Bay of Bengal Programme

Development of Small-Scale Fisheries

REDUCING THE COST OF SMALL FISHING BOATS

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REDUCING THE FUEL COSTS OF SMALL FISHING BOATS

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The first part of this paper describes the principles of power requirements for smaTl fishing boats and details ways of saving fuel which can be applied both with existing boats and new boats. It also illustrates by example how to estimate the savings from measures to conserve fuel.

The second part of the paper describes fuel consumption trials carried out in Sri Lanka. During the trials the two most common Sri Lankan boats — the 18 footer and 28 footer — were used with different engines, propellers and hull conditions, and actual fuel consumption was recorded. The fuel consumption performance of two BOBP craft — SRL-14 and SAL-iS — was tested in comparison with that of the standard 28-footer of Sri Lanka; the fuel performance of another BOBP craft, SRL-17, was compared with that of Sri Lanka's standard 18-footer. The results of the trials confirmed the validity of the principles and fuel-saving recommendations described in the first part.

The trials were conducted in 1982 at the request of the Ministry of Fisheries, Sri Lanka. A report was submitted to the Ministry soon after the trials.

This paper, and the trials it describes, are activities of the small-scale fisheries project of the Bay of Bengal Programme (BOBP). Begun in 1979, the project is funded by SIDA (the Swedish International Development Authority) and executed by the FAO (Food and Agriculture Organization of the United Nations), and covers five countries bordering the Bay of Bengal—Bangladesh, India, Malaysia, Sri Lanka and Thailand. It is a multi-disciplinary project, active in fishing craft and gear, aquaculture and extension. The project's main goals are to develop, demonstrate and promote appropriate technologies and methodologies to improve the conditions of small-scale fisherfolk in the BOBP's member countries.

This document is a working paper and has not been cleared either by the government concerned or by the FAO.

CONTENTS

SUMMARY

The first part of this paper deals with the principles of power requirements for small boats (below 12 m in length) and how they vary with speed, displacement, shape of hull, propellers, etc. Nine different ways of saving fuel are identified which to a varying degree can be applied to new and existing boats. Examples of how to estimate savings by the use of a standard diagram are given.

The most effective fuel saving measure is the selection of a low-powered engine, which also saves on capital investment, and reduces operating speed.

As a guideline it is suggested that the installed engine power should not exceed 5 hp(maximum continuous rating) per tonne (t) of displacement. The engine should be operated at 3 hp actual output per tonne at about 80% of maximum rev/mm.

It is also suggested that the best criterion for comparison is the fuel consumption per nautical mile, i.e., mileage. For a 8 m long boat with 3.5 t displacement the following fuel saving possibilities were estimated.

Fuel economy measures		Approximate saving
Speed reduction from 7 to 6 knots (kn)		37%
Longer hull from 8 to 10 m (by design)		23%
Lighter displacement from 3 to 2.5 t (by material)		19%
Increase engine gear reduction ratio from 2 to 4		14%
Removal of barnacles from a badly fouled hull	to	40%
Regular engine maintenance as compared to no maintenance	up to	30%

From a case study of an 18 ft boat in Sri Lanka, it was also concluded that at 1985 prices, and with 600 hours per year operation, the use of a small diesel inboard engine does not mean lower yearly costs than use of a kerosene outboard engine. Petrol outboard engines have 20% higher yearly costs. The advantage of a diesel engine becomes greater with increased operation time.

Two examples of the use of sail are given. The net gain will depend on the degree of utilization of the sail and on the costs of sail and rig.

The second part of the paper is a summary record of fuel saving trials in Sri Lanka using two of the most common boats i.e., the 18-footer powered by 7-12 hp outboard kerosene engine and the 28-footer (3.5 tonner) powered by 30 hp inboard diesel engine. In addition three new designs – SRL-14, SRL-15 and SRL-17 – have been tested to determine the potential for fuel saving.

The trials by and large confirm the general considerations in Part I.

For the 18 ft. outboard powered boat it was found that using the 7 hp instead of the 12 hp outboard engine reduces the fuel consumption per nautical mile by 29%.

The SRL-17 outrigger canoe with a 7 hp outboard engine has 25% lower fuel consumption than the 18 ft boat.

For the diesel powered boats – the 28 ft. boat and the new SRL-14 and SRL-15 – the fuel saving from reducing the speed fwm 7.5 to 6.5 kn ranges from 35 to 55%.

The new designs SRL-14 and SRL-15 with a 20 hp engine have, at a speed of 6.5 kn, between 38 to 40% lower fuel consumption than the existing 28 ft boat with a 30 hp engine.

Part I. Methods of Fuel Saving

1. INTRODUCTION

Mechanized fishing is an energy consuming way of producing food. The construction and maintenance of fishing boats and fishing gear requires some energy but between 80% and 90% of the total energy input is in the form of fuel for the propulsion machinery.

The amount of fuel required to catch one kilogram of fish depends very much on the fishing method employed. The table below illustrates the present situation in Scandinavia

Fishing method	*Kg of fuel needed to catch one kg of fish*
Trawling	0.8
Longlining and gillnetting	0.15 - 0.25
Purse Seining	0.07

Because of the high fuel consumption for trawlers, there has been considerable development towards the use of large reduction gears, large diameter propellers and nozzles to improve efficiency.

This paper outlines ways of reducing the fuel consumption of coastal fishing vessels below 12 m (40 ft) in k9ngth, using passive gear such as gillnets, longlmnes and handlines.

The first part of the paper gives background material and shows various principal approaches to fuel saving. The second part describes some investigations carried out on motorized fishing craft in Sri Lanka.

1.1 ALTERNATIVE FUEL SAVING MEASURES

Possible approaches to fuel saving are given in the table below. It is useful to distinguish between what measures can be adopted in boats of new design and what can be done on existing ones. It is also important to know what measures can be introduced without cost, what measures can even reduce costs, and what measures will involve extra expenditure.

The fuel-saving measures that entail additional expenditure require economic analysis of whether the saving justifies the investment and maintenance cost.

Fuel-saving measures for small fishing boats

	Fuel-saving measure	New design to implement measure	Implementing measures on existing boat	Extra expenditure required
1.	Reduce speed	Can be done	Can be done	none
2.	Change hull design	Can be done	Difficult	Low for new design
3.	Adjust operating range of engine and change propeller	Can be done	Can be done	Low
4.	Change gear reduction and propeller	Can be done	Can be difficult	Low in design
5.	Change type of engine (outboard engine to inboard diesel)	Can be done	Can be difficult	High
6.	Use sail	Can be done	Can be difficult	Medium
7.	Keep hull clean from fouling	Can be done	Can be done	Low
8.	Keep engine well maintained	Can be done	Can be done	Low
9.	Change mode of operation (stay longer out sea)	Can be done	Can be difficult	Medium to high

2. MAIN FACTORS INFLUENCING FUEL CONSUMPTION

2.1 Speed

The po..ver required to propel a boat is mainly a function of

- Speed
- Length of waterline
- Displacement i.e. weight of the boat including crew, fishing gear, fish and ice.

The relationship is shown in Fig. 1 which is valid for boats with reasonably good hull shapes and for average propulsion efficiencies. A simple graph cannot cover all types and shapes of boats, but plotting of actual performance data of fishing vessels has shown that Fig. 1 gives a good picture of the relationship between the main parameters influencing the power.

The lower curve is for calm water and no fouling on the bottom. This curve corresponds to the *trial condition.*

In *service condition,* however, the boat operates in waves and with some fouling on the bottom. This leads to an increase in power requirement. It is not possible to give exact figures for this power increase, but the upper curve gives an estimated average value. The use of Fig. 1 is best shown by an example

A boat has a waterline length of 8.0 m and a displacement in service condition of 3.5 t. What will be the approximate power requirement and fuel consumption in *service condition?*

We first enter the lower graph along the line of LWL = 8.0 m until we meet the required speed and then go vertically upwards to the upper graph and read off the values for the hp per tonne displacement on the upper curve for *service condition.*

The values can be entered in a table as shown below

Speed in knots	hp/t per tonne	hp (Displ. = 3.5)	Fuel consumption l/h
5.0	1.9	6.7	1.7
5.5	2.3	8.0	2.0
6.0	3.0	10.5	2.6
6.5	4.0	14.0	3.5
7.0	5.5	19.2	4.8
7.5	7.2	25.2	6.3

The fuel consumption in litres (l) per hour (h) is calculated by assuming that the engine burns 0.25 l/h of fuel for each hp it develops. This figure actually varies with the engine rpm and the propeller selected, but 0.25 l/hp/h is close enough for estimation. The result is plotted in Fig. 2.

With the above table it is possible to find what effect the speed has on fuel consumption. We can for example find out what saving in fuel will be possible by reducing the service speed from 7.0 knots (kn) to 6.0 kn. and 5.0 kn.

Speed in kn	Fuel consumption l/h	Fuel consumption l/n mile
5.0	1.7	0.34
6.0	2.6	0.43
7.0	4.8	0.69

When reducing the speed from 7.0 kn to 6.0 kn, the saving in fuel consumption is (4.8 – **2.6) = 2.2 l/h. This is a saving of (2.2/4.8) x** 100 = 46%. But this is not the true fuel saving. With a speed of 7 kn, we will be able to travel 7 n miles in one hour while with a speed of 6 kn only 6 n miles will be covered. To get the *true fuel saving* we therefore have to find out *how much fuel is consumed for one n mile travelled* expressed in litres per nautical mile (l/n mile). This is found by dividing the fuel consumption in litres per hour with the number of n miles travelled in one hour which is the same as the speed expressed in knots. This is shown in the last column in the example above. The true fuel saving is therefore

0.69 l/n mile – 0.43 l/n mile = 0.26 l/n mile – which is a saving of (0.26/0.69) x 100 = **37%.**

The true fuel saving is therefore 37% and not 46% as found by considering only fuel consumption in litres per hour.

From the above example it is clear that there is a good potential for fuel saving by reducing the speed. Slower speed means that it takes longer to cover a certain distance. Will the saving in fuel be worth the extra time? This can only be answered by a case study.

Example : The boat in the previous example has to travel daily to a fishing ground situated 20 n miles from the harbour. (Total daily distance = 40 n miles). What will be the fuel saving and extra daily time required with alternative speeds? The fuel cost is 0.35 *$/1.*

Speed (kn)	Fuel consumption (l/n. mile)	Fuel cost 1$/n mile)	Fuel cost per day ($)	Travelling time per day (h)
5.0	0.34	0.12	4.80	8.0
6.0	0.43	0.15	6.00	6.7
7.0	0.69	0.24	9.60	5.7

We will now consider two alternatives for saving fuel

	Fuel saving per day (US$)	Extra time per day (h)
Step 1: Reduce speed from 7.0 kn to 6.0 kn	3.60	1.0
Step 2: Reduce speed from 6.0 kn to 5.0 kn	1.20	1.3

We have to consider whether in Step 1 the extra hour spent travelling is worth the $ 3.60 in fuel saving. By reducing the speed down to 5.0 knots, as in Step 2, it is possible to further increase the saving by $ 1.20 but we have to spend 1 hour and 20 minutes more at sea than in Step 1. We therefore have to consider how much the extra time spent travelling is worth, compared with **what we save.**

2.2 Hull design

Fig. 1 shows that reduction in power can be achieved by

- Increasing the length of the waterline (LWL)
- Reducing the displacement.

