The faired values of the revolutions are also used for determining the B.H.P. from the torsion records, in accordance with the formula given previously. These B.H.P. are then plotted against speed of vessel as shown in Fig. 3. Two methods

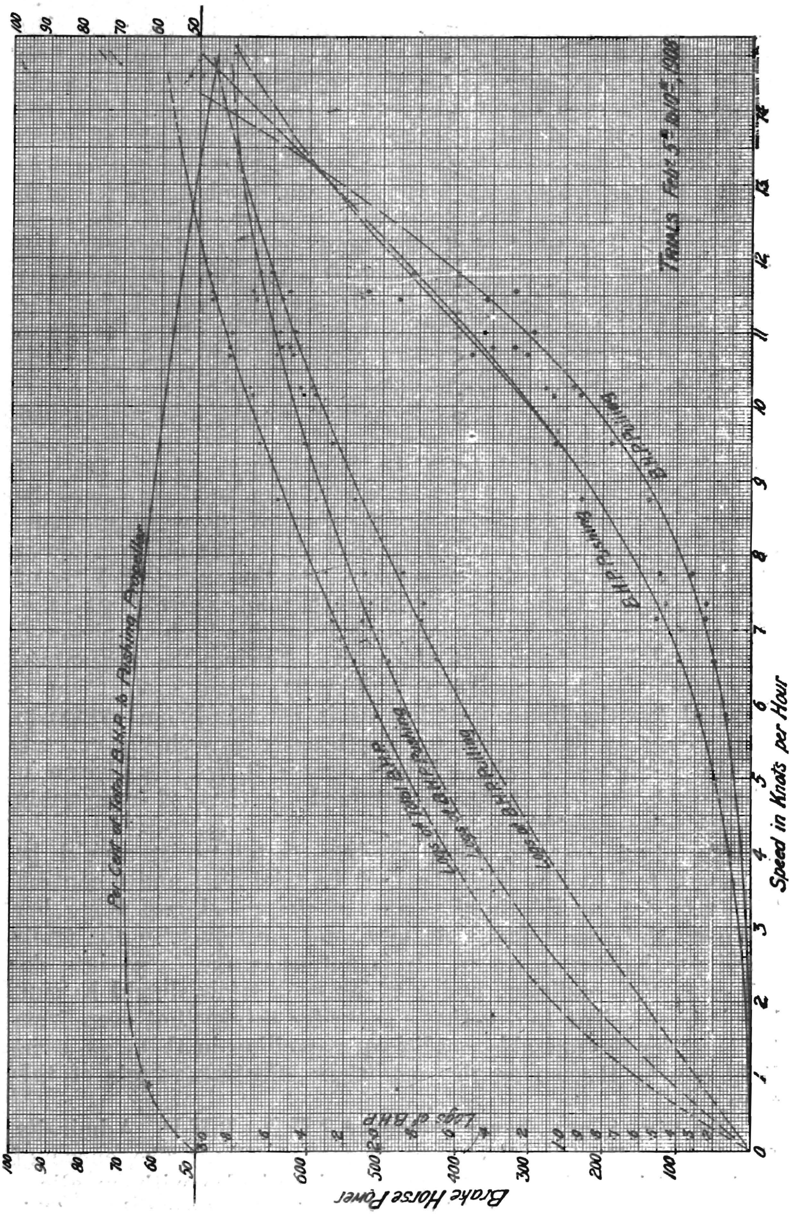

Fig. 3.

of plotting are given, to act as checks one on the other. Some difficulty was experienced in fixing the mean lines for these spots, but by referring to the curves of Logs, of B.H.P., the method adopted can be readily followed. The total B.H.P. is first plotted, and a fair curve run through the spots. It will be observed that such a line can easily be put in. The B.H.P. for each propeller (that is the pushing or pulling propeller as the case may be) is then plotted, and fair lines obtained. These are seen to be rather irregular, and show the effect of wind and tide in altering the distribution of work done by each propeller very clearly—the reason for this will appear later. However, a mean line can be obtained for each propeller, by fairing in the curves (giving weight to the spots according to the wind and tide) and making adjustments on them, till the sum of the two curves gives the total agreeing with the curve of total B.H.P. It may be noticed that the divergence of the spots for the total B.H.P. from the mean line, is not large, certainly not more so than would be expected from trials of this nature.

