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Comment on the use of Brake Horse Power as a parameter for the fishing power

by

E.J. de Boer, Chief Technical Section, Technical
Fisheries Research Department,
IJmuiden, the Netherlands.

Introduction

Since decades the fishing power of fishing vessels has been related to technical parameters of such vessels. One of the parameters applied to fishing methods using a towed gear, is the power of the engine. The power of diesel engines is indicated by the number of Brake Horse Power (B.H.P.; P_B*). For definitions of the ratings of marine diesel engines see Appendix 1.

The word "brake" indicates the measuring method of the power. The determination of the number of B.H.P. is performed at the testbed by means of a waterbrake. The definition of the number of B.H.P. is the maximum power the engine continuously can deliver, when running at nominal revolutions.

For vessels having a steam engine as prime mover, the power of the steam engine is expressed in Indicated Horse Power (I.H.P.; P_I*). The word "indicated" denotes the power being determined by the mean effective pressure in the cylinders, calculated of an indicator diagram. The power a steam engine can deliver to the propeller is far less due to the internal losses in the steam engine.

In the following only attention will be paid to propulsion systems using a diesel engine.

The delivered power at the propeller

For the propulsion of a vessel the power available for driving the propeller is of importance. This power is indicated by "delivered power at propeller" (D.H.P.; P_D*). The delivered power at the propeller is the power measured in the propeller shaft, just in front of the hub. In Appendix 2 a summary of power definitions of propulsion system is given.

The delivered power at the propeller is the power the prime mover delivers under the momentary operating conditions decreased with:

a. - the power consumption of machinery driven by the prime mover, gearbox (power-take-off) and propeller shaft (generators, pumps, etc.), and

*symbols according to "International Towing Tank Conference"

b. - the losses in shaft bearings, gearbox, thrust block, etc.

The losses in the propeller shaft are approximately 3 per cent of the B.H.P. of the prime mover. The efficiency of a marine gearbox of good quality with single reduction gearing is 97 per cent.

Because of the increase in number of energy consumers on board fishing vessels, due to the continuing mechanization and automation, the power needed for general service augments considerably. On board Dutch fishing vessels the general service generator is driven by the main engine. Nowadays 50 - 80 kW general service generators are normal for 600 - 800 B.H.P. trawlers.

Fishing vessels having a considerable freezing capacity, need a lot of power for the freezing plant. This power is in most cases also delivered by the main engine. A 1700 B.H.P. freezer trawler e.g. has, under fishing conditions and simultaneously freezing at 70 per cent of the capacity, approximately 1300 D.H.P. available for propulsion.

Therefore, the conclusion is that the use of the B.H.P. of the engine as parameter for the fishing power has to be discouraged. A far better parameter is the use of the delivered power at the propeller under fishing conditions.

The propeller

In case the power available for driving the propeller (P_D), and the rotational speed of the propeller (n) are known, the torque (Q) can be calculated. The propeller converts this torque (Q) in a thrust (T). The thrust (T) gives vessel and gear a speed through the water (V). At this speed (V) the thrust (T) will be equal to the sum of the resistance forces (R_T).

The resistance forces during fishing operations are the wind and water resistance of the vessel and the resistance of the gear. The latter being far bigger than the former.

The best parameter for the propulsive performance during fishing operations is the effective power (E.H.P.; P_E*). This power is defined by R_T . V . horse power.

*symbols according to "International Towing Tank Conference"

The ratio between the effective power (P_E) and the delivered power at the propeller (P_D) is the Quasi Propulsive Coefficient (Q.P.C.; η_D*).

$$\eta_D = \frac{P_E}{P_D} = \frac{R_T \cdot V}{2\pi \cdot Q \cdot N}$$

When designing a propeller the intention is to make η_D as high as possible for the selected operating condition(s).

The η_D can be split up into the following parts:

a. - the open water efficiency of the propeller (η_O);
b. - the relative rotative efficiency (η_R);
c. - the hull efficiency (η_H).

The efficiency of the propeller in open water is the efficiency under tank conditions. This means the propeller is not working behind a vessel, and there is no influence of vessel, rudder, etc. on the performance of the propeller. The open water efficiency is the most important of these three efficiencies and varies considerably depending on the operating conditions of the propeller.

The relative rotative efficiency for single seren vessels is approximately 1.05.