Increasing the length of the waterline while keeping other dimensions the same, will also make it possible to obtain a sharper bow and thereby reduce the resistance. Although the weight of the boat itself is increased by the greater length, the overall effect on the hull resistance is beneficial. The limiting factor is the cost increase of the hull which must be balanced against the fuel saving. There has been a trend over the last 20-30 years towards beamy **vessels with a blunt bow coupled** with a large increase in engine power.

Trials in Norway and Denmark have shown a 15% to 25% reduction in resistance by fitting a sharper bow and increasing waterline length on existing vessels.

Example:

A boat has the following characteristics

Length of waterline	= 8.0 m
Displacement	= 3.5 t
Weight of hull excluding engine	= 2.0 t
Service speed	= 6.5 kn

What would be the saving in fuel keeping the beam and depth the same, but increasing the length of waterline to 10.0 m?

Weight of 10.0 m hull = 2.0 t x (10.0/8.0) = 2.5 t

Displacement of 10.0 m hull = 2.5 + 1.5 = 4.0 t

From Fig. 1, at a *service speed* of 6.5 kn

Length of waterline (m)	(hp/t)	Displacement (t)	Power (hp)	Fuel saving (%)
8.0	4.0	3.5	14.0	–
10.0	2.7	4.0	10.8	**23%**

If a 8.0 m boat spends $ 1,000 on fuel yearly, the saving in fuel with the 10.0 m hull would be $ 230. This saving has to be balanced against the increased construction cost. The 8.0 m hull costs US $ 4,000. The 10.0 m hull will cost approximately $ 4,000 x (10.0/8.0) = $ 5,000.

The increase in the investment is $1,000. The yearly fuel saving of $230 gives a return on the investment of (230/1000) x 100 = 23%. In this case the longer hull would be a reasonably good investment.

Reduction in displacement would contribute to a lower fuel consumption. Hulls built of aluminium, FRP and plywood will be lighter than those built of steel, ferro-cement or conventional wood plank construction.

Example:

What would be the fuel saving if the hull weight of the 8m boat given in the example above was reduced from 2.0 t **to 1.5** t and hp/t = **4.0?**

	Hull Weight (t)	Displacement (t)	Power at 6.5 kn (hp)	Fuel Saving (%)
Old hull	2.0	3.5	14.0	0
New hull	1.5	3.0	12.0	14

The monetary advantage of the fuel saving might be absorbed by the higher construction cost of the new hull, but lower maintenance cost and longer service life are also factors that have to be considered

The real saving in weight can only be determined in each particular case. The lower hull weight might lead to more uncomfortable movements when the sea is rough. It is quite common, for this reason, to put concrete ballasts in fishing boats made of FRP in which case there may be no weight saving.

2.3 Engine power and operating range

From Fig. 1 we had found that a service speed of 6 kn and a waterline length of 8.0 m would require 3.0 hp/t displacement or 10.5 hp for a displacement of 3.5 t. Obviously it would not be wise to go and buy an 11 hp engine and run it at full throttle. A power margin is necessary. The question is : How big should the power margin be?

First of all, when talking about engine power we must be sure in what way the engine manufacturer has measured the power. For fishing boats we are only interested in *continuous power;* that is what the engine can deliver for an unlimited time. This should be clearly marked on the engine power curve shown in the manufacturers' leaflet. A common standard is DIN 6270 "A" for heavy duty commercial application. The DIN 6270 "B" standard is for light duty pleasure boats and gives 10% more power than the "A" rating. Since customers are used to comparing "horsepower", many manufacturers use the "B"rating when selling engines. A 20 hp engine would then only give 18 hp continuous power.

In a tropical climate with high humidity and temperature, a 6% reduction in power output should be assumed from the manufacturer's claim. With loss in shaft bearing, available power at the propeller is about 10% lower than is shown in the manufacturers' leaflet for continuous duty.

An internal combustion engine does not operate at peak efficiency throughout the whole range of rev/mm and power output. From the specific fuel consumption curve, which shows how much fuel is burned for each hp developed (usually given in g/hp/h), we will see that most engines have a minimum specific fuel consumption in the range 70-80% of maximum rev/mm (see Fig. 3). This is where the engine is burning the fuel most efficiently, and should be selected as the operating range in service condition.

Figure 3 shows that the propeller should be designed to allow the engine to operate in the area of the lowest specific fuel consumption. The propeller should in *service condition* absorb 60% of maximum power (DIN 6370 "A") and at an engine rev/mm close to the minimum point on the specific fuel consumption curve, which is often about 80% of maximum continuous rev! mm. The propeller demand curve "A" satisfies this criteria. This means that when the power to maintain service speed has been determined from Figure 1, we need to install an engine of 1.6 to 1.7 times this power when rated to DIN 6270 "A". The propeller designed for 60% power and 80% rev/mm curve "A" in Fig. 3 will not allow the engine to reach full rev/mm, but it will achieve maximum fuel economy in service condition.

If a propeller is selected to absorb 100% of continuous power at 100% rev/mm (Curve "B" in Fig. 3), the propeller will not allow the engine to operate in the optimum specific fuel consumption area in *service condition.* The specific fuel consumption might be 5-7% higher as shown on the lower curve and the propeller efficiency reduced because the propeller. is turning at a higher rev/mm.

Example: A boat has a waterline length of 8.0 m and a displacement of 3.5 t. The *service speed* should be 6.0 kn. What size of engine is required to achieve this speed?

From Fig. 1:

hp/t = 3.0

hp = 3.0 x 3.5 t = 10.5 hp.

An engine of about 1.6 to 1.7 times this power needs to be selected if the manufacturers' rating is DIN 6270 "A", that is about 17 to 18 hp continuous duty.

After a market survey, an engine developing 18 hp at maximum 2600 rev/mm, with a 3 : 1 reduction gear, is selected. The engine should be run in service condition at 2600 x 0.80 = 2100 rev/mm.

The propeller will turn at 700 rev/mm.

The propeller should be designed to absorb 10.5 hp at 700 rev/mm for a vessel speed of 6.0 kn or a propeller advance speed of 5.4 kn.

The important decision regarding engine power is often based on the urge to go a bit faster than other fishermen. The justification is sometimes the need to be first back to the market to obtain the highest price for the fish. The effect has been the same in all fishing countries : an escalation of engine power and a corresponding increase in costs which have hurt first of all the fishermen themselves. Governments could by regulation or through subsidy and credit schemes limit the size of engine that can be used on a particular boat and in this way prevent waste.

As a guideline for economical powering of small fishing vessels except trawlers, one should not install engines larger than 5 hp/t displacement (continuous duty DIN 6270 "A"). The engines should be operated in service condition at about 3 hp per tonne actual output at about 80% of maximum rev/mm.

2.4 Reduction gear and propeller

The efficiency by which the propeller converts the engine power to thrust depends mainly on propeller revolutions, assuming that an optimum propeller diameter and pitch is used.

Example:

Service power = 10 hp, Engine speed = 2000 rev/mm.
Speed of vessel in waves Vs = 6.0 knots, propeller speed of advance Va = 5.4 kn.

Gear Ratio	**2** : 1	**3** : 1	**4** : 1
Propeller speed (rev/mm)	1000	667	500
Optimum – propeller diameter (mm)	430	560	620
Propeller efficiency %	52	57	61
Savings in fuel %	0	9	14

From the above table it is clear that a large reductmon ratio can mean considerable fuel savings *provided the boat speed is maintained the same. If the higher thrust available with larger reduction ratios is used to increase the speed there will be very little saving.*

Higher gear reduction ratio means larger propeller diameter and increased draught. With shallow harbour entrances this might be a limiting factor unless a type of lmfting propeller is utilized. As a general rule, the maximum available gear reduction ratmo should be chosen. It is important, however, to ensure that the propeller aperture is large enough to provide adequate propeller clearances. Lack of sufficient propeller clearance is a very common fault in boat designs. After calculating the optimum propeller, Fig. 4 will provide a guide to minimum propeller clearances.

2.5 Type of engine

Two types of engines are used in small fishing boats.

- Outboard engine consuming petrol and/or kerosene.
- Inboard diesel engine.

Many attempts have been made to develop outboard diesel engines but so far none has been produced in large numbers. Technical development could change this in the future.

The outboard engine has gained wide use in the fishery of developing countries because of

- low initial cost, usually about one-third of the diesel engine, in most countries
- low weight (less than one-third of the diesel engine)
- ease of installation and saving of space.

The main disadvantage of the two stroke outboard engine is the high fuel consumption

	Specific fuel consumption
Inboard diesel engine	0.25 l/hp/h
Petrol and kerosene outboard engine	0.50-0.60 l/hp/h

Another disadvantage of the outboard engine is the high propeller speed which means low propeller efficiency at speeds below 10 kn.

The high cost of petrol has spurred a switch to kerosene as fuel for outboard engines in countries where kerosene is subsidized because it is used for cooking. There needs to be a considerable price difference to justify this change because of the disadvantages of running on kerosene : greater wear of the engine and more carbonization.

Engine cost, fuel cost, hours of engine operation and the need for beachlanding are factors that vary from one fishery to another and from country to country. The possible savings by changing from outboard engines to inboard diesel engines can, therefore, only be determined in a case study. (See Appendix 1).

Fig. 5 shows that the viability of an inboard diesel engine is highly dependant on the number of operating hours per year. With rising fuel costs the odds are in favour of the diesel engine. However the advantage of low cost and portabilmty means that there will always be a market for smaller outboard engines of 2-8 hp, may be in combination with sail. In this case the number of hours of engine operation per year might not justify the high investment cost of a diesel engine.

2.6 Use of sail

When considering the use of sail for fuel saving on a fishing boat, the following factors need to be taken into account

- The use of sail depends on satisfactory stability of the boat. The *Righting Moment* at a heeling angle of 30 degrees is often used by Naval Architects as a criterion to determine the maximum allowable sail area. Ballast will often be required to permit a sufficmently large sail area to be carried. The weight of ballast increases resistance and thereby fuel consumption when under power.
- Windward ability depends on a deep and effective keel area. The increased draught causes problems in shallow areas.
- Windward ability requires sails set on a high mast to be effective. The wire rigging often interferes with the fishing operation. The wind resistance of mast and rigging will increase fuel consumption when under power in a head wind.
- Only a case by case study will determine whether the cost of the sail and rigging is justified by the saving in fuel. The critical factor is the motivation of the fishermen for the use of sail.

Example:

A boat with a displacement of 3.5 t has a fuel cost per year of $ 1,000. The boat is to be fitted with a sail rig with the following investment cost and yearly capital cost

	Investment cost $	Service life (yr)	Yearly capital cost at 15% interest $
Mast and standing rig	500	10	100
Sails and running rig	300	4	105
Ballast	100	10	20
Total	900		225

The Naval Architect determines on the basis of stability data that a ballast of one tonne is required to make the boat safe under sail. The ballast keel increases the displacement from 3.5 to 4.5 t and the corresponding increase in fuel consumption can be estimated as roughly proportional with the displacement. Assuming that the engine is used 60% of the time without sails, the increase in fuel consumption = $ 1,000 x 0.6 x 4.5/3.5 = $ 77.00.

Total yearly cost is therefore $ 302 which corresponds to 30% of the yearly fuel cost of the boat without sail and ballast. This means that to make sense economically the sails must be used at least 30% of the time with the engine stopped or 60% of the time with engine running at the half power, to justify the investment. This is probably unlikely to be achieved in practice.