The B.H.P., pushing and pulling, is also plotted against the speed of the vessel. Curves are then faired in, the values for which are obtained from the faired curve of the Logs of B.H.P. An estimate of the values of the spots can now be obtained, weight being given for the state of the wind and tide. It will be seen that it would be difficult to spring in a curve at the higher speeds, but a reference to the curve of Logs of B.H.P., shows at once the direction that the curve must take. These curves have been continued past the highest observed speed, and by reference to the curve showing the percentage of power to each propeller (see Fig. 3), some justification is obtained for the line given, but as it is entirely an extension of the data available, it is put forth as only probably correct.

In obtaining the above faired curves, it has been borne in mind that the object to be attained, is that of reasonably correct mean results.

To obtain results with absolute certainty, it would be necessary to have the conditions of the trial well under control. This was not possible in this case, as the vessel was doing her ordinary duty as a ferry steamer, and consequently the trials could not be run to order. It is not necessary to go into detail as to the conditions under which such trials should be run, but it is sufficient to say that the writer thinks that even from trials under the unstable conditions prevailing in this case, some light can be thrown on the conditions affecting vessels of this type.

In Fig. 4, are shown curves of I.H.P., B.H.P., Admiralty Co-efficient, Engine Efficiency, Apparent Slip. The curve of engine efficiency is given as measured and also with an allowance of 1½ per cent. for frictional loss in the stern tubes. This

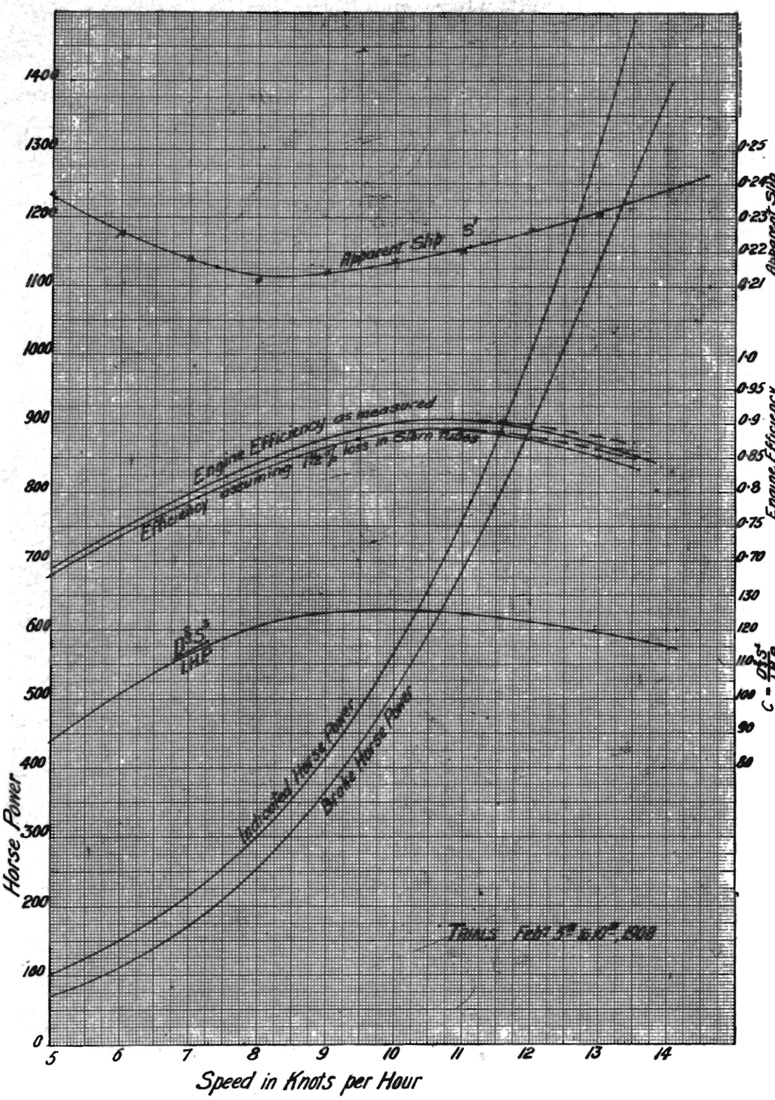

Fig. 4.