The hull efficiency depends on the wake fraction (w) and the thrust deduction coefficient (t). The former being constant for a certain vessel ($w = -0.05 + 0.5 \cdot C_B$; wherein C_B - block coefficient); the latter varies with the speed of the vessel ($t = 0.05 + 0.15 \cdot V$; V is speed of vessel in knots).

Types of propellers

One can distinguish propellers, according to the pitch setting possibilities, in fixed pitch propellers (f.p.p.), controllable pitch propellers (c.p.p.), and adjustable pitch propellers (a.p.p.).

The fixed pitch propeller is limited in its working performance by the fixed pitch setting. The adjustment of the desired thrust is performed by the variation of the rotational speed of the propeller.

*symbols according to "International Towing Tank Conference"

The controllable pitch propeller gives the possibility to select for each working condition the best pitch setting. The adjustment of the thrust is performed by the variation of the rotational speed and/or the pitch.

The adjustable pitch propeller has e.g. two pitch settings, one for the towing and one for the free running condition.

In order to get an idea about the factors influencing the performance of a propeller some examples, referring to fixed pitch propellers, shall be given in the following.

Factors of influence on the propeller performance

a. - The design speed, is the speed of the vessel where the maximum power available for driving the propeller, is fully absorbed. If the fishing speed is less than the design speed, the propeller needs at full rotational speed a bigger torque (Q), than for the design condition. However, the maximum torque is delivered at the design speed, and due to the constant torque characteristic of the diesel engine, the prime mover will decrease in revs. to a value where the absorbed torque of the propeller is equal to the maximum torque of the prime mover. The result is that the delivered power at the propeller will decrease. The decrease of delivered power becomes more if the difference between fishing speed and design speed increases. The power of the prime mover is approximately proportional to the number of revolutions.

Figure 1, 2 and 3 show the propulsive performance of a 800 B.H.P. trawler, the propeller being designed for 4.0, 9.0 and 12.3 knots respectively. The delivered power at the propeller is 750 D.H.P.. The values of the maximum available pull at a speed of 4.0 knots are 7800 kgf, 7100 kgf and 6400 kgf respectively.
The diagrams show that the design speed is of great influence on the propeller performance when towing (and free running).
The choice of the design speed depends mainly on the sailing distance to the fishing grounds. For the Dutch double-rig beam trawlers this distance is 200 nautical miles at a maximum.

Because the influence of the free running speed on the number of useful fishing hours per trip is small, and the resistance of this type of vessel increases tremendously for speeds exceeding 10 knots, the design speed of the propeller in general is 4 knots. The Dutch wet fish and herring trawlers, a lot of which are converted to beam trawling, have propellers with a design speed of 9 knots (compromise propeller) or more (free running propeller). Comparing the fishing power of these vessels with specific beam trawlers having the same engine output and without taking into account the design speed of the propellers, gives a wrong picture of the actual fishing power ratio.

b. - The rotational speed of the propeller

The rotational speed can be predicted by the choice of the prime mover. When applying prime movers with an output of less than approximately 1200 B.H.P. having a nominal speed of less than 400 r.p.m., it is unusual to reduce the rotational speed of the propeller by means of a gearbox. In this case the rotational speed of the propeller is fixed. The optimum diameter D_{opt} (and the pitch P) is calculated for this rotational speed; the optimum diameter being the diameter for optimum efficiency.

One of the limiting factors for the rotational speed of the propeller is the blade tip speed. In general this speed may not exceed a value of 36 m/sec. in order to avoid cavitation (cavitation damage and decrease in efficiency).

The influence of the rotational speed on the fishing power can be illustrated by the following example. Of a 1300 D.H.P. Dutch stern trawler the propeller has a rotational speed of 380 r.p.m. and the propeller diameter (D) is 2060 mm. The thrust T (1-t) at 4 knots is 11000 kgf.

For the same installation, but with a gearbox reducing the rotational speed of the propeller to 250 r.p.m., D_{opt} = 2600 mm. The thrust T (1-t) at 4 knots increases to 12700 kgf or by 15.4 per cent.

It will be clear that the rotational speed of the propeller influences the fishing power strongly, and that it has to be taken into account when comparing the fishing power.

c. - <u>The diameter of the propeller</u>

According to the axial momentum theory the highest efficiency is obtained at the largest possible diameter at optimum rotational speed. In general the tendency is therefore to select a propeller with a diameter as great as possible, and calculate the optimum rotational speed n_{opt}.

