than the shipbuilders. It was largely owing to shipowning friends of mine, who recognized the disastrous effect which the immense losses of mercantile tonnage would eventually have on the country, that steps were taken which led to the inception of the design and construction of the ships forming the subject of this paper. Without knowing anything as to the merits of ferro-concrete for shipbuilding purposes, they considered that if small craft had already been built with such material it was worth a trial, under present conditions, in larger ones, and after much consideration and investigation of the work previously done in this direction the author finally agreed with them.

The system of construction calls for a minimum amount of steel and a minimum amount of skilled labor. Such construction also reduces capital expenditure on yard plant, as it is much less costly than ordinary shipyard plant and requires less skilled attention. Another point in favor of ferro-concrete construction is that, compared with ordinary shipyard labor, there is not so great a variety of trades involved. For example, the same men who, at a later date, are employed on casting the hull, are in the initial stages utilized in casting and laying concrete blocks and in making ferro-concrete piles for the building berths and other necessary preliminary work, for which this material can be used extensively instead of timber or steel, both of which require skilled labor of different trades.

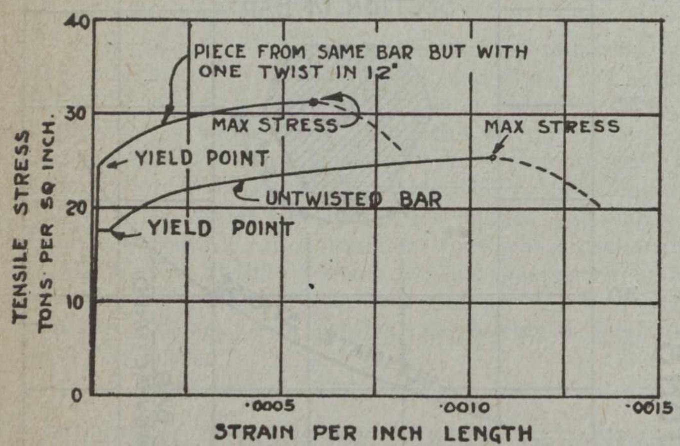

Fig. 2—Stress-strain Diagram for a ⅞ in. Diameter Bar, Before and After Twisting, Showing Respective Yield Points, Maximum Stress and Strain

Although the suitability of ferro-concrete under present abnormal conditions and on economical considerations was apparent, its acceptability for ship construction had to be investigated from the naval architect's point of view. With this object in view, we decided to design a sea-going cargo vessel of reasonably large dimensions, to assure ourselves that such a vessel, constructed of ferro-concrete, would satisfy conditions of strength, seaworthiness, deadweight capacity, etc. The difficulties in preparation of the design proved much greater than was anticipated, for whilst we, as shipbuilders, could prepare and supply the particulars and drawings of the vessel and approximate to the maximum stresses coming on the various members, we had no practical experience of the construction of the ferro-concrete part of the hull, so that it became necessary to work in conjunction with a reliable firm of ferro-concrete engineers, who would carry out this part of the design, basing it on work actually done. This association of shipbuilders and ferro-concrete engineers has proved mutually satisfactory and advantageous, and each party found that it had something to learn from the other with respect to shipbuilding of this type.

It was eventually decided that a self-propelled cargo vessel of about 1,150 tons deadweight was as large as we were justified in commencing as a first venture. It was agreed that the vessel should comply with all the requirements obtaining for steel vessels, and the general scheme was based on that of a similar ship constructed of steel. The dimensions, for reasons which occurred in preparing the design, differed from those of a steel ship of the same deadweight carrying capacity, especially in length. The dimensions and other particulars finally decided upon were as follows:—

Length between perpendiculars ..	200 ft.
Breadth moulded	32 ft.
Depth moulded	19 ft. 6 in.
Draught when loaded	15 ft. 6 in.
I.H.P. (about)	400
Speed (about)	7¾ knots.

The various arrangement drawings were prepared and scantlings arranged in accordance with Lloyd's Rules for Steel Ships. Using these scantlings, a list was made up of the calculated section moduli of the various members. Upon these particulars the engineers prepared constructional sections, on the principle of "equivalent strength," which were adopted as a basis of calculation of weights, etc.

Lower Centre of Gravity

The design was then carefully reconsidered and calculations made as far as possible for the stresses which the vessel would be subjected to, both longitudinally and transversely, under all reasonable conditions of construction, launching, and service.

One of the first things observed in the case of the ferro-concrete hull was that the centre of gravity of the structural material worked out much lower than in the case of a steel hull, the result being a greater metacentric height than was desirable. To minimize this, the original beam of 34 ft. was reduced to 32 ft., and in order to obtain the same hold capacity the depth was increased from the original 17 ft. 6 in. to 19 ft. 6 in., fortunately, from the point of view of longitudinal strength, a modification in the right direction.

Longitudinal Strength

In calculating longitudinal stresses the vessel was first of all assumed to be in still water with the holds loaded uniformly to the full-load condition, giving a displacement of 2,350 tons. In this condition the maximum bending moment worked out at about 4,100 foot-tons. For hogging stresses the vessel was taken as being in the same load condition and on the crest of a trochoidal wave of length equal to the length B.P. of vessel, and height equal to $\frac{\text{Length}}{20}$, giving a maximum shearing force of 180 tons and a maximum bending moment of 10,000 foot-tons.

In the sagging condition the vessel was much more severely loaded, three-fifths of the cargo being placed in the middle of the hold space, and one-fifth at each end respectively, resulting in a maximum shearing force of 180 tons and a maximum bending moment of 7,000 foot-tons.

In the case of launching, the maximum shearing force reached as high as 220 tons, with a maximum bending moment of 10,000 foot-tons. A generous margin was al-