is assumed to be the same at each end of the vessel. The torsion-meters were fixed as close to the stern glands as possible, and are abaft and ahead of the thrust block in each case. It will be noticed that this curve is also shown as a dotted line at the higher speeds, the writer being led to think, in the final running out of the distribution of power, that the efficiency did not fall off so rapidly as shown by the full line. This is also indicated in Fig. 3, where an alternative line is shown for the pushing propeller at the higher speeds. The efficiency shown is higher than the writer would have generally allowed for this type of engine, but he can see no reason to doubt the result given; that is, that at the propellers a maximum of 89 per

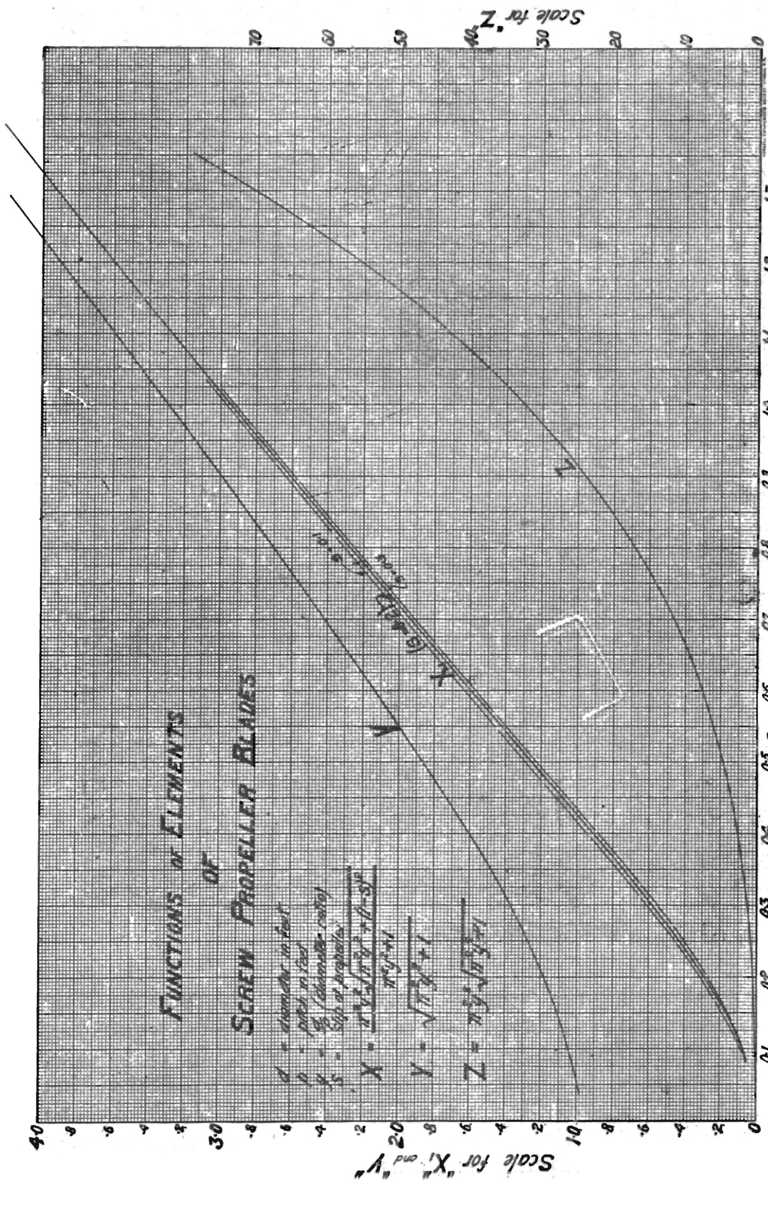

Fig. 5.

cent. of the I.H.P. is available. Recent researches on marine machinery by Profs. Frahm, Föttinger, and others, have shown that the efficiency is higher than had been estimated by such authorities as Blechynden and Froude.*

From the foregoing the power available at the screws has been obtained. In Fig. 9; these results are plotted as a frictional loss in the engine, comprised of two parts, initial and load friction. The initial friction is found by taking the M.E.P. at zero revolutions from Figs. 1 and 2, and assuming the I.H.P. due to it, to be lost in turning the engine at the revolutions corresponding to the speed. The load friction is taken to be the difference of the B.H.P. at the screws, and the I.H.P. less initial friction.