This optimum rotational speed determines for a certain type of prime mover the reduction ratio of the gearbox.

However, the propeller diameter is limited by the draught aft (T_a). In order to avoid that the propeller comes above the water surface, due to the vessels' pitching (decrease of propulsive performance and increase of cavitation), the diameter has to be $D \leq 0.7\ T_a$. The draught aft (T_a) depends mainly on the dimensions and the construction of the vessel.

A limitation of the draught aft can be the restricted depth of the entrance to the harbour, as is the case for some harbours in the Netherlands. In such cases an increase of the engine power above a certain limit gives only a relative small increase in propulsive power, and has to be dissuaded. Nevertheless, in the Dutch fishing fleet several vessels have propellers with a too small diameter.

Another reason for a too small propeller diameter in relation to the power of the prime mover can be caused by the replacement of the prime mover by a stronger one, without having the opportunity to increase the diameter of the propeller, due to the dimensions of its aperture.

An example of the influence of the propeller diameter gives the comparison of two 705 B.H.P. beam trawlers. One has a restricted diameter of 1900 mm (n_{opt} = 307 r.p.m.), and delivers at 4 knots a thrust T (1-t) of 7300 kgf. The other one has a propeller diameter of 2050 mm (n_{opt} = 248 r.p.m.) resulting in a thrust T (1-t) of 7860 kgf at 4 knots.

d. - <u>Ducted propellers</u>

The ducted propeller is a propulsion system that for various ranges of operating conditions meets the main requirements for ship propulsion systems. In the Dutch fishing fleet the number of ducted propellers is increasing continuously.

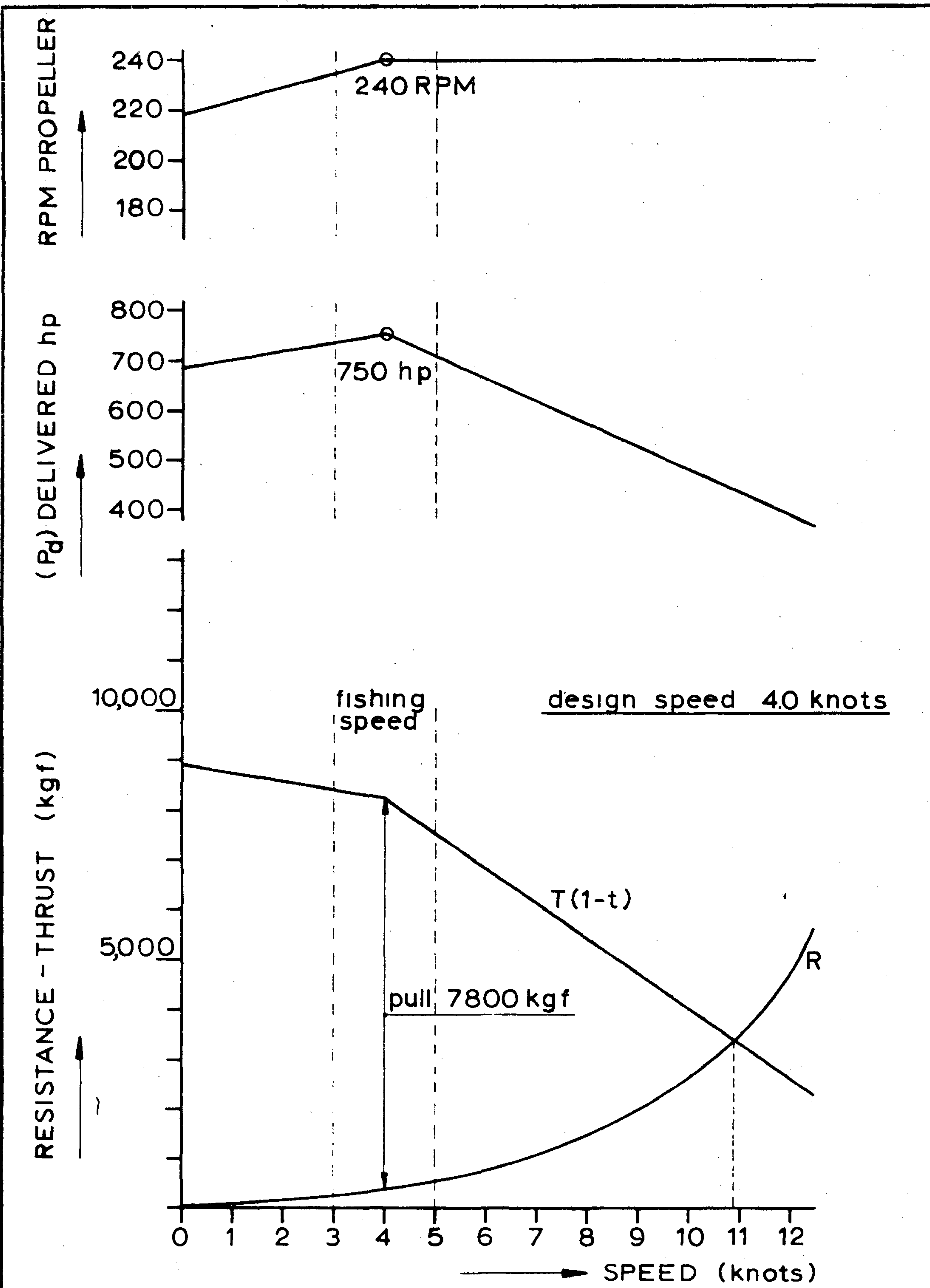
Figure 4 shows the propulsive performance of a 800 B.H.P. trawler with a ducted propeller. Due to the nozzle the propeller diameter has to be decreased, but nevertheless at 4 knots a pull of 9200 kgf is available.
The nozzle is of great influence on the performance of the propeller. Several Dutch beam trawlers claim an increase in pull between 12 to 18 per cent under fishing conditions.

