, decorating, natural and artificial lighting; art, as exemplified in the beautiful panelling, pictures, and trimmings; but the silken bond of consistency draws one back to my theme—the Engineering Side of Shipbuilding.

With that end in view, then, we turn with bowed head and great respect to the mechanical engineer, for he most certainly is seen at his best and in all his glory when he sets out to make the wheels go round in a modern liner.

Of late years there have been rapid changes from compound to triple and quadruple reciprocating, turbines, direct combination of reciprocating and low pressure, turbines, and, lastly, geared turbines. I am not here to act in the capacity of "prophet," so leave internal combustion engines, as applied to big liners, for one of my successors.

For reasons I will not discuss, the shell boiler still obtains in the British-built liner, but such advances have been made in them as to warrant some comment.

It is quite common to hear the engines discussed and all the credit of good performance attributed to them, and this even amongst people who know. How seldom, however, does one hear the boilers alluded to? This is all wrong; for the best installation of engines will fail if the boiler power be not adequate.

Referring, then, to the shell boilers of to-day, broadly it may be said that the Engineers who design them have to make up their minds between two general principles, viz., the use of mild steel or of high tension steel.

It may be said that boilers of high tension steel are, as yet, not fully tried out, while those of mild steel have been long enough in use to afford all data required for their successful construction and up-keep.

Circumstances outside the mere choice of material play their part in this connection, the most important one being space available. Practically 16 feet diameter is the limit of a shell boiler in mild steel, and that requires a plate 1¾in. thick; while the same thickness of plate in high tension steel permits of a diameter of 17 feet 6 inches.

Now, the the point is, how many can be got in abreast? And that is obviously governed by the beam of the vessel.

Three abreast is common, four not unusual; while in the case of the "Olympic" and "Titanic" room was found for five double-ended boilers of 15 feet 9 inches diameter abreast, each having six 3ft. 9in. furnaces, and a grand total of 159, including those in the single-ended boilers, of which there are five. Almost without exception the boilers are fitted for forced draft, though some few of the finest liners afloat depend on natural draught.

A word as to the uptakes from these furnaces must not be omitted, on account of their extreme importance and ramifications, for, in some instances, a funnel draws from no less than twenty branches, each in turn drawing through three furnaces, making sixty in all; and when one thinks of the necessity of each and every one of those furnaces getting the same draw, particularly in the case of those vessels with natural draught, one is again inclined to bow one's head to the man who can design such vast structures with such a keen sense of proportion. (Figure 11.)

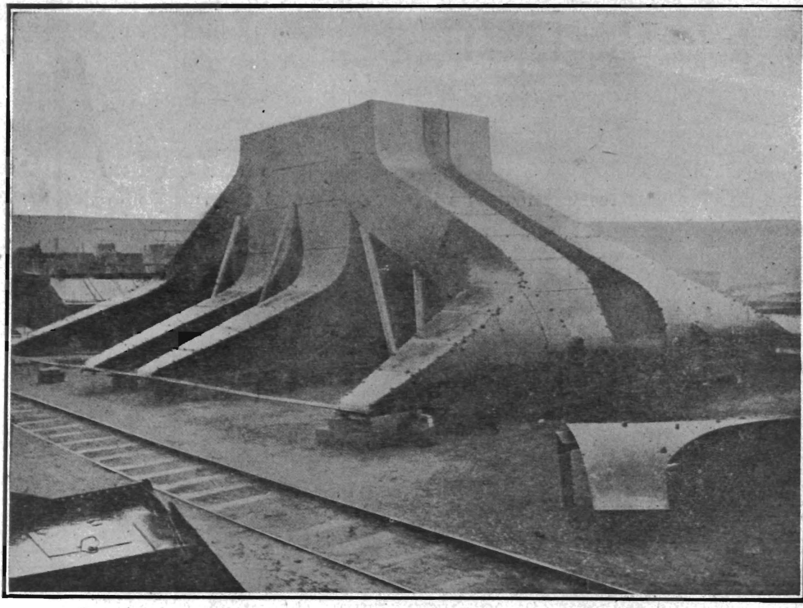

Fig. 11

Funnels of to-day's liners are remarkable chiefly for their immense size, running, as they do, to oblong shapes as much as 24 feet 6 inches by 19 feet, and as long as 150 feet from furnace bars to top. (Figure 12.) As, however, the funnels play an important part in the general appearance of the finished ship, utility alone is not enough; grace and elegance can be obtained or entirely lost by a very small difference in rake and set; so the designer must have an eye to the artistic as well as to the strictly utilitarian.

