PROPELLER SELECTION FOR SMALL TRAWLERS

by

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ABSTRACT

The conditions of working and the special duties of small fishing boat propellers are brought out in detail with special reference to trawlers. The feasibility of using Standard Series diagrams for design analysis are discussed. A useful chart is specially developed and presents the power absorbed and the thrust developed by a propeller in the trawling condition purely in terms of the diameter and the pitch ratio.

I. INTRODUCTION.

Effective utilisation of the installed power has always been an important feature of the overall performance and economy of fishing boats. Of late, considerable attention was being given to the development of small wooden fishing boats, along modern lines, to make them suitable for operation with more efficient gears. The requirement of larger horse powers, for this purpose, necessitated the selection of engines running at higher rpm so that the sizes and weights of engines could be kept within reasonable limits in relation to the sizes of the boats. Thus the propeller of a small fishing boat was required to absorb, in full, large power from a high rpm unit and deliver thrust to propel the boat at low speed (in the absolute sense). This raised certain special problems in the selection of suitable propellers and had engaged the attention of the persons connected with the development of small fishing vessels.

Presented and discussed here are the studies conducted in this respect, at the Indian Central Institute of Fisheries Technology (CIFT), Cochin. They pertained specially to the boats having horse powers from 10 to 60 and engaged in stern trawling, but were also applicable to boats engaged in other types of fishing.

II. THE PROBLEM

The speed-length ratio, $V/\sqrt{L}$, corresponding to the cruising speeds of small fishing boats were between 1.1 and 1.3, in which range relatively large differences in power or propulsive efficiency would cause small differences in the speed of the boat. So in such cases, the propulsive efficiencies could not be judged on the basis of speed.

For small boats it was customary to obtain the "standard propellers" offered along with the engines, and they were generally available in three sizes corresponding to direct drive, 2:1 and 3:1 reduction ratios. Unless specially ordered, all of these propellers conformed to the requirements of general purpose launches. An examination of the cruising speed-power relationships of these launches (Barnaby, pp. 132-133) would show that they were in good agreement with those of the light duty fishing boats like the gill netters, the powers for the latter category being on the higher side. As a result, if the necessary reduction gear was selected, the corresponding "standard propellers" were generally suitable for gill netters. The installed powers in the trawlers were 50% or more above those of gill netters of equivalent size, but their top speeds, limited by the already high $V/\sqrt{L}$ ratio were not much different from the gill netters and the general purpose launches. For this reason, the "standard propellers" supplied with these engines, (designed for a higher speed of advance) when fitted in trawler would overload the engines during cruising conditions and probably during trawling conditions also. This was quite evident during the speed trials of several small trawlers fitted with "standard propellers" and indicated the need for individual attention for the selection of propeller dimensions also for small trawlers.

The diesel engines fitted in these boats ranged from 1,000 to 2,000 rpm for maximum continuous rating, 1,500 rpm being very common. The choice of suitable propeller rpm was limited to those corresponding to direct drive, 2 : 1 and 3 : 1 reduction ratios. Quite often, the limitations imposed by the size of the boat on the diameter of the propeller made it impossible to fit the propeller corresponding to 3 : 1 reduction ratio and so a much higher rpm corresponding to 2 : 1 reduction ratio had to be accepted since nothing else was available in between. Generally, the loading of these propellers was very high and was beyond the range of optimum efficiencies.

The problem here was not the selection of propellers of optimum efficiencies for propelling boats at the most economical speeds, but the selection of compromise propellers which would absorb the varying powers developed by the engines over the range of rpm from cruising conditions to trawling conditions, without seriously overloading or underloading the engines and would deliver thrust with maximum possible efficiencies (may not be optimum efficiencies) under these conditions. A method of predicting the performance of these types of propellers was also necessary.