Recommendations

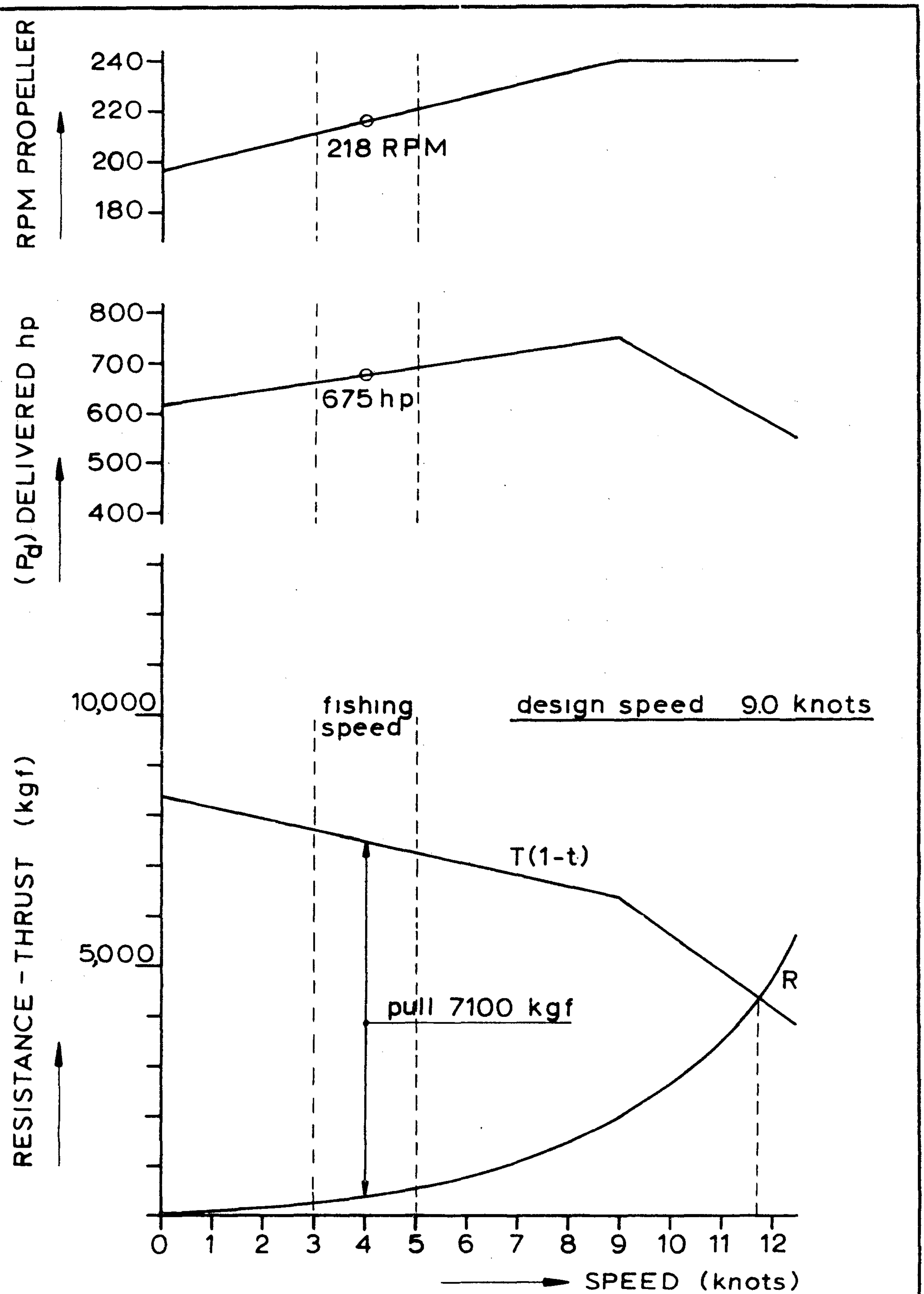
1. It is recommended to use the "delivered power at the propeller" under fishing operations as fishing power parameter, instead of the B.H.P. of the prime mover.