Small fishing boats do not necessarily need extra ballast if heavy fishing gear such as large mesh driftnets are stored low in the hull and the crew can act as “live ballast” to increase the righting moment. The cost of the sailing rig can be kept low by making mast and spars of timber, grown locally.

Example:

A beachlanding boat in India of 8.5 m LOA and a displacement of 1.6 t was fitted with a sail area of 26 m2 (see Fig. 6). The boat is fishing with large mesh driftnets. The driftnets weigh 600 kg and are stowed low in the hull.

The cost of the sailing equipment including lee board, rudder, mast and cotton sails was $ 250 in 1983. The boat is fitted with an engine of 8 hp consuming about 1.5 l of fuel, at a service speed of 6 kn. Yearly capital cost of the sail rig is calculated in the same way as in the above example to $ 75. With a fuel price of 0.30 s/l, the cost of the sailing rig would be covered in 170 h of sailing per year with the engine stopped. This is 17% of the total travelling time per year (1000 h) and the sail rig in this case seems well justified.

If sail is used as the main propulsion, one can reduce the size of the engine to what is required for manoeuvring in and out of harbours and on the fishing ground, and on days with unfavourable wind. The minimum speed satisfactory for this purpose is about 5.0 kn and a relatively small engine would provide this speed. Based on Figure 1 we find that a boat with 8 m waterline length and 3.5 t displacement will require 6.5 hp to achieve a service speed of 5 kn. If an engine of around 11.00 hp is installed, it would considerably bring down investment cost, compared with the 16-18 hp engine necessary if only engine were to be used. The fishermen must however be willing to accept the slower speed compared with a "normal" powered boat when going against wind and waves. In countries with a living tradition in the use of sails, the low powered fishing boat with efficient sails could be an attractive alternative. Another case is when fuel and spare parts are in short supply; a sailing boat will then be able to continue fishing.

Sail is often necessary as a safety measure in case of engine breakdown. In this case a simple dipping lug rig will be satisfactory.

2.7 Hull fouling

The rate of fouling depends on local conditions and temperature. In the tropmcs the increase in surface friction due to fouling has been estimated to be between 0.6% and 1.5% per day. Assuming a figure of 0.7% per day as average and that the friction resistance is about 35% of the total resistance at the normal operating speed of fishing vessels, the effect on fuel consumption will be as follows

Period of fouling	Increase in fuel consumption
1.month	7%
6 months	44%
12 months	88%

From the above figures it is clear that *hull fouling can mean a substantial increase in fuel consumption if no anti-fouling paint/s used* or if the boat is not taken out of the water for removal of barnacles and shells at intervals of 1 to 2 months. If this is not done, the extra cost in fuel can be considerably more than the cost of the anti-fouling paint.

2.8 Engine maintenance

The loss in efficiency of a badly maintained engine can be as high as 30%. To prevent this it is necessary to clean or replace injectors regularly and perform oil changes at intervals recommended by the engine manufacturer. With fuel contaminated by dirt and water, there is a need to install an extra fuel filter and water separator between the fuel tank and the engine.

2.9 Mode of operation

Instead of travelling daily to the fishing ground and back again, it is possible to save fuel by staying several days on the fishing ground. This will necessitate better crew accommodation, cooking facilities and an insulated fish hold – this will again normally require a larger boat. The cost/benefit of this can only be determined through a case study.

Part II. Fuel Consumption Trials in Sri Lanka

1. TYPES OF BOATS TESTED AND MEASURING METHOD

Two types of fishing vessels are used in large numbers in Sri Lankan fishery

The *18 ft (5.5 m) outboard powered boat* is shown in Fig. 7. About 6,000 were in operation in 1983. All are built in FRP. They are powered with 7 hp and 12-15 hp kerosene outboard engines and mainly utilized for small mesh gillnetting within 10 n miles from the shore. The crew usually consists of two men.

The *28 ft (8.5 m) inboard powered boat* is shown in Fig. 8. It is originally a wooden boat of FAO design, introduced in 1958. Nearly 3,000 were operational in 1983, mainly built of FRP. The boats are generally powered with a diesel engine developing 30 hp at 2200 rev/mm. The installed power is 9 hp/t which is almost twice what was recommended in Section 2.3. Originally a 16 hp engine was installed in these boats but general power escalation over the years has led to the 30 hp engine presently used.

This boat is used for overnight fishing, mainly with large mesh driftnets up to 30 n miles from the shore. It has a crew of 4 men.

In addition to the two established types of boats used in the Sri Lakan fishery, three new boat types which have been developed by the FAO-BOBP project were tested

SRL-14 Designed to do the same large mesh driftnet fishery as the standard 28 ft boat, but with the capability of surflanding on beaches. Main changes compared with the 28 ft boat are an engine of 20 hp at 2,500 rev/mm with a gearbox of 3.65 : 1 reduction. The engine is fitted in a pivoting box which permits retraction of propeller and rudder for landing on the beach.

SRL-15 Harbour-based boat with the same 20 hp engine and gearbox as the SRL-14 but with a stretched hull to permit an icehold and crew accommodation for fishing trips of a few days duration. The bow is sharper than so far common on fishing boats of this size.

SRL-17 Single outrigger canoe as a fuel-efficient alternative to the 18 ft outboard powered boats. The idea is based on the local type of outrigger canoe, but with better shape for use with an outboard engine and with a good sail performance.

Further details about the boats tested are given Appendix 2.

Measuring methods: Trials were conducted in calm water inside the break water in the port of Colombo. Vessel speed was measured by an electronic trailing log, care being taken to reduce as far as possible any inaccuracies arising from the effects of propeller slip stream and the wake of the boat by towing the trailing log from a pole lashed across the forward part of the boat to keep the impeller clear of the bow wave system.

Fuel consumption was measured by taking the time, with a stopwatch, for the level of the fuel in an auxiliary glass tank to fall from one mark to another; the volume between the marks was 100 cc; (see Fig. 9). The fuel injector return flow was collected in a measuring cylinder and the difference gave the fuel actually burnt in the engine in the measured time. Engine speed (rev/mm) was measured in the case of inboard engines by applying a revolution counter to the flywheel and for outboard engines by a vibration tachometer. The data was entered in a recording sheet (Appendix 3).

2. RESULTS OF TRIALS

2.1 Outboard powered craft

The 18-footer and the SRL-17 were tested with the same loading of 400 kg and the same engines, a YAMAHA 8BK developing 7 hp when operated on kerosene and a YAMAHA 15AK developing 12 hp on kerosene. Fig. 10 shows the fuel consumption in l/n mile. The following conclusions can be drawn regarding operation in calm water

- Using a 7 hp outboard instead of the 12 hp outboard and operating at 6.0 kn instead of 9.0 kn with the 18 ft boat, reduces the fuel consumption from 0.73 l/n mile to 0.52 l/n mile or a saving of 29% besides the saving in investment. At 6.0 kn speed 33% more time is required to go a certain distance.

- The SRL-17 outrigger canoe with the 7 hp engine has 25% lower fuel consumption than the 18 ft boat at a speed of 6.0 kn.
- The SRL-17 outrigger canoe with the 12 hp engine has 33% lower fuel consumption than the 18 ft boat at a speed of 9.0 kn.

2.2 Diesel powered craft

The results have been plotted in Fig. 11. The following conclusions can be made for *trial condition* calm water, low wind speed, no waves and a clean underwater hull.

- Reducing the speed from 7.5 kn to 6.5 kn gives the following fuel savings:

28 ft boat	40%
SRL-14	55%
SRL-15	35%

The conclusion is that *speed reduction is the most effective way of saving fuel.*

- At a speed of 6.5 kn the SRL-14 has a fuel saving of 38% and the SRL-15 a fuel saving of 40% compared with the existing 28 ft boat. The reasons for the better performance are given below.
- To achieve a speed in trial condition of around 6.5 kn, only about 9 hp is required. The 30 hp engine fitted in the 28 ft boat has a poor fuel efficiency when operated at only 9 hp output. The 28 ft boat has been fitted with a "heavy" propeller that gives 1,850 rev/mm at full throttle (maximum rated speed = 2,200 rev/mm). If a "lighter" propeller (smaller diameter and pitch) is fitted to allow 2,200 rev/mm, the efficiency at an output of 9 hp would be even lower. In addition, the 30 hp engine on the 28 ft boat is an old model with a high specific fuel consumption.

  The 20 hp engines fitted in SRL-14 and SRL-15 operate closer to their optimum range at an output of 9 hp. Using the principles outlined in section 2.3, an engine of maximum continuous duty of 15 hp to 18 hp would have been sufficient when operated at a service output of 9 hp and at a rev/mm of 80% of continuous rating. Engine selection will, however, have to be adjusted to what is available in the market.
- The engines of the SRL-14 and SRL-15 are fitted with a gearbox of 3.65 reduction compared with 2.13 for the 28 ft boat. At 6.5 kn the propeller of the new designs turn at 415 rev/mm with a propeller efficiency of 66%, while the propeller of the 28 ft boat has an efficiency of 58%. This gives a fuel saving of 12%. The new designs also have a better fairing of the skeg in front of the propeller, giving a better flow of water into the propeller.
- The SRL-15 has a longer waterline length and a sharper bow than the 28 ft boat which gives a marked fuel saving for speeds above 7.0 kn.

The fuel consumption figures are for *trial condition* – that is with no waves and wind. This is necessary to get comparable results with different boats. For *service condition,* as is experienced normally with waves and wind and some fouling, the fuel consumption will increase. To add a certain percentage to the fuel consumption figures through the whole speed range underestimates the effect of wind and waves at lower speed. It is better to assume a certain increase per tonne displacement at different speeds as is done in Fig. 1. If the same values are used we will get the following increases in fuel consumption with a displacement of 3.2 t