III. DESIGN ANALYSIS CHARTS

The analysis charts of the standard series developed by Troost of the Wageningen Tank were widely used for the design of propellers. The propellers corresponding to this series had combination of circular back and aerofoil sections, pitch reduction, skew back and other refinements. But for small fishing boats, generally, the circular back section and elliptical blade outlines were used; mainly because they required less skill in their manufacture and were also cheaper. There were no fixed standards in the various proportions defining the geometry of these blades. Strictly speaking, it was not possible to use the design analysis charts of the Troost Series for predicting the performance of these propellers. But a comparison of the various analysis co-efficients corresponding to Troost Series to those of the average values calculated by Taylor (Barnaby pp. 270-271) from the test results of a large variety of propellers would be of interest here. It was found that in the region of the optimum efficiencies the values obtained from Troost Series were better than the average values. But in the range of high BP values e.g., 40-80 (which corresponded to the small boat propellers under cruising conditions), the values obtained from the two sources were practically the same, the differences being below 2%. Further the values of co-efficients of static pull for a variety of propellers including Troost Series compiled by Barnaby (pp. 280-284) showed that these differences were small under towing conditions also.

Differences up to 5% in the results of calculations for small boat propellers could be neglected, since errors of this order were quite possible in the estimation of the basic factors like wake fraction, speed, etc. From these considerations, it might safely be assumed that, as long as the number of blades and the blade area ratio remained the same, the Troost Series Charts could be used for predicting the performances both for cruising and trawling conditions. In the analysis included here Troost Charts for B 3.50 (50% blade area ratio) was used.

IV. DETERMINATION OF DIAMETER AND PITCH

As mentioned before, the powers absorbed by the propeller should always be "matched" with the corresponding engine powers under all conditions of service. Since this matching involved the torque rather than the horse power, the horse powers should always be simultaneously considered along with the corresponding rpm. The transmission losses in the gear and shafting were about 10% and so the horse power available at the propeller P_D could be estimated at 90% of the P_S the shaft horse power of the engine.

For the estimation of the propeller dimensions, the absorbed powers and propulsive efficiencies for the cruising conditions, the B_P diagrams could be used. No simplified procedures were proposed, since any attempt in this direction would involve too many assumptions and so the results would be extremely limited in their applications.

For the purposes of the estimation of the trial speeds, the shaft horse power P_S and the trial speeds for small trawlers are shown in figure. The particulars of the boats are also included in this diagram.