2. In case of a ducted propeller the value of the delivered power at the propeller has to be multiplied by a correction factor because of the higher efficiency, compared with an un-ducted propeller.

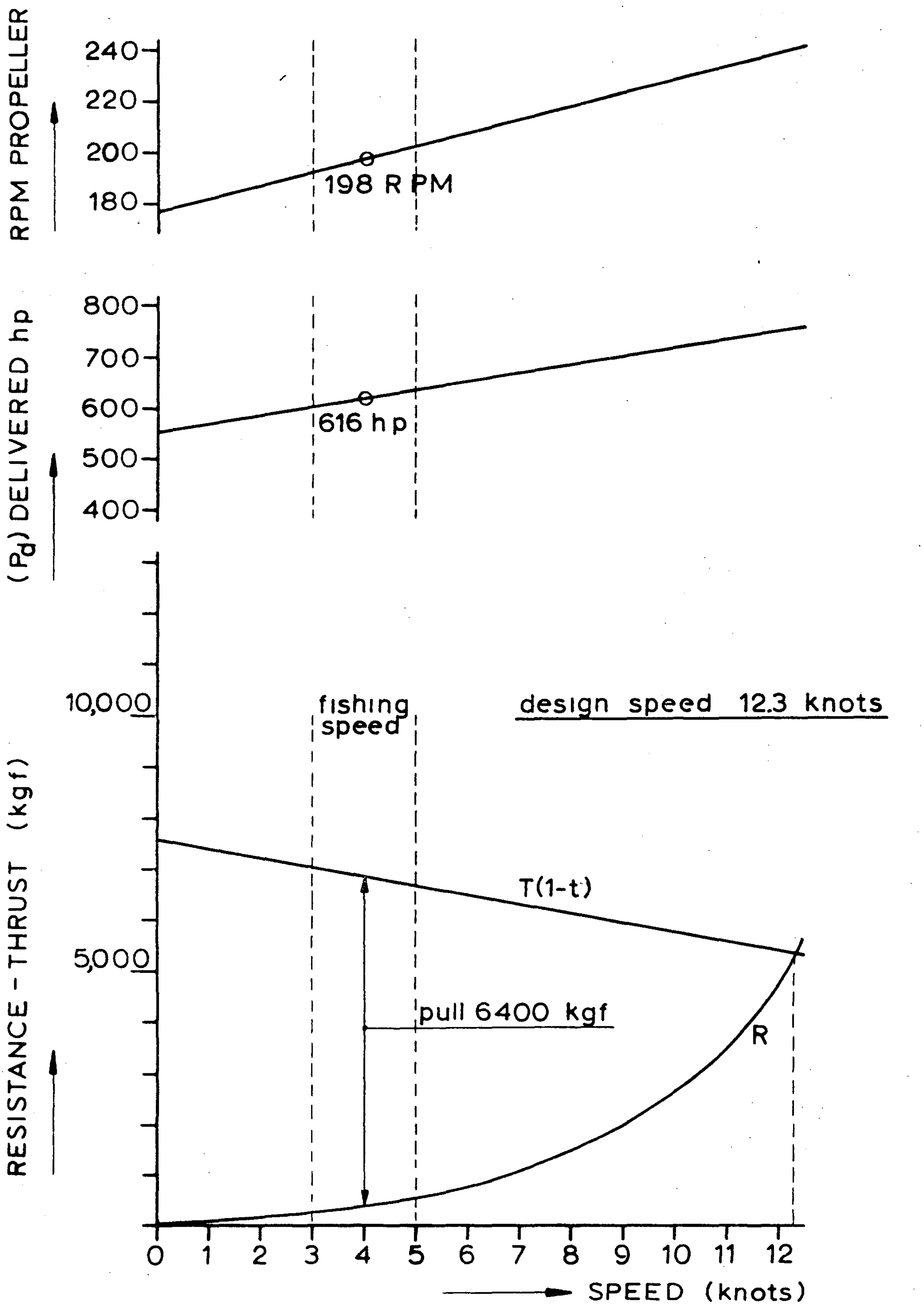
3. In order to correct for the differences in propeller efficiency a factor depending on the rotational speed of the propeller has to be determined.