Coming now to the main engines. This is a subject for solemn conclave between the heads of the interests concerned; and when it be remembered that the decision on this all-important problem will be made on differences in expected results in over-all economy of, perhaps, 2½ per cent. or 3 per cent., set against that innate inclination on the part of even the most progressive of men to play for safety, it is no wonder that we find the finest ships in the world differing much in the systems of this main propelling power.

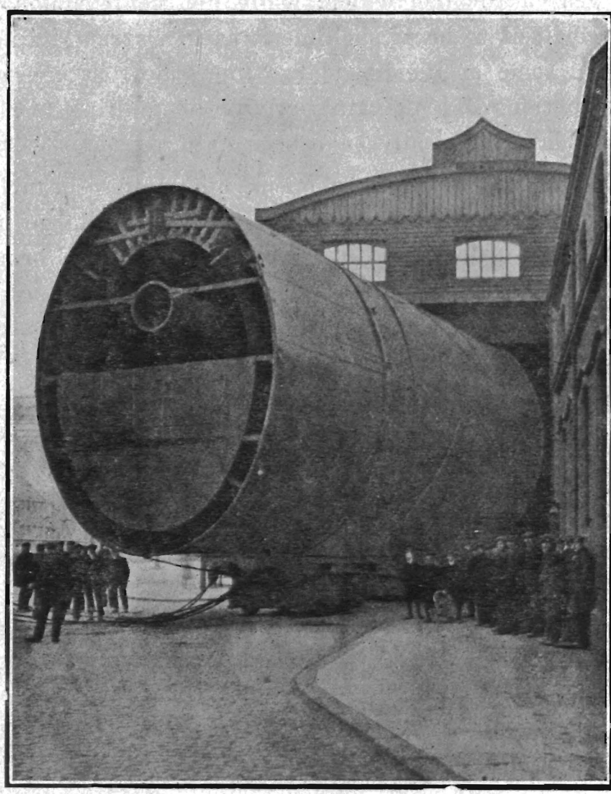

Fig. 12

It may, however, be said that three systems only remain in the field of practical politics—they are the combination of reciprocating engines taking steam at high pressure, expanding it through their several stages, and discharging to low press turbines, whereby the power of the low pressure steam is extracted to a greater extent, and thereby more economically than can be done in any L.P. cylinder. This, as is well known, is called the combination system, and usually spells triple-screw steamer. The straight-out turbine, direct driven, lends itself to quadruple screws, or even a greater number; and lastly, the geared turbine, which, while not yet common, has proved itself to be of such merit as to warrant its adoption in some of the new large liners now in course of construction. This again permits of multiple screws; but to date three only have been used.

The question of pumps opens up another branch of mechanical engineering, and one on which a large number of best-trained men have spent their lives. Formerly practically all the pumps were driven off one of the main crossheads. At the present time all pumps are independent, and largely electrically driven.

The turbine has brought in its wake yet another sub-branch of engineering—I mean the necessary lifting gear, mechanism in itself both ingenious and beautiful.