Increases due to waves and wind in service condition

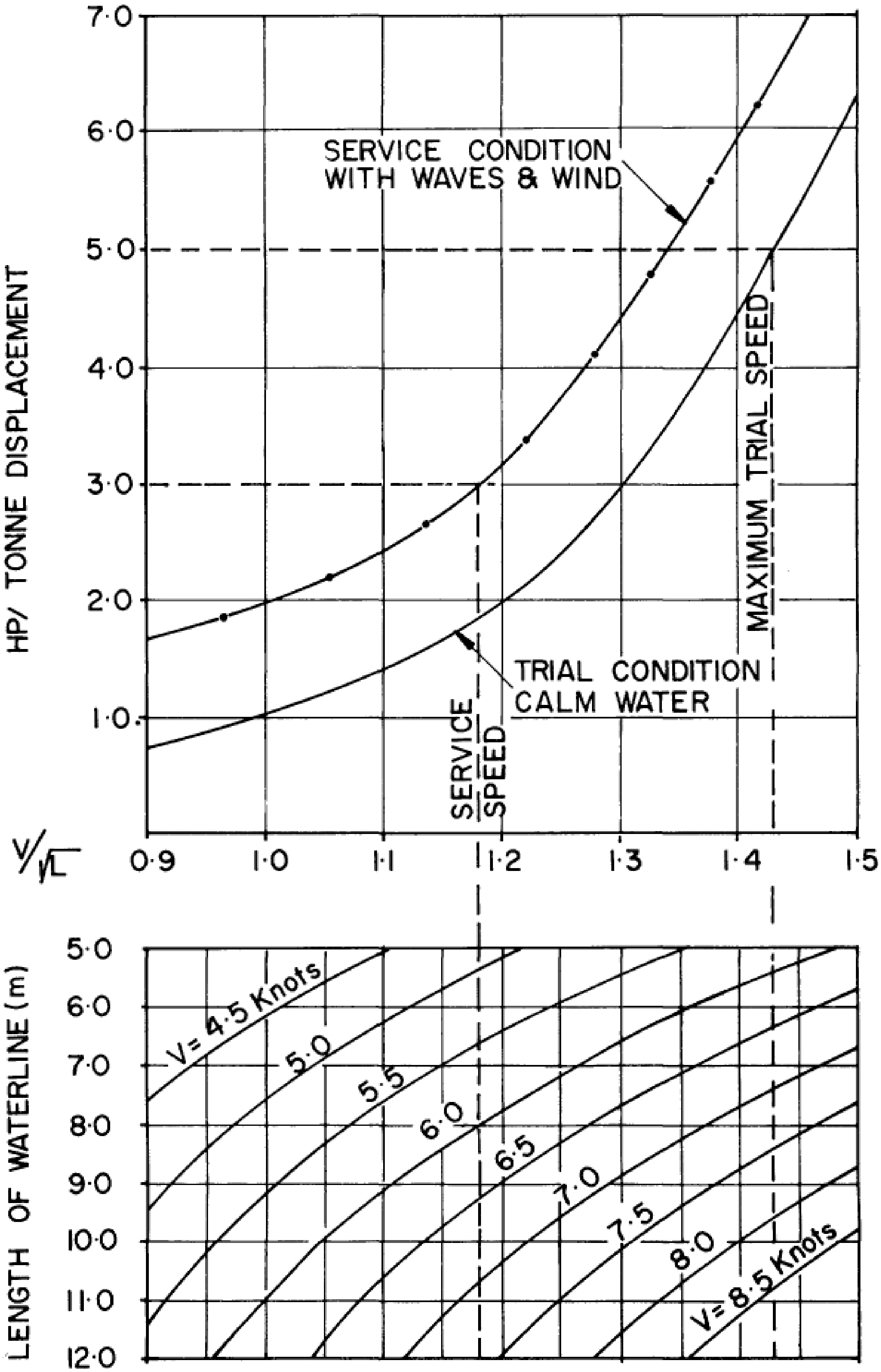
Speed (kn)	*hp/t*	*hp*	*l/h*
5	1.0	3.2	0.80
6	1.2	3.8	0.95
7	1.5	4.8	1.20

The figures for fuel consumption have been added to the *trial condition* figures in Fig. 12 to produce a curve for fuel consumption in *service condition.*

Since wind and waves have a proportionally bigger effect at lower speed, the fuel saving expressed in per cent when reducing speed will be lower than for *trial condition.* When the speed is reduced from 7.5 to 6.5 kn, the saving which was 40% in *trial condition* is reduced to about 32% in *service condition.* Reduction in service speed however still remains the best bet for fuel saving.