Benaming PROPULSIVE PERFORMANCE 800 hp TRAWLER			
		Formaat A4	FIG. 1
fisheries directorate technical research dept Auteursrecht voorbehouden volgens de wet	Schaal Getekend	Gecontroleerd Gezien	Rangschikmerk



Benaming		Formaat	
PROPULSIVE PERFORMANCE 800 hp TRAWLER		A 4	FIG. 2
fisheries directorate technical research dept	Schaal / Getekend	Gecontroleerd / Gezien	Rangschikmerk

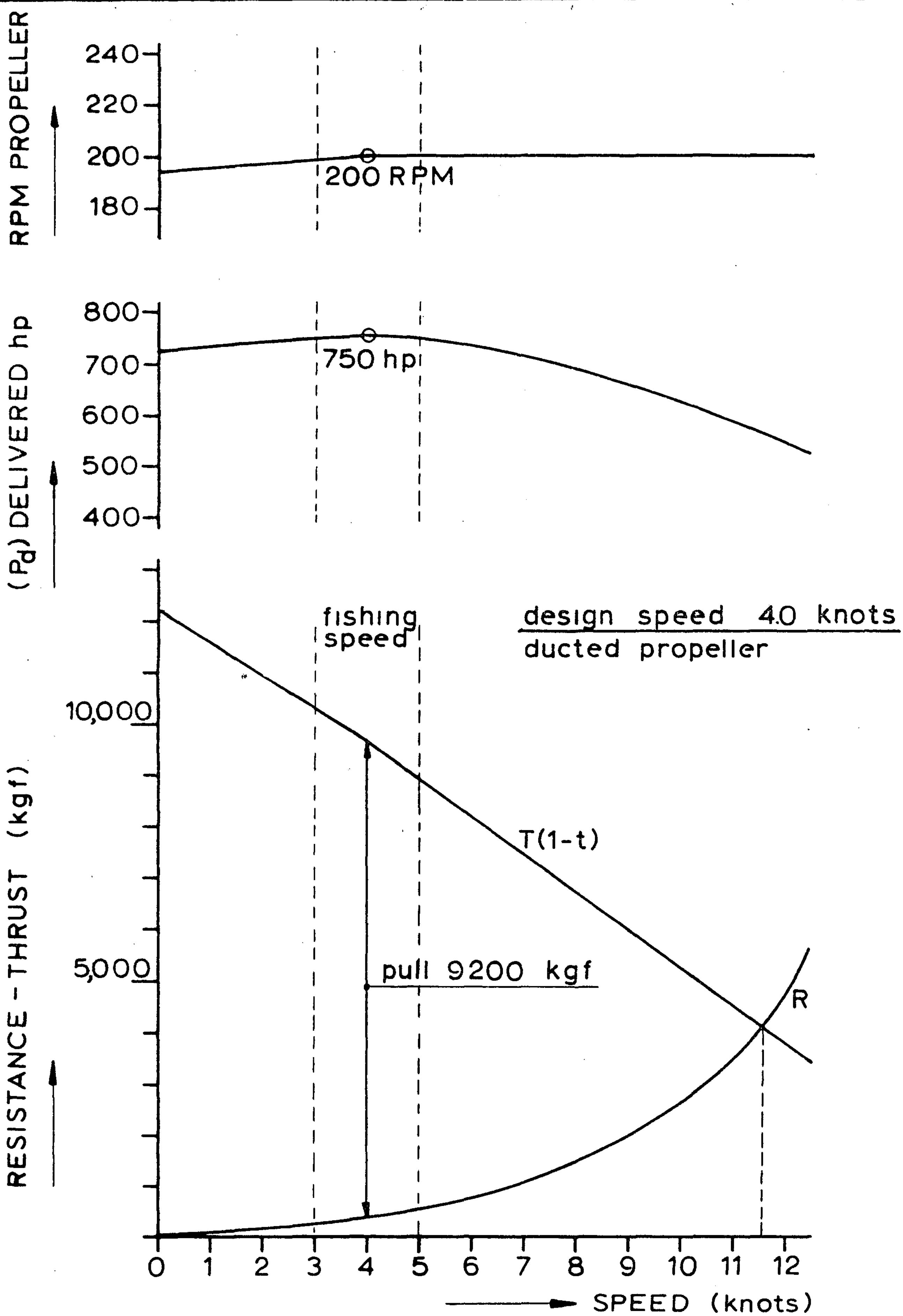


Benaming

PROPULSIVE PERFORMANCE 800 hp TRAWLER

fisheries directorate
technical research dept

Schaal	Gecontroleerd	Formaat A4	FIG. 3
Getekend	Gezien	Rangschikmerk	



Benaming			
PROPULSIVE PERFORMANCE 800 hp TRAWLER		Formaat A4	FIG.4
fisheries directorate technical research dept	Schaal	Gecontroleerd	
	Getekend	Gezien	Rangschikmerk

Ratings of marine diesel engines

Maximum rating : The maximum output the engine is capable of developing for periods not exceeding five minutes duration. The engine is stripped of all accessories.
This output is obtainable under standard conditions of temperature and altitude on dynamometer test only.

Intermittent rating: The maximum output permissible for applications which require variable speed and variable load.
The average load factor has to be in the region of 50 - 70%.
The fuel pump is set to limit the output of the engine to this rating.
Applications of this rating are fork trucks, cranes, belt conveyors, roadrollers, etc.

Continuous rating : The output the engine can develop continuously at nominal speed under standard conditions of ambient temperature and altitude.
This rating should be used for fishing vessels, where heavy continuous load is required and adverse operating conditions, such as poor maintenance and/or long periods of unattended running at high load factor, are involved.
To cater for this requirement the fuel pump will in general be set to this rating and no overload allowance is provided.