LOSSES AT THE PROPELLERS.

The method adopted in analysing the losses at the propellers is that due to Froude, and exemplified by Naval Constructor Taylor in the analysis of the trials of the U.S.S. "Yorktown."†

The determination of the necessary characteristics for the propellers of the "Bingarra," is shown in Fig 6. In Fig. 5 are given the functions of elements of screw propeller blades, plotted from the tables given by Bauer and Robertson. They are shown here so that the method of dealing with this particular case can be readily followed.

The formulæ for the screw propeller are as follow:—

$$U = p^3R^3d^2 \left[as\,(1 - s)\,X_c - f\,(1 - s)\,Y_c\right] n$$

$$P = p^3R^3d^2 \left[as\,X_c - f\,Z_c\right] n$$

in which—

U—The useful work done by the screw; that is, the thrust developed by it.

P—The total power absorbed by the screw.

n—The number of blades.

p—The pitch in feet.

R—The number of revolutions per minute.

d—The diameter of the propeller in feet.

s—The slip, expressed as a fraction of the speed of the screw, or

$$s = \frac{V^1 - V}{V^1}$$

f—The co-efficient of friction of the screw surface.

a—The thrust constant as determined by Froude.

X_c, Y_c, Z_c, are characteristics determined for any particular propeller as hereafter shown, from values of the functions of elements of screw blades.

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* Bauer and Robertson, "Marine Engines," chap. 1. page 4.

† A full description of the derivation of the formulæ used, is given by Taylor in his book "The Resistance of Ships and Screw Propulsion," and also in "Marine Engines," by Bauer and Robertson.

$$X = \frac{\pi^2 y^2 \sqrt{\pi^2 y^2 + (1 - s)^2}}{\pi^2 y^2 + 1}$$

$$Y = \sqrt{\pi^2 y^2 + 1}$$

$$Z = \pi^2 y^2 \sqrt{\pi^2 y^2 + 1}$$

in which y denotes the diameter ratio $\frac{d}{p}$

The values of X, Y, Z, for different ratios of $\frac{d}{p}$ are shown in Fig. 5.