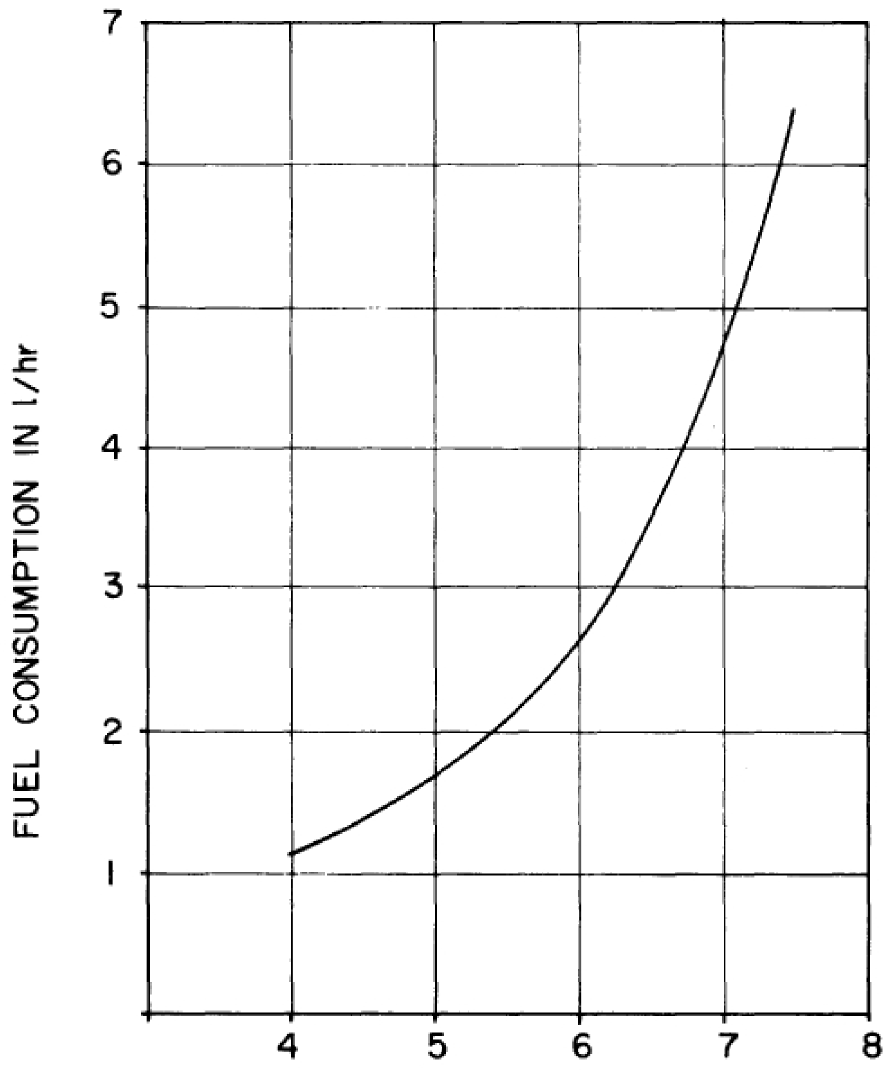
Figure 1

POWER- SPEED DIAGRAM



NOTE: CONTINUOUS POWER AT 'DIN A' RATING

Figure 2



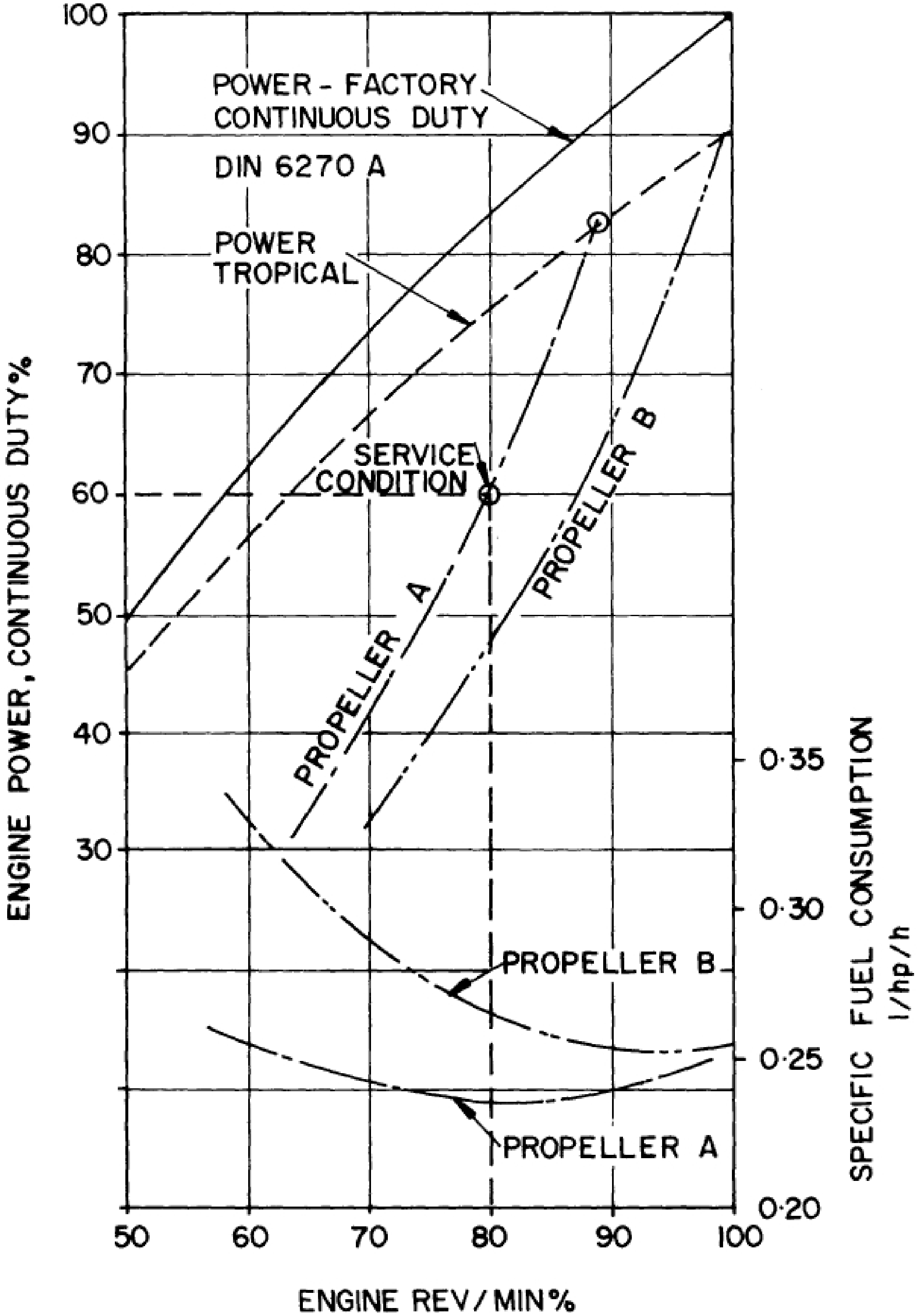
ESTI MATED FUEL CONSUMPTION

SERVICE CONDITION

LWL =8Om

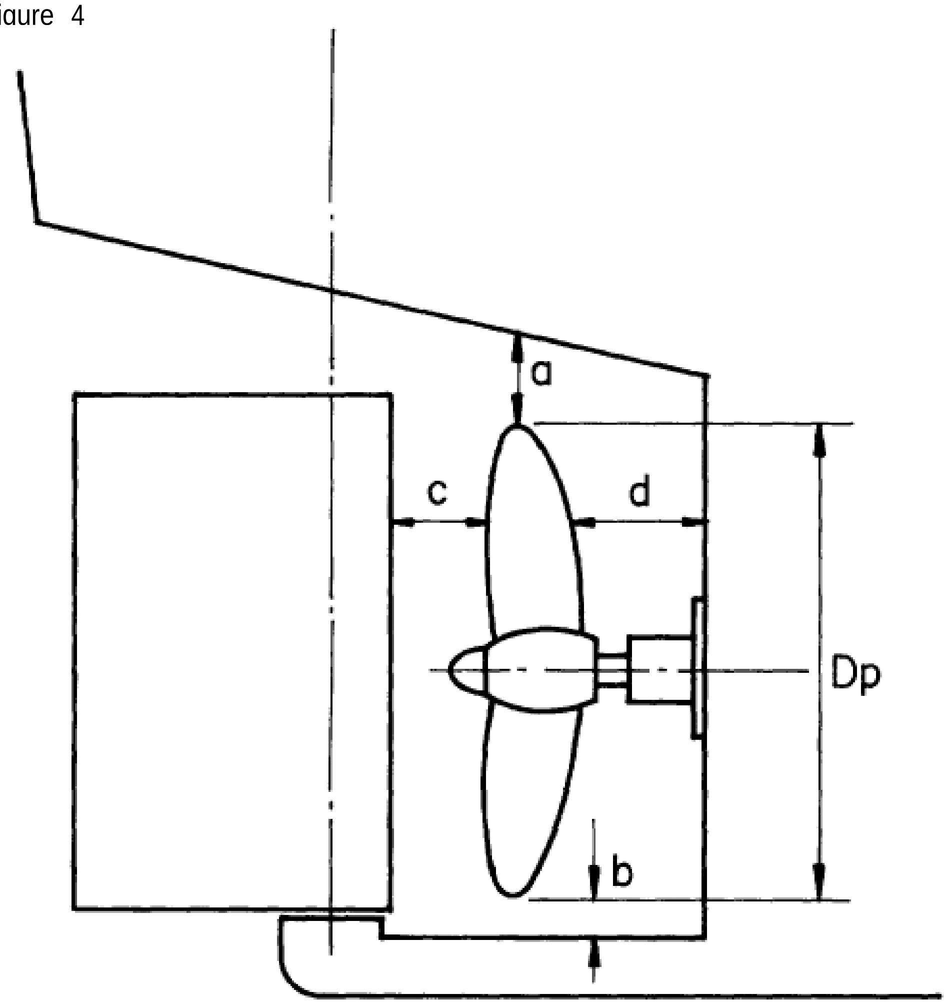
DISPLACEMENT = 35 tome

Figure 3



ENGINE POWER AND OPERATING RANGE

Fiaure 4



a 017 X Dp

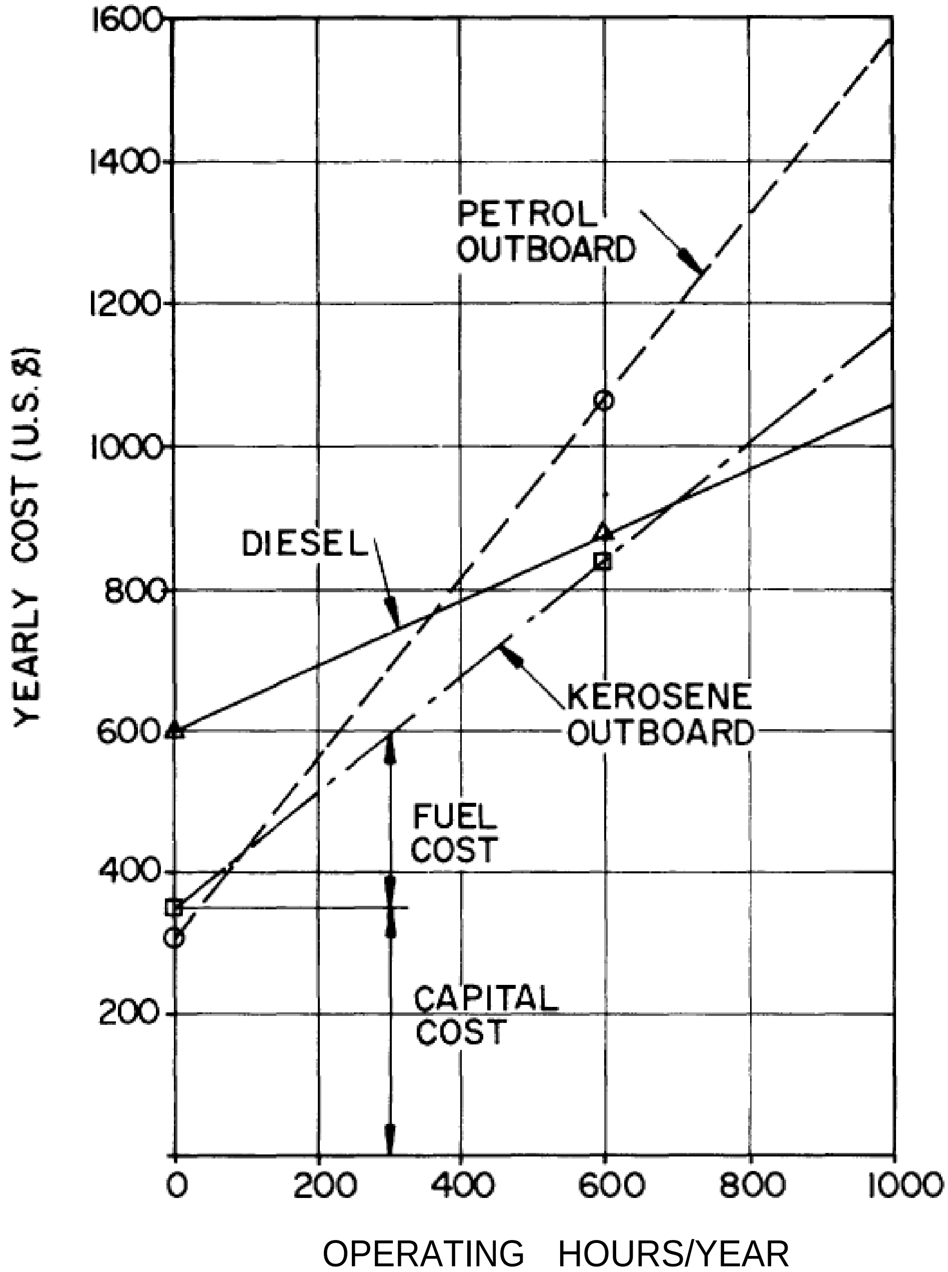
b 0.05 x Dp

O•17 x Dp

d = 0.27 x Dp

MINIMUM CLEARANCE:
PROPELLER / HULL

Figure 5



OUTBOARD KEROSENE ENGINE vs DIESEL ENGINE

For basic data see Appendix I

Figure 6
THE IND-20B DESIGN WITH GUNTER RIG

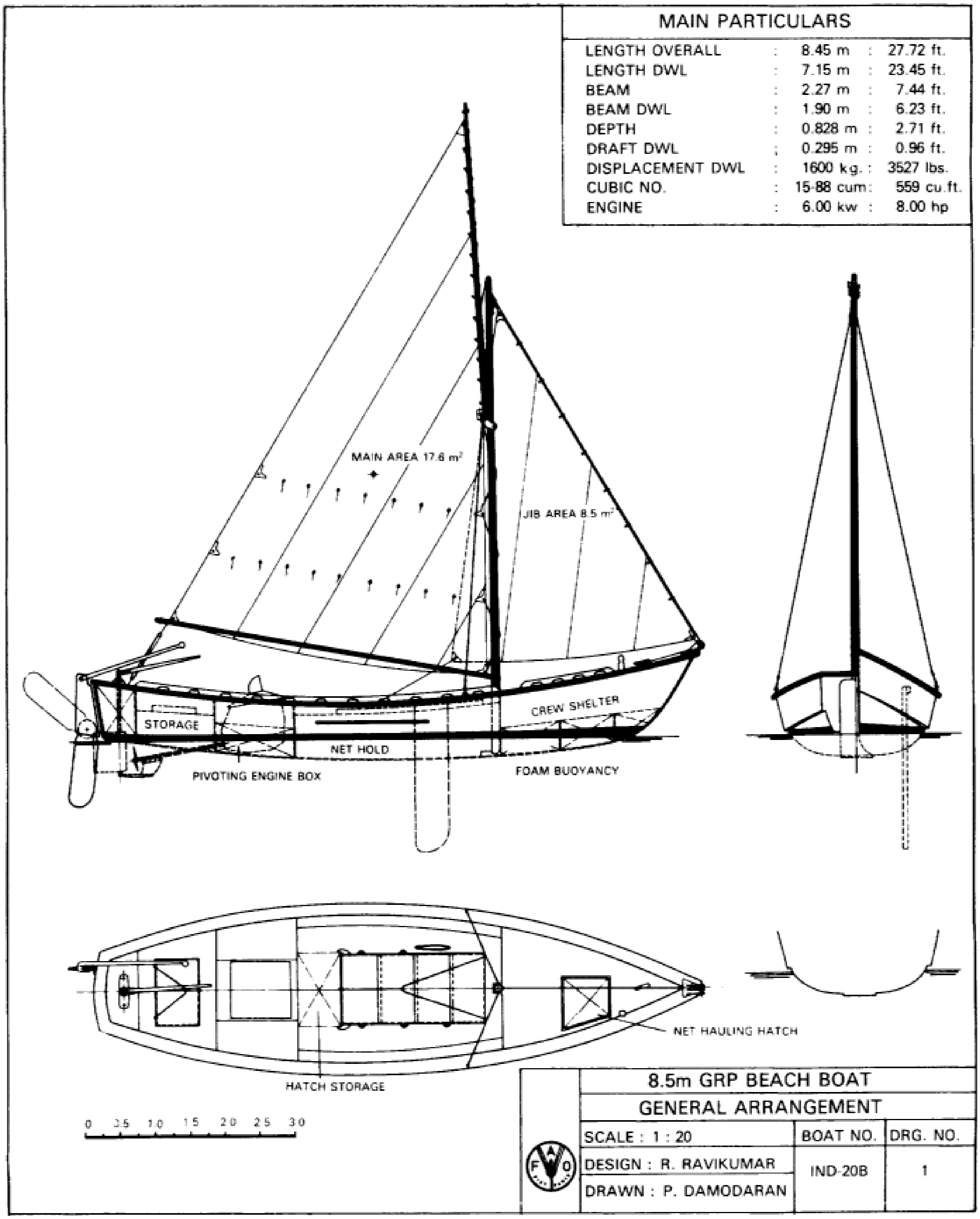


Figure 7
18 FT. SRI LANKAN **(5.5 m) BOAT**

MAIN PARTICULARS		
LENGTH OVER ALL	:	5·40 m
LENGTH DWL	:	4·90 m
BEAM MOULDED	:	1·75 m
BEAM DWL	:	1·50 m
DEPTH RABBET SHEER	:	0·75 m
DRAFT DWL	:	0·30 m
CU NO	:	7·00 m^3
PROPULSION	:	8 - 12 HP OUT BOARD MOTOR