The continuous rating can also be determined according to British Standard B.S. 649 or DIN 6270 A (Continent). According to these standards, an overload of 10% above the continous rating is obtainable for 1 hour in any period of 12 hours consecutive running. The fuel pump will be set to limit the output of the engine accordingly. It will be clear that the user can operate at the 10% overload conditions continuously. This means for the engine a continuous effective overload, which e.g. reduces the periods between overhaul.

In general the above mentioned ratings are for standard conditions of 750 mm Hg (29.5 in Hg) atmospheric pressure, intake air temperature up to 29°C (85°F) and a relative humidity of up to 60 per cent. One has to decrease the output by 3.5 per cent for every 300 m (1000 ft) over 150 m (500 ft) above sea level; 2 per cent for every 6°C (10°F) above 29°C (85°F); 6 per cent at a maximum for the most adverse relative humidity.

When comparing the ratings of engines one has to be aware of the difference between the metric and British horse power. The former has a value of 75 kgf.m/sec., the latter 550 ft.lb/sec. = 76.04 kgf.m/sec.

Power definitions of propulsion systems

Description	Symbol I.T.T.C.	Former identification	Definition
brake power	P_B	B.H.P.	
shaft power	P_S	S.H.P.	$P_S = P_D$ + losses in propeller shaft
delivered power	P_D	D.H.P.	$P_D = 2\pi \cdot Q \cdot n$
thrust power	P_T		$P_T = T \cdot V_A$
effective power	P_E	E.H.P.	$P_E = R_T \cdot V$

In the above given definitions the following parameters are used:

Q - torque delivered at propeller

n - rotational speed of propeller

T - thrust of propeller

V_A - speed of advance of propeller = $V\,(1-w)$

R_T - total resistance of ship (and gear)

V - speed of vessel

w - wake fraction ($w = -0.05 + 0.5\,C_B$)

C_B - block coefficient