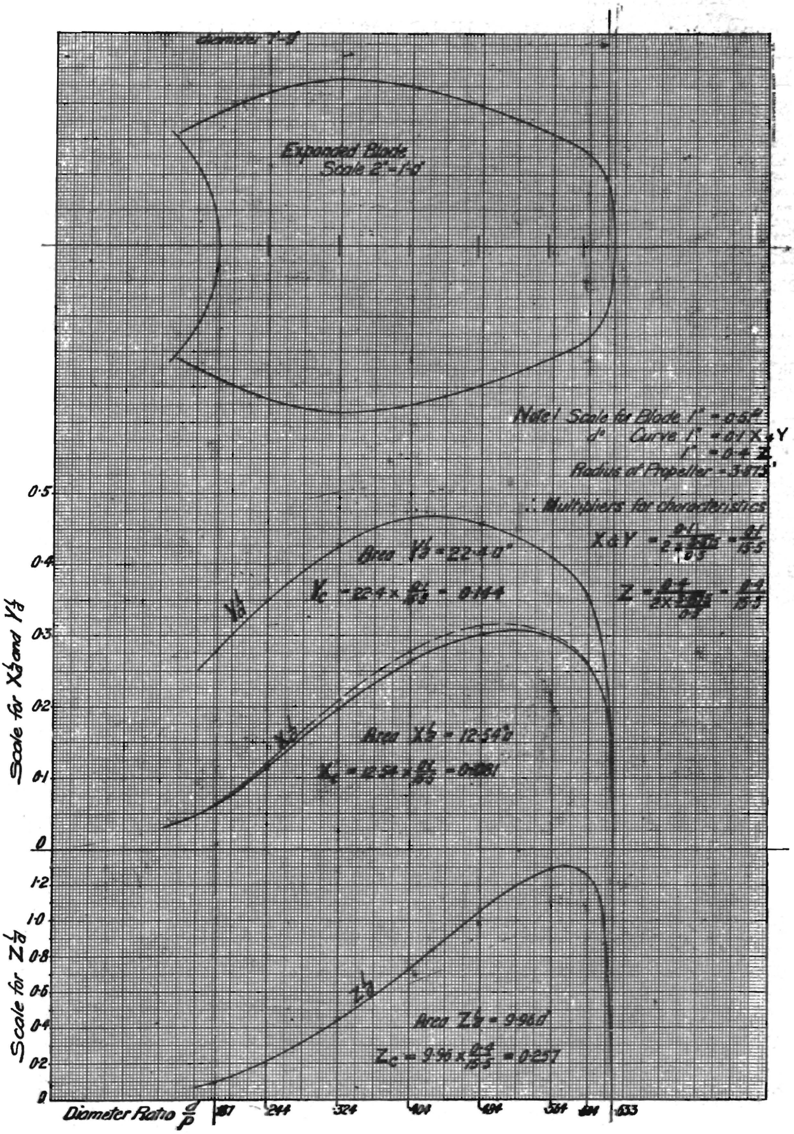

FIG. 6,

These values apply to elements or thin laminæ of a blade, considered as an inclined plane moving through the water. To obtain values for use an area must be assigned to this plane, and in any particular case it may be done by dividing the propeller blade into a number of elementary areas or planes, and summing the results to obtain the value for the whole blade.

In Fig. 6 is shown a drawing of the expanded blade of the "Bingarra," and the vertical lines indicate the points for which the characteristics are determined. The width of the blade is scaled off the drawing and multiplied by the value of the characteristic for the particular diameter ratio dealt with, and divided by the diameter of the propeller; that is, the value obtained is the function of the blade element multiplied by the width ratio at that element, say—

$$X \frac{l}{d} ; \quad Y \frac{l}{d} ; \quad Z \frac{l}{d} ;$$

where l is the width of the blade, scaled off the drawing at the diameter ratio desired.

This value is set up at each point, and a fair curve drawn through the spots obtained. The area under this curve, multiplied by a factor to suit the scales employed in drawing the blade and the curves, gives the characteristic (X_c, Y_c, Z_c) for the whole blade.

These curves are shown in Fig 6. It may be noticed that in Fig. 5, three curves are drawn for the X characteristic. This is because the expression for "X" contains "s" the true slip, which at this time is unknown. Uusually this slip is assumed at 20 per cent., and it can be seen that such an assumption introduces only a very small error, as the slips met with in practice are usually between 15 per cent. and 30 per cent. This difference is shown in Fig. 6, where the X^1 curve is drawn dotted for a slip of 10 per cent. The true slip can safely be assumed at 20 per cent. as shown by the full line curve, as it is evident that the apparent slip is the true slip for the pulling propeller.

The values for the characteristics being found, the known values can be inserted in the equation for the gross work absorbed. The unknown quantities in this are a, s, and f. Of these, f must be assumed, but usually a and s can be deduced from the trial trip data. The usual proceedure adopted for finding these values has been gone through in this case, but it was not found possible to obtain a definite value for a and s, owing evidently to the interference of the "wake" caused by the working of the pulling propeller. After inserting the known values in the equation for each propeller, there is obtained an equation of the form—

$$a \cdot s + 0{\cdot}143 = \frac{P}{\left(107{\cdot}2 \frac{R}{100}\right)^3}$$

f having been assumed at a standard value of 0.045.

"a·s" can therefore be determined for each speed by the insertion of the corresponding revolutions and B.H.P. for each screw.

At this stage it is seen that to determine a and s it is necessary to know the wake percentage (w) for the vessel. It