The electrical installation of the modern liner is a branch all to itself, and finds food for thought, skill and inventiveness for yet another batch of our brethren; and especially when it is remembered that electricity is used not only for lighting, but for deck cargo cranes, boats, engineroom winches, passenger elevators, stoves, mail and pantry lifts, ventilating and stokehold fans, cabin fans, motors for cylinder lifting gear, turbine turning and lifting gear, workshop machine tools, kitchen and pantry machinery—such as ice rocker, dough mixer, potato peelers, roasters, knife cleaners, mincers, hot-plates, electric irons, heaters, baths; sounding machines, watertight doors, helm indicator, loud speaking and ordinary telephones, submarine signalling, wireless telegraphy, and other things, and that the installations run to plants exceeding those of some large cities, or, in other words, four sets of generating plants of 400 kilowatts each, with an output of 16,000 amps. at 100 volts, equal to 2320 H.P., besides auxiliary sets placed high up on the ship for emergency purposes of about 200 I.H.P.

The steam steering gear and windlass, together with the numerous warping capstans about the deck, constitute yet another branch of mechanical engineering, and though only thus lightly mentioned, brings our list to a close.

I cannot, however, close my paper altogether without a word about the man to whom we look for our salvation when all the beautiful things done by all these clever men are put out of action by some, may be, small accident, and the vessel in on the weather side of some frowning rock-bound coast—I mean the man who makes the ground gear. On the screen are pictures of them. (Figures 13 and 14.) They speak for themselves.

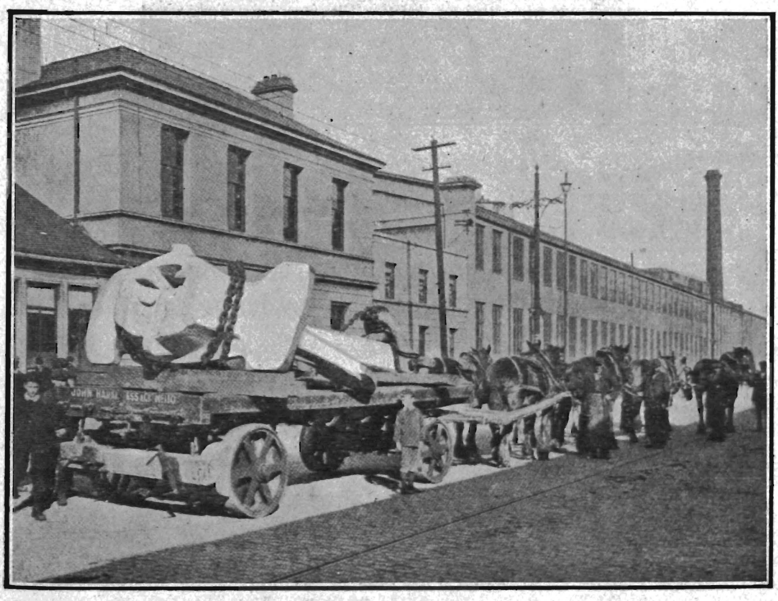

Fig. 13.

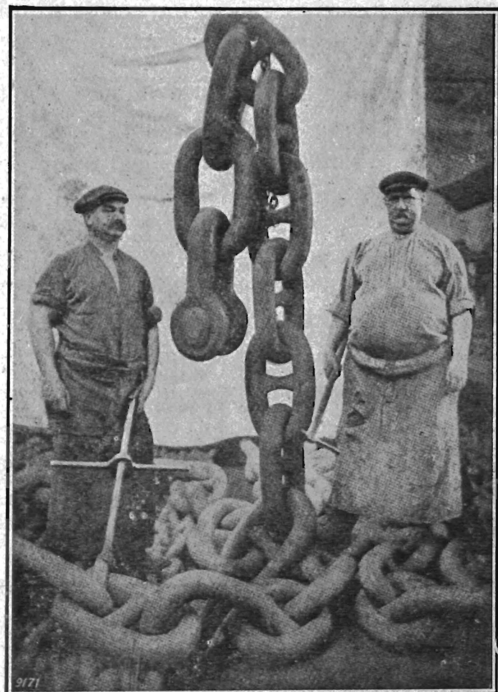

Fig. 14

If I have succeeded in shewing that modern engineering is interdepending, and that modern shipbuilding is an exemplification of that interdependence, then it follows that the shipbuilder is one who should be "treated with the deference due to a man of high degree."