SCALE 1 : 10

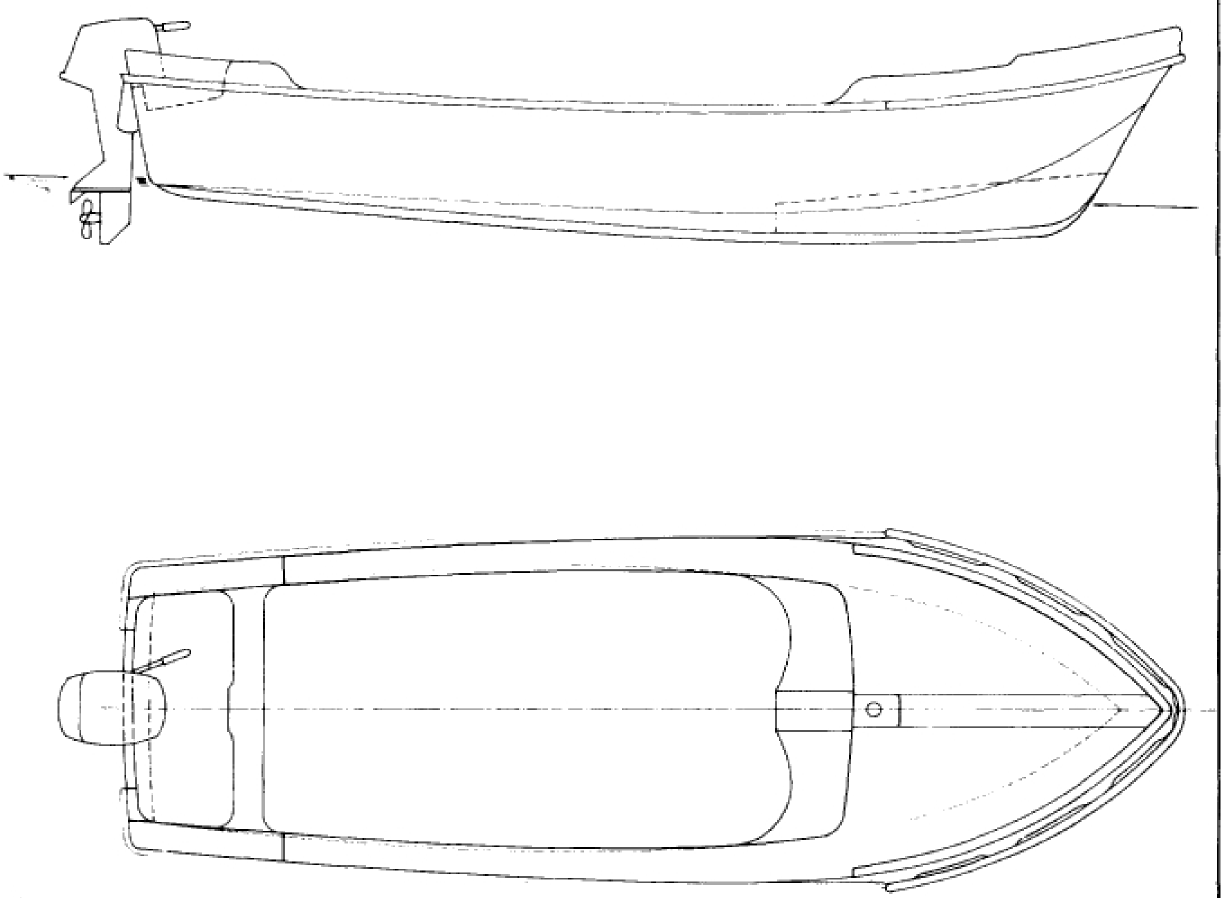
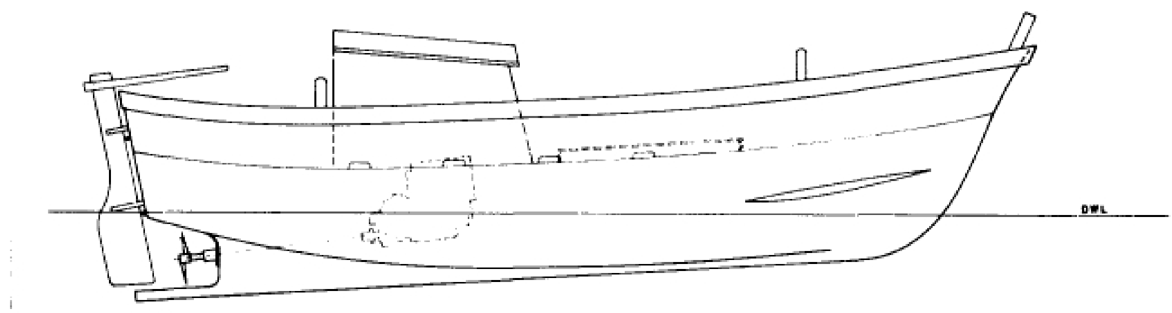


Figure 8
28 FT. SRI LANKAN (8.5 m) BOAT

MAIN PARTICULARS	
LENGTH OVER ALL	: 8·75 m
LENGTH DWL	: 7·60 m
BEAM MOULDED	: 2·60 m
BEAM DWL	: 2·30 m
DEPTH RABBET SHEER	: 1·43 m
DRAFT	: 0·76 m
CU. NO.	: 32·00 m^3
PROPULSION YANMAR 2SME 30 HP/2200 RPM	

SCALE 1:20



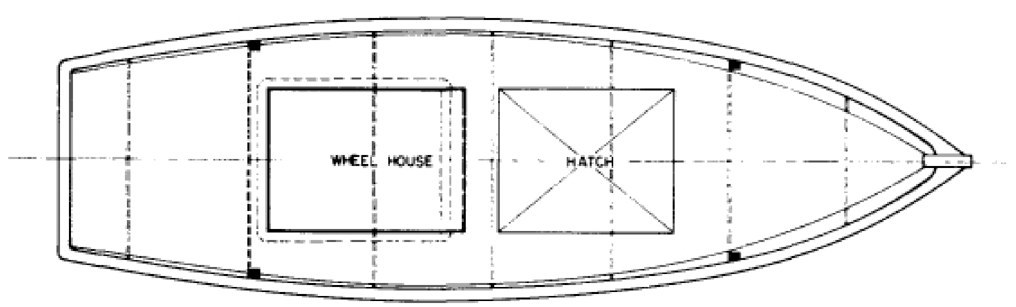


Figure 9

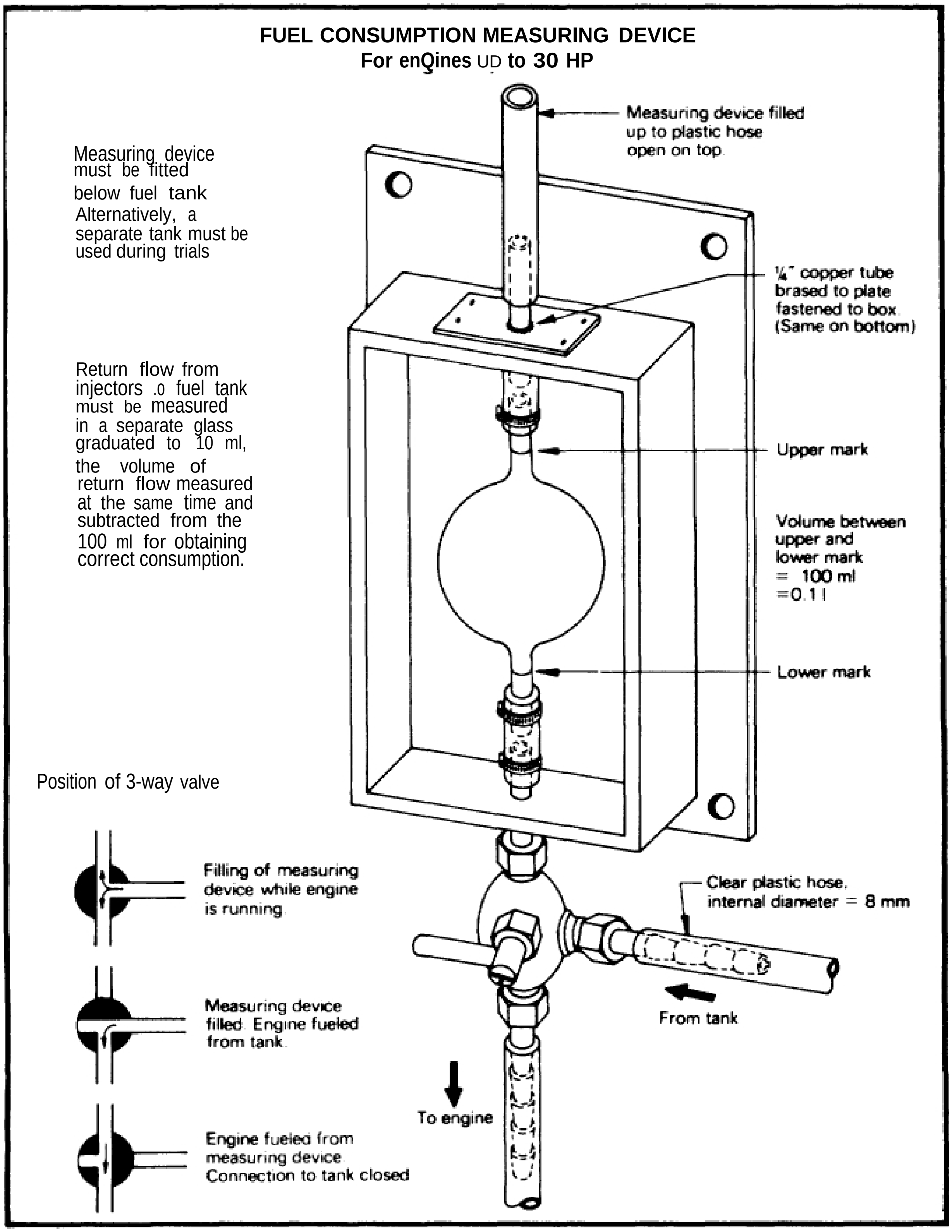
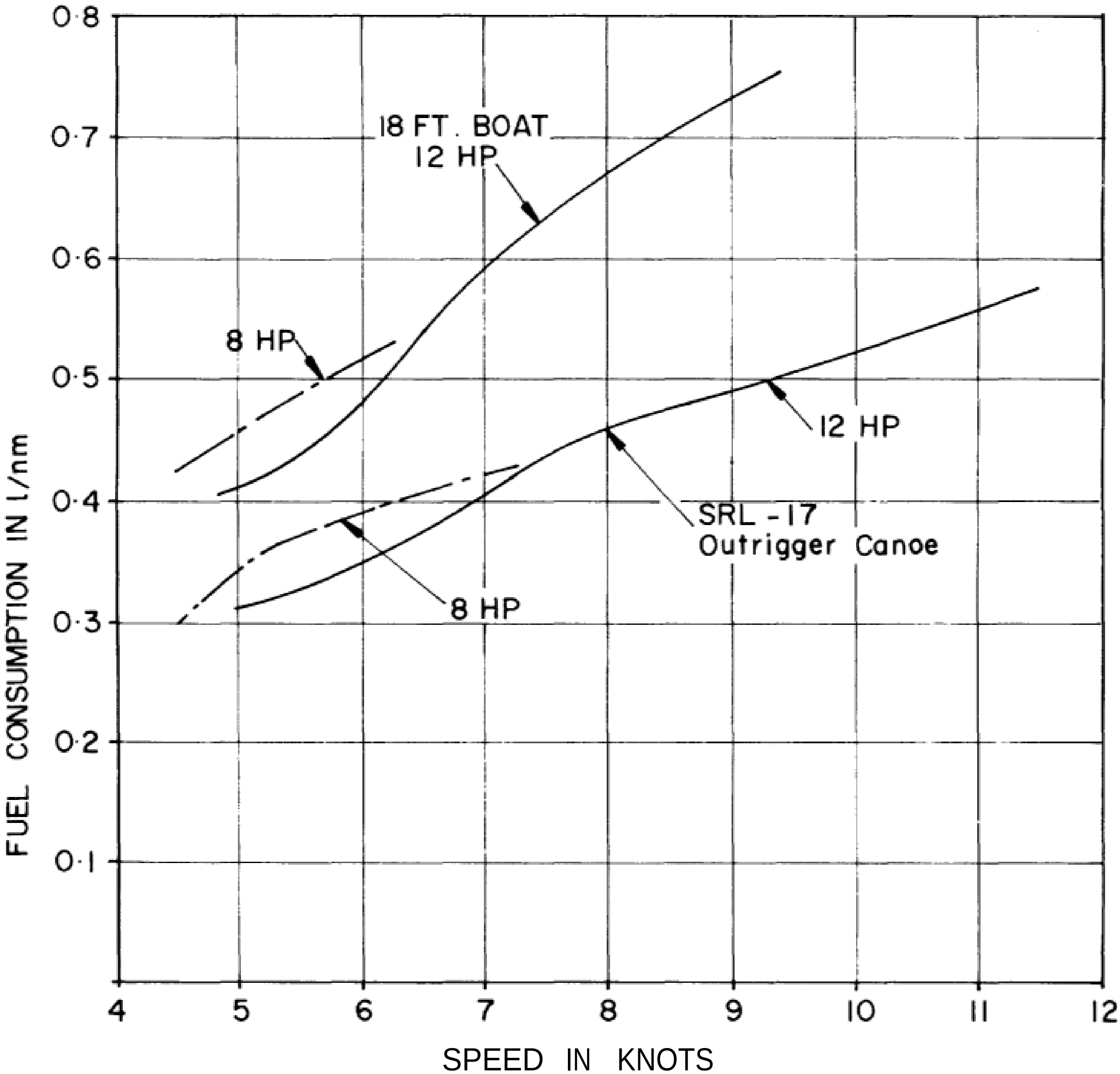