$L_{OA}/L_{WL} = 1.07 - 1.16$

$L_{WL}/B_{WL} = 2.95 - 3.40$

$L_{WL}/\nabla^{1/3} = 4.55 - 5.15$

$\psi = 0.57 - 0.59$

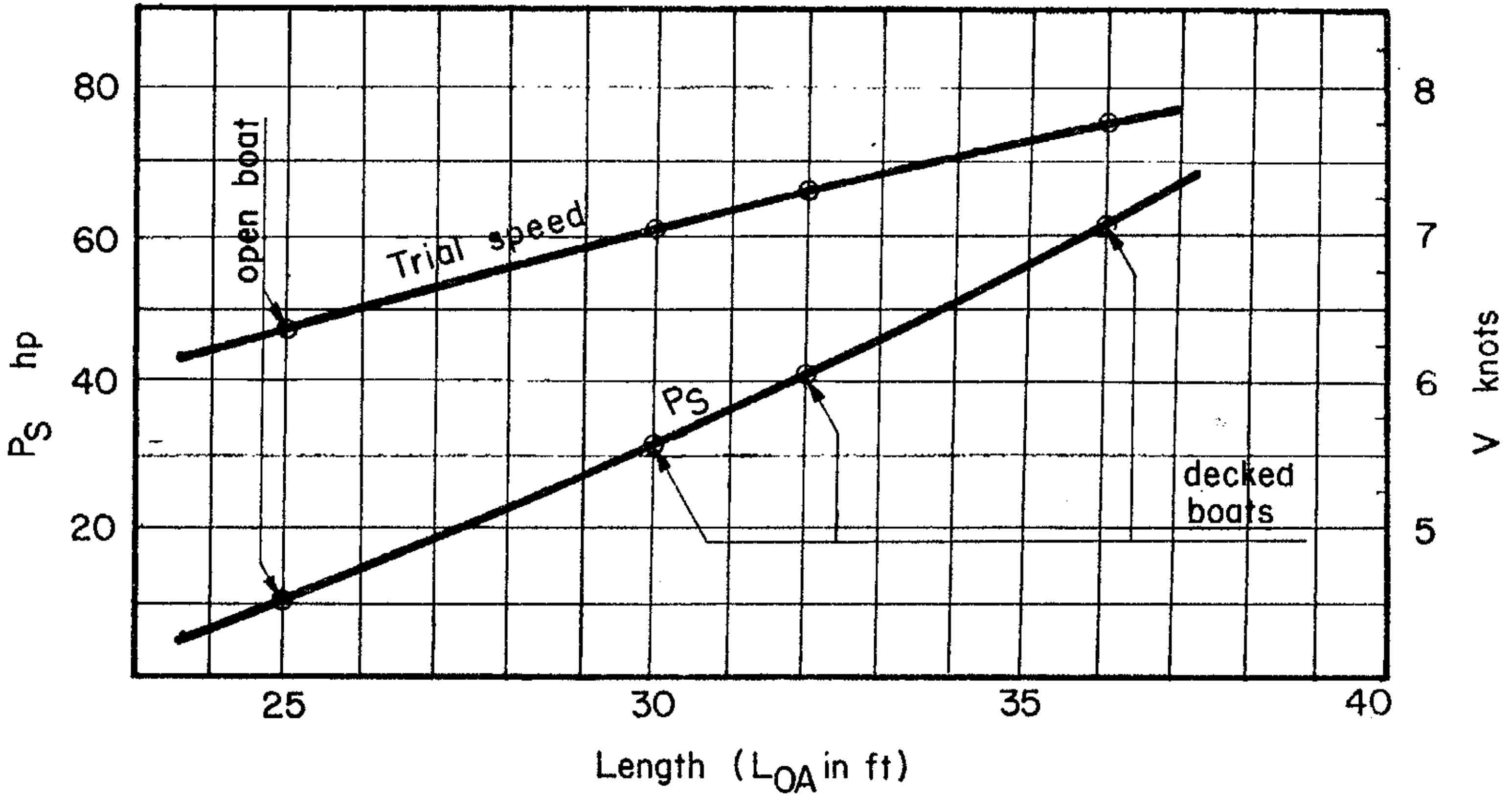

Fig. I

The values of the wake fractions (W) applicable to these boats were between 0.10 and 0.15 giving V_A/V values of 0.90 to 0.85 respectively. The thrust deduction fractions were also in the range of 0.10 as estimated by the "cylinder" method (Saunders, pp. 372 Vol. II). This was subject to the condition that the stern post was not unusually thick and was sharpened properly. Quite often this was not done specially, when the motorised boat was a conversion from a sailing boat. *It might be pointed out that these thick and unsharpened stern posts considerably increased the thrust deduction, in addition to the general obstruction of the flow into the propeller.*

From the above considerations of the wake fraction and the thrust deduction the hull efficiency was nearly equal to unity. In the absence of any precise data the relative rotative efficiency could be assumed as unity as in the case of single screw ships. So the propulsive efficiency, for all practical purposes, was equal to the open water efficiency obtained from the B_P diagrams. Efficiencies in the region of 55% for the cruising condition could be considered as good.

For an examination of the performance under trawling conditions, it was first necessary to estimate the corresponding available power. With fixed pitch propellers it was customary to reduce the rpm to about 80-85% of the full continuous rated rpm and as a result the available power from the engine was only about 60% of the corresponding rated horse power. If possible the exact power available should be verified from the informations supplied with the engine.