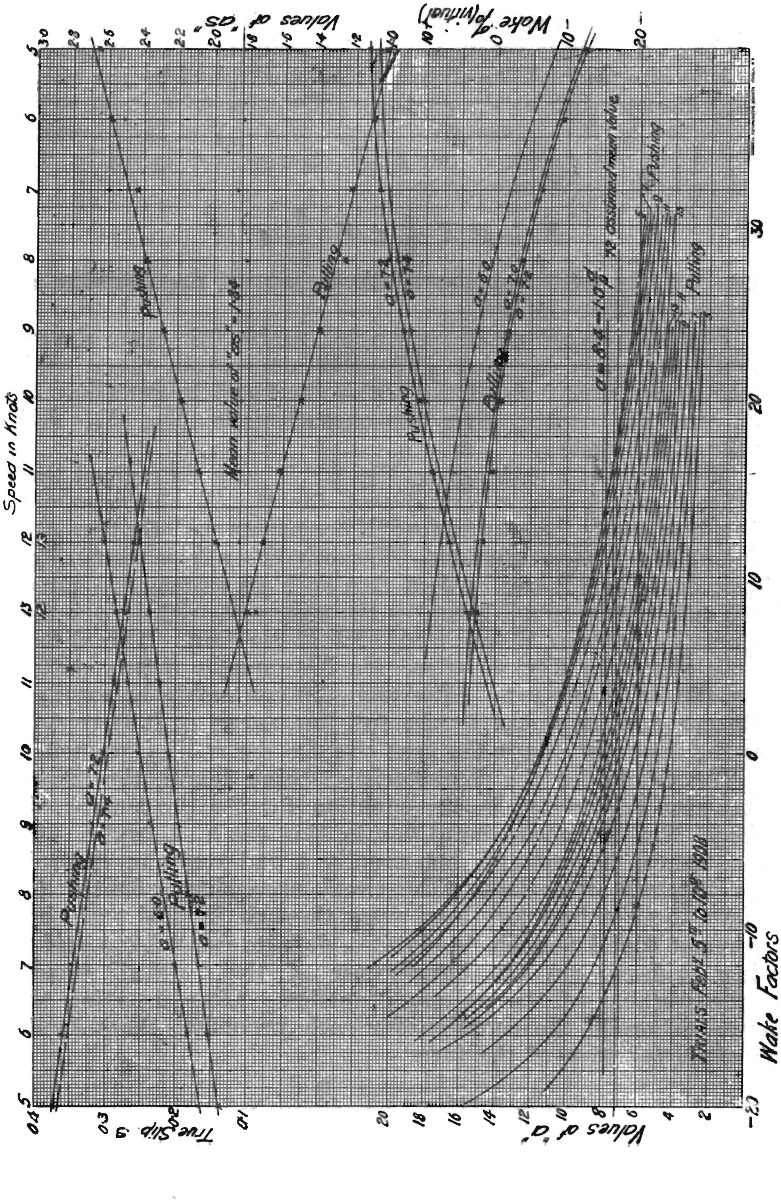

FIG. 7.

can usually be obtained by assuming different values of wake, and for each assumption, finding the corresponding values of "a" and plotting them against the assumed wake. The various curves so obtained should give a focal value of "a" and "w." This has been done for both screws in Fig. 7. It is seen that there is no tendency for the values of "a" and "w" to show a focus, but that the curves are asymptotic. This means that it will be necessary to assume a value for "a" or "w." It is generally assumed that for any ship, "w" is a constant percentage of the speed, and that for any propeller "a" is an experimental constant (which can be satisfactorily deduced in the manner described above). In this case the writer considers it more satisfactory to assume a value for "a," and from it deduce "w," which will not in this vessel be a constant percentage of the vessel's speed but a variable, owing to the action of the water thrown back by the pulling screw.

It is evident that the water in which the pulling screw is working is fed to it, at the rate at which the vessel is travelling, and that therefore the wake in which this propeller works should be nil, and the apparent slip should be the true slip. This would, from the data, give "a" for the pulling screw a value varying with the speed (5 to 13 knots) from 4.1 to 7.9 (see Fig. 7). This could be done; but the writer has considered it more convenient to take "a" as a constant and vary the wake, calling this value so obtained the "virtual wake" for the vessel.

It can be understood that the capacity of the pushing propeller to do work, may increase or decrease with the speed, as the condition of feed set up by the pulling propeller and the speed of the vessel may decide. At the same time the pulling propeller may be able to work more, or less satisfactorily owing to its rate of feed being that due to the speed of the vessel only, which may not be suitable to the revolutions at which the propeller is running, this resulting in a loss or gain of thrust, and an alteration in the value of "a."

Taylor's formula for the thrust constant, for four-bladed screws is—

$$a = 8.4 - 1.0 \frac{d}{p}$$

giving a value of 7.9. As this would only be expected for blades of standard form, well shaped in the sections and smooth of surface, the writer has adopted a mean value of 7.2 from which the curves of "virtual wake" have been derived. Other values of "a" have been assumed, and the results plotted, and in the writer's opinion the most probable values of "a" are 7.4 for the pushing screw, and 7.0 for the pulling screw. The pulling screw is working on a rounded face, and this would affect the thrust constant; 7.2 however has been used as the mean value.