FUEL CONSUMPTION MEASURING DEVICE
For enQines UD to 30 HP
Measuring device must be fitted below fuel tank Alternatively, a separate tank must be used during trials
Return flow from injectors .0 fuel tank must be measured in a separate glass graduated to 10 ml, the volume of return flow measured at the same time and subtracted from the 100 ml for obtaining correct consumption.
Position of 3-way valve
Filling of measuring device while engine is running.
Measuring device filled. Engine fueled from tank.
Engine fueled from measuring device Connection to tank closed
Measuring device filled up to plastic hose open on top.
¼" copper tube brased to plate fastened to box. (Same on bottom)
Upper mark
Volume between upper and lower mark = 100 ml =0.1 l
Lower mark
Clear plastic hose, internal diameter = 8 mm
From tank
To engine

Figure 10



OUTBOARD ENGINES YAMAHA 8 BK KEROSENE

PROPELLER : 9" x 5 3/4"

YAMAHA 15AK KEROSENE

PROPELLER 9 3/4" x 8"

LOAD 400 Kg. (Same in both boats)

Calm condition

18 FT.BOAT AND SRL17:

FUEL CONSUMPTION PER NAUTICAL MILE

Figure 11

28 FT. BOAT, SRL-14 AND SRL-15:
FUEL CONSUMPTION PER NAUTICAL MILE
Load :1300 kg.(4Onetsi- 8 men)

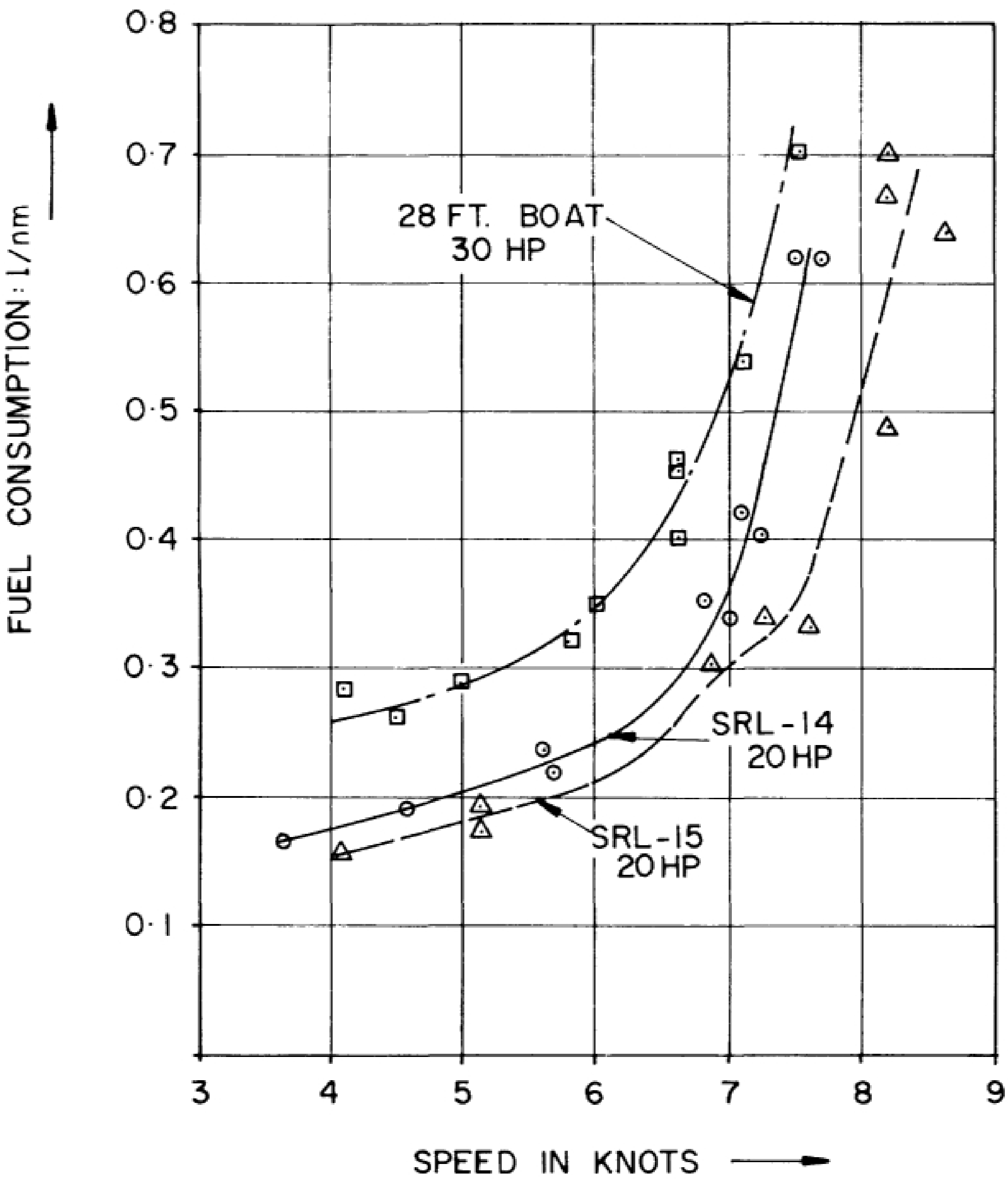
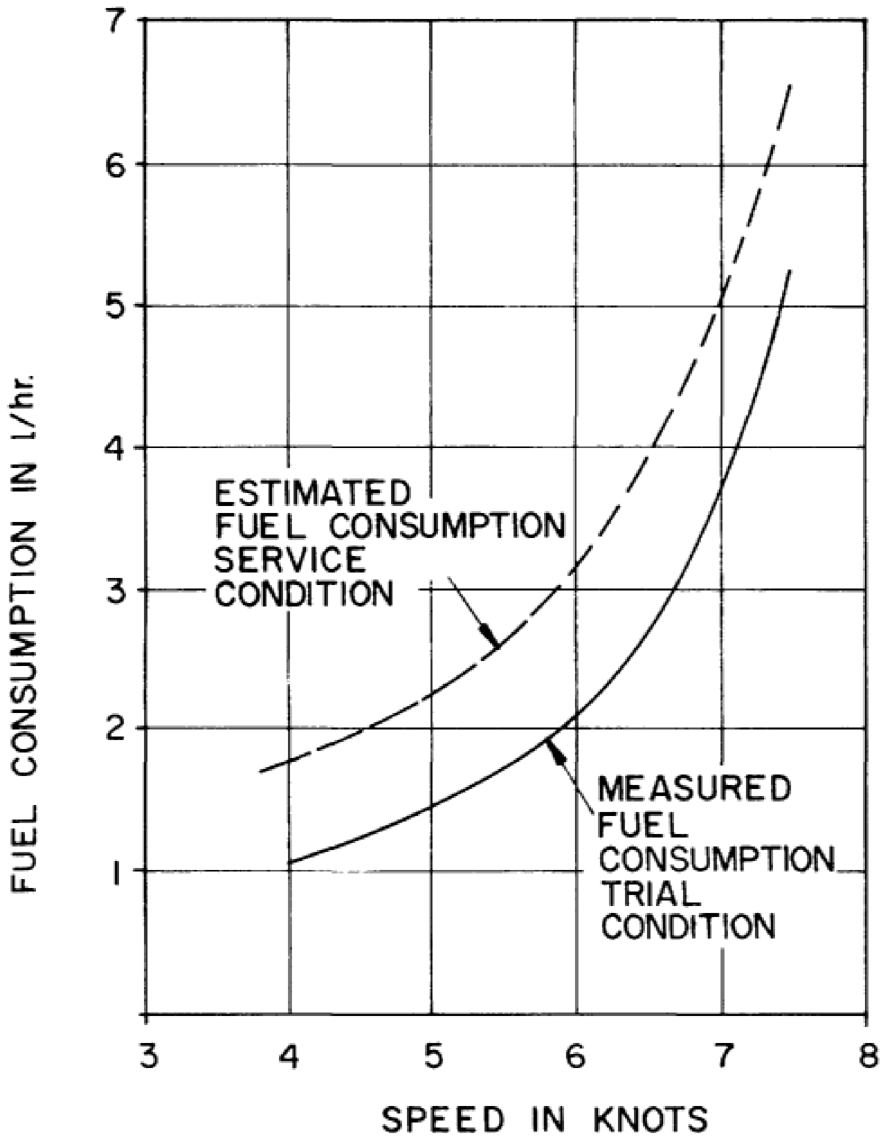


Figure 12



28 FT. BOAT WITH 3OHP ENGINE
FUEL CONSUMPTION PER NAUTICAL MILE

LOAD 1300 Kg. (4ONETS + 8 MEN)

Appendix 1

COST COMPARISON BETWEEN OUTBOARD ENGINE AND DIESEL INBOARD ENGINE FOR A 18 FT. FRP BOAT IN SRI LANKA

The outboard powered boat is shown in Fig. 7. The outboard engine is a kerosene engine starting on petrol developing maximum 7 hp at 5000 rev/mm.

The trial data in Fig. 10 show that this boat has a fuel consumption of about 2.60 I/h at a cruising speed of 5.5 kn. A diesel engine developing about 4 hp in service condition will give the same speed. An engine around 6 hp continuous power needs to be installed. Fuel prices (per litre) in Sri Lanka are (Dec. 1985)

Petrol	US $ 0.50
Kerosene	$ 0.27
Diesel	$ 0.34
Lubricating oil	$ 1.20

Fuel costs (per litre) for the different engines are

Outboard petrol	(Oil/petrol = 1/50)	=$ 0.51
Outboard kerosene	(Oil/kerosene = 1/30)	=$ 0.31
Diesel	(Oil/diesel = 1/130)	=$ 0.35

Cost comparison : *Outboard engine versus inboard diesel engine compared at the same speed = 5.5 kn*

	Outboard		*Inboard*
	Petrol	*Kerosene*	*Diesel*
Weight of engine including installation (kg)	27	27	100
Fuel consumption (I/h)	2.50	2.60	1.00
1. Fuel cost per litre including oil ($/l)	0.51	0.31	0.35
2. Fuel cost per hour ($/h)	1.28	0.81	0.46
3. Running time per year (hI	600	600	600
4. Fuel cost per year ($)	768	486	275
Cost of Capital:			
5. Initial cost ($)	600	700	2,000
6. Life of engine (yr)	2.5	2.5	5
7. Annuity factor at 15% interest	0.50	0.50	0.30
8. Capital cost per year ($)	300	250	600
9. Yearly cost of engine (4 + 8) ($1	1068	836	875

The conclusion in the case study above is that the petrol driven outboard engine is about 20% higher in yearly cost than the other alternatives.