The B_P diagrams were unsuitable for the analysis of trawling conditions since the B_P values tended to infinity as the speed of advance tended to zero. But the torque coefficient K_Q and thrust coefficient K_T had finite values at zero speed of advance and so the K_T-K_Q diagrams could be used for this purpose. From the considerations of the size of the propeller aperture, the smaller boats in the range had relatively small propellers. But the trawling speeds for them were also less. The propeller rpm, trawling speeds and the propeller diameters for different sizes of boats were interconnected in such way that the advance co-efficient $J = \frac{V_A}{nD}$ in the trawling condition was fairly constant about a mean value of 0.10. The thrust constant (K_T) and torque constant (K_Q) did not vary much with small variations in the value of J from 0.10. So the K_T, K_Q values corresponding to $J = 0.10$ could be considered as independent from the towing speed (within the usual limits of these boats). The K_T and K_Q then varied only with pitch diameter P/D, ratios. With this simplification it was possible to derive some relationships directly in terms of diameter, pitch, absorbed power etc. as shown below:

Thrust developed (T) $= K_T \rho D^4 n^2$ .... (1)
$P_D = K_Q \rho D^5 n^3$ ..... (2)
K_T = Thrust constant.
KQ = Torque constant.
D = Diameter of propeller in ft.
n_1 = Revolutions of propeller per second.
ρ = Density of sea water.
= 1.99 lb/cubic feet.

Once the trawling rpm of the propeller was known 'n_1' could be treated as constant. So Equations (1) and (2) could be reduced to the form:

$P_D = C_1 . K_Q D^5$ .... (3)
$T = C_2 . K_T D^4$ .... (4)
C_1 and C_2 were constants.

K_T and K_Q were now functions of P/D (pitch ratio), 'J' being constant at 0.10.

The relations of K_T and K_Q with P/D could be determined from the K_T and K_Q diagram and were presented in Fig. 2. From equations. (3) and (4) and Fig. 2 it was now possible to plot P/D to a base of D with Power P_D and T as parameters, Fig. 3 was prepared for 400 rpm which corresponded to the trawling rpm of an engine rated at 1500 rpm maximum and fitted with a 3 : 1 reduction gear. The power absorbed by the propeller, the thrust developed for the reasonable range of propeller diameters and pitch ratios were readily available from this diagram. However, the thrusts determined from the Figure 3 should be *multiplied by 0.90 to obtain the value of useful thrusts.* This reduction represented the thrust deduction. The horse power derived from the diagram represented *the power actually absorbed by the propeller* and this was to be matched with the power developed by the engine at reduced trawling rpm

It would appear from the diagram that a propeller of a particular diameter could go on absorbing increasing amounts of power and correspondingly deliver increasing amounts of thrusts simply by an increase in pitch. There was another limiting factor to the process. The power and the thrusts for a particular diameter would increase with P/D ratio up to the point where cavitation set in. After that the power and thrust would rapidly drop off from the lines shown on the diagram. If the cavitation characteristics were known they could be presented in the diagram. But if the P/D ratio was limited to 0.8 the danger of cavitation could generally be avoided.

From equation (1) and (2) it was seen that everything else being constant the power absorbed and thrust delivered by a propeller varied as n^3 and n^2 respectively. It was quite easy to use this diagram (for 400 rpm) to find out the power absorbed and thrust delivered (trawling condition) for a propeller running at any other rpm

For example, it was required to find out the power absorbed and thrust delivered by a 32″ diameter propeller with 0.7 P/D ratio running at 500 rpm.

From the diagram a propeller of above dimensions running at 400 rpm absorbed 26 hp and delivered 1150 lb thrust. So for 500 rpm the

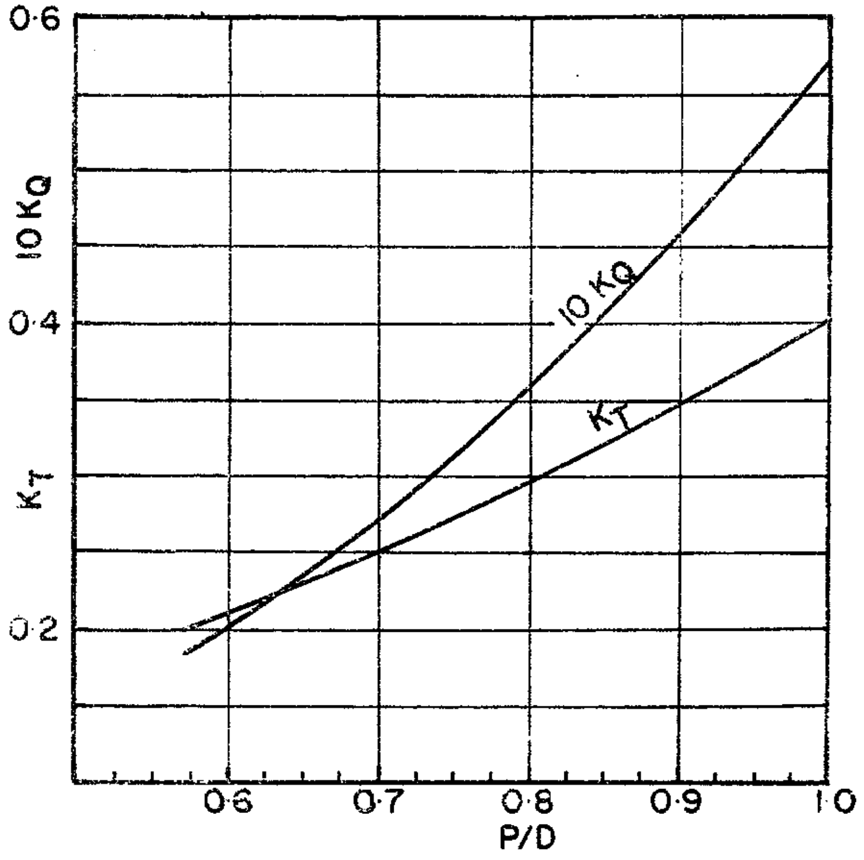

Fig.2 Value of K_T & K_Q for J = 0 10

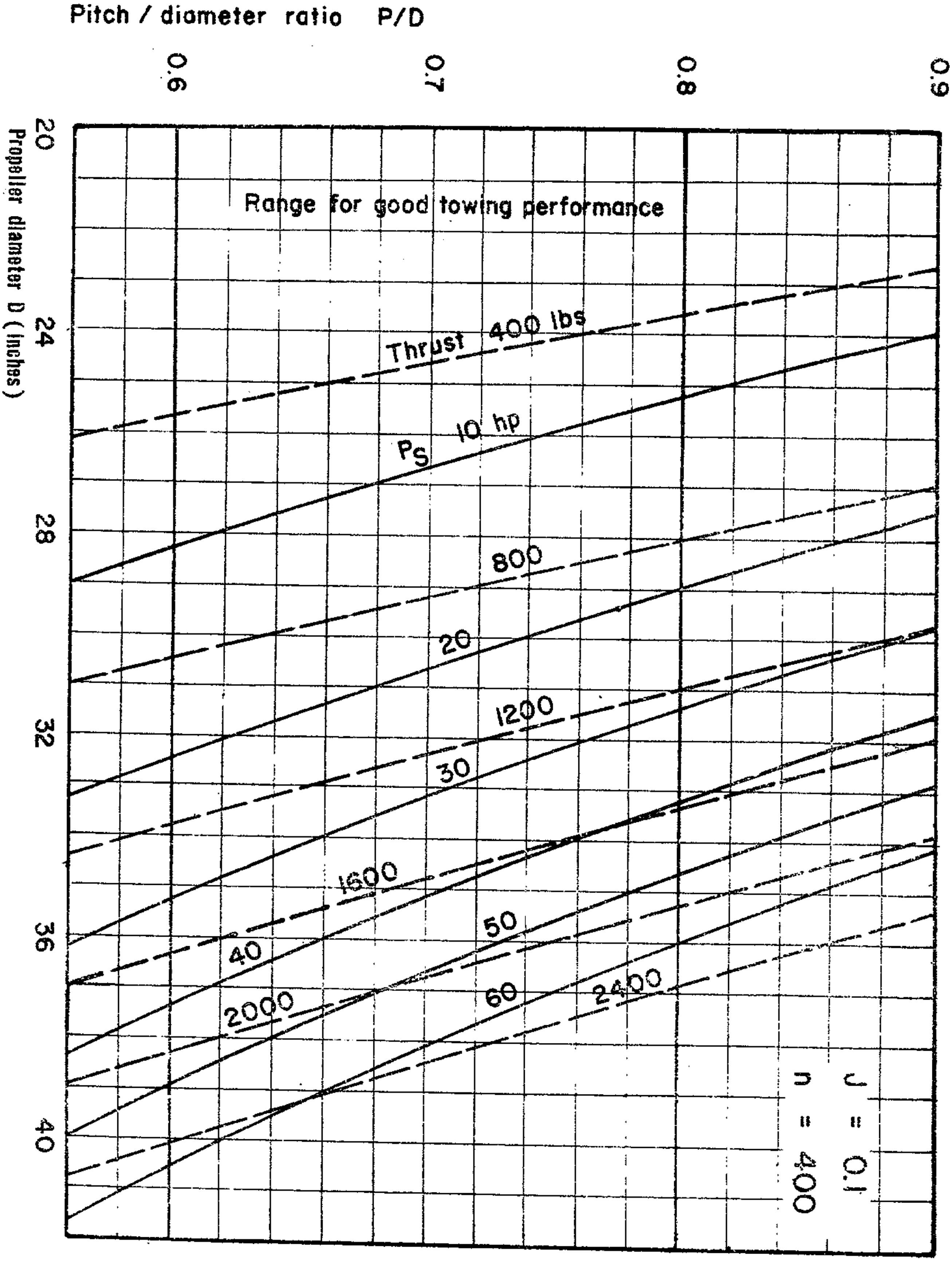

Fig. 3 Variation of power and thrust with P/D

absorbed power will be $26 \times \left(\frac{500}{400}\right)^3 = 51$ hp and delivered thrust $1150 \times \left(\frac{500}{400}\right)^2 = 1800$ lb.

Another example:

It was required to find out the propeller dimensions which would absorb 40 hp at 500 rpm (trawling condition) and also to estimate the thrust delivered by it.

At 400 rpm the same propeller would absorb $40 \times \left(\frac{400}{500}\right)^3 = 20.4$ hp. Entering the diagram for 400 rpm with 20.4 ph it was found that the propeller diameter, say for 0.7 pitch ratio, was 31″ diameter and the delivered thrust 1000 lb.

So the diameter of a propeller with 0.7 P/D absorbing 40 hp at 500 rpm would be 31″ and it would deliver $1000 \times \left(\frac{500}{400}\right)^2 = 1560$ lb thrust.

V. GEOMETRY OF BLADES:

A blade area ratio (BAR) of 0.50 was quite sufficient for these boats. Experiences with propellers having BAR of 0.42 did not show any cavitation damage or apparent loss of thrust. A rake of about 12° was considered essential to maintain the clearances from the hull. The insufficient clearances between the blades and the hull caused shock loads each time the blades passed the stern post. Skew back and specially wide tips could minimise the intensity of these loads. An elliptical blade outline with blade widths at the root and 0.5 R same as the corresponding widths of a Troost series propeller of the same BAR, gave sufficiently wide tips. Skew backs made the construction difficult and might be ignored. Higher thrust loadings under trawling conditions made the circular back sections more suitable for these propellers. They also had good backing properties. The sections at the root could be given a setback at leading and trailing edges by an amount 0.3 × thickness of section.

Considerations of wake adaption for increased efficiency and the chances of root cavitation required a pitch reduction at the root. But experiments carried out by Burrill and Yang (Saunders, Vol. II, pp. 59) showed that the proposition of increased efficiency with wake adaption was open to question. So for fishing boat propellers a constant face pitch could be used, as this considerably simplified their construction. If the amounts of setbacks mentioned were provided at the root sections they would reduce the effective pitch of the root sections and thus meet the requirements of wake adaption and reduction of the chances of the onset of cavitation to a large extent.

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