With only 600 hours' operation per year, the diesel installation is not economically any better than the kerosene outboard engine. In addition there is the disadvantage of the high investment cost, the deep keel and increased weight when hauling the boat up the beach. This conclusion is based on present fuel prices and an estimated 600 hours of engine operation per year. As the number of hours of engine operation increases, the diesel engine becomes more attractive, as shown in Fig. 5.

Appendix 2

MAIN PARTICULARS OF BOATS TESTED

	Outboard powered		Diesel powered		
	18 ft.	SRL-17	28 ft.	SRL-14	SRL-15
Length over all LOA (ml	5.4	8.0	8.75	8.60	9.65
Beam moulded B (ml	1.75	0.9	2.60	2.62	2.67
Depth, rabbet to top of sheer O (ml	0.75	0.85	1.43	1.10	1.25
Cubic number to top of sheer CUNO = LOA x B x O (m3)	7	6	32	25	32
Length waterline (ml	4.90	7.40	7.60	8.15	9.00
Beam waterline (m)	1.50	0.64	2.30	2.40	2.60
Draft (ml	0.30	0.30	0.76	0.4/0.6'	1.00
Displacement light It)	0.3	0.5	1.9	1.6	2.1
Load (t)	0.4	0.4	1.3	1.3	1.3
Displacement loaded It)	0.7	0.9	3.2	2.9	3.4
Engine model	Yamaha	Yamaha	Yanmar	Faryman	Faryman
Maximum continuous hp/rpm	8 BK 7/5000	8 BK 7/5000			
Maximum continuous hp/rpm	15 AK 12/5000	15 AK 12/5000	30/2200	20/2500	20/2500
hp/t	8 BK-10; 15 AK-17	8 BK-7.8 15 AK-13.3	9.0	6.9	5.9
Reduction gear	2.08	2.08	2.13	3.65	3.65
Propeller	7 hp — 230	7 lip — 230	580	610	640
Diameter (mm)	12 hp — 248	12 lip — 248			
Propeller	7 hp — 146	7 lip — 146	330	410	450
Pitch (mm)	12 hp — 203	12 lip —203			

excluding volume of outrigger.

stern gear of pivoting engine installation in "down" position.

Appendix 3

FUEL CONSUMPTION DATA SHEET

Boat Type:
Date:

Persons/Organizations responsible for the trials

Trials must be performed only in protected water without waves on days with wind speed below 10 knots. With the same throttle setting one run must be made against the wind and one run with the wind. Eight different throttle settings should be made, starting from about 4.0 knots up to maximum speed. Load on the boat should be the same as given on the boat date sheet and in the same position as normally placed. Hull under water must be newly cleaned.

MEASUREMENTS						CALCULATIONS			
			(1)	(2)	(3)	(4)	(5)	(6)	7)
Wind Against	With	Engine	Boat speed	Time for 100cc	Time for lOOc	Return from injector	Fuel consump-tion = 100cc ÷ (3)	Fuel consump-tion (5)x3.6	Fuel consump-tion ***(6)/(1)***
		rev/mm	kn	mm sec	sec	cc	cc/sec	I/h	I/n mile
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Publications of the Bay of Bengal Programme (BOBP)

The BOBP brings out six types of publications:

Reporss (BOBP/REP/....) describe and analyze completed activities such as seminars, annual meetings of BOBP's Advisory Committee, and projects in member-countries for which BOBP inputs have ended.

Working Papers (BOBP/WP/...) are progress reports that discuss the findings of ongoing BOBP work.

Manuals and Guides (BOBP/MAG/...) are instructional documents for specific audiences.

Miscellaneous Papers (BOBPJMIS/. . .) concern work not originated by BOBP staff or consultants — but which is rdevant to the Programme's objectives.

Informaiwn Documents (BOBP/INF...) are bibliographies and descriptive documents on the fisheries of member-countries in the region.

Newsletters ***(Baj** of Bengal Xews),* issued quarterly, contain illustrated articles and features in non-technical style on BOBP work and related subjects.

A list of publications follows.

Reports (BOBP/REPJ...)

1. Report of the First Meeting of the Advisory Committee. Colombo, Sri Lanka, 28—29 October 1976. (Published as Appendix 1 of IOFC/DEV/78f44.1, FAO, Rome, 1978)
2. Report of the Second Meeting of the Advisory Committee. Madras, India, 29—30 June 1977. (Published as Appendix 2 of IOFC/DEV/78/44.l, FAO, Rome, 1978)
3. Report of the Third Meeting of the Advisory Committee. Chittagong, Bangladesh, 1—10 November 1978. Colombo, Sri Lanka, 1978.
(Reissued Madras, India, September 1980)
4. Role of Women in Small-Scale Fisheries of the Bay of Bengal. Madras, India, October 1980.
5. Report of the Workshop on Social Feasibility in Small-Scale Fisheries Development. Madras, India, 3—8 September 1979. Madras, India, April 1980.
6. Report of the Workshop on Extension Service Requirements in Small-Scale Fisheries. Colombo, Sri Lanka, 8—12 October 1979. Madras, India, June 1980.
7. Report of the Fourth Meeting of the Advisory Committee. Phuket, Thailand, 27—30 November 1979. Madras, India, February 1980.
8. Pre-Feasibility Study of a Floating Fish Receiving and Distribution Unit for Dubla Char, Bangladesh. G. Eddie, M. T. Nathan. Madras, India, April 1980.
9. Report of the Training Course for Fish Marketing Personnel of Tamil Nadu. Madras, India, 3—14 December 1979. Madras, India, September 1980.

10.1 Report of the Consultation on Stock Assessment for Small-Scale Fisheries in the Bay of Bengal. Chittagong, Bangladesh, 16—21 June 1980. Volume 1: Proceedings. Madras, India, September 1980.

10.2 Report of the Consultation on Stock Assessment for Small-Scale Fisheries in the Bay of Bengal. Chittagong, Bangladesh, 16—21 June 1980. Volume 2: Papers. Madras, India, October 1980.

II. Report of the Fifth Meeting of the Advisory Committee. Penang, Malaysia, 4—7 November 1980. Madras, India,January 1981.

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13. Report of the Sixth Meeting of the Advisory Committee. Colombo, Sri Lanka, 1—5 December 1981. Madras, India, February 1982.
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15. Report of the Consultation-cum-Workshop on Development of Activities for Improvement of Coastal Fishing Families. Dacca, Bangladesh, October 27—November 6, 1981. Madras, India, May 1982.
16. Report of the Seventh Meeting of the Advisory Committee. New Delhi, India, January 17—21, 1983. Madras, India, Match 1983.
17. Report of Investigations to Improve the Kattumaram of India's East Coast. Madras, India, July 1984.
18. Motorization of Cosintry Craft, Bangladesh. Madras, India, July 1984.
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20. Coastal Aquaculture Project for Shrimp and Finfish in Ban Merbok, Kedah, Malaysia. Madras, India, December 1984.

21. Income-Earning Activities for Women from Fishing Communities in Sri Lanka. Edeltraud Drewes. Madras, India, September 1985.

22. Report of the Ninth Meeting of the Advisory Committee. Bangkok, Thailand, February 25—26, 1985. Madras, India, May 1985.

23. Summary Report of BOBP Fishing Trials and Demersal Resources Studies in Sri Lanka. Madras, India, March 1986.

24. Fisherwomen's Activities in Bangladesh: A Participatory Approach to Development. Patchanee Natpracha. Madras, India, May 1986.

25. Attempts to Stimulate Development Activities in Fishing Communities of Adirampattinam, India. Madras, India, May 1986.

26. Report of the Tenth Meeting of the Advisory Committee. Male, Maldives. 17—18 February 1986. Madras, India, April 1986.

27. Activating Fisherwomen for Development through Trained Link Workers in Tamil Nadu, India. Edeltraud Drewes. Madras, India, May 1986.

28. Small-Scale Aquaculture Development Project in South Thailand: Results and Impact. E. Drcwes. Madras, India, May 1986.

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30. Summary Report of Fishing Trials with Large-Mesh Driftncts in Bangladesh. Madras, India, **May** 1986.

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1. Investment Reduction and Increase in Service Life of Kattumaram Logs. R. Balan. Madras, India, February 1980.

2. Inventory of Kattumarams and their Fishing Gear in Andhra Pradesh and Tamjl Nadu. T. R. Menon. Madras, India, October 1980.

3. Improvement of Large-Mesh Driftnets for Small-Scale Fisheries in Sri Lanka. G. Pajot. Madras, India, June 1980.

4. Inboard Motorisation of Small G.R.P. Boats in Sri Lanka. Madras, India, September 1980.

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6. Fishing Trials with Bottom-Set Longlines in Sri Lanka. G. Pajot, K. T. Weerasooriya. Madras, India, September 1980.

7. Technical Trials of Beachcraf't Prototypes in India. 0. Gulbrandsen, G. P. Gowing, R. Ravikumar. Madras, India, October 1980.

8. Current Knowledge of Fisheries Resources in the Shelf Area of the Bay of Bengal. B. T. Antony Raja. Madras, India, September 1980.

9. Boatbuilding Materials for Small-Scale Fisheries in India. Madras, India, October 1980.

10. Fishing Trials with High-Opening Bottom Trawls in Tamil Nadu, India. G. Pajot, John Crockett. Madras, India, October 1980.

11. The Possibilities for Technical Cooperation between Developing Countries (TCDC) in Fisheries. E. H. Nichols. Madras, India, August 1981,

12. Trials in Bangladesh of Large-Mesh Driftnets of Light Construction. G. Pajot, T. K. Das. Madras, India, October 1981.

13. Trials of Two-Boat Bottom Trawling in Bangladesh. G. Pajot,J. Crockett. Madras, India, October 1982.

14. Three Fishing Villages in Tamil Nadu. Edeltraud Drewes. Madras, India, February 1982.

15. Pilot Survey of Driftnet Fisheries in Bangladesh. M. Bergstrom. Madras, India, May 1982.

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18. Review of Brackishwatcr .Aquaculture Development in Tamil Nadu. Kasemsant Chalayondeja and Anant Saraya. Madras, India, Augsist 1982.

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21. Improved Deck Machinery and Layout for Small Coastal Trawlers. G. Pajot, J. Crockett, S. Pandurangan and P. V. Ramamoorthy. Madras, India, June 1983.

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25. Fishing Craft Development in Kerala: Evaluation Report. 0. Gulbrandsen. Madras, India, June 1984.

26. Commercial Evaluation of IND-l3 Beachcraft at Uppada, India. R. Ravikumar. Madras, India, June 1984.

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30. Mackerels in the Malacca Straits. Colombo, Sri Lanka, February 1985.

31. Tuna Fishery in the EEZs of India, Maldives and Sri Lanka. Colombo, Sri Lanka, February 1985.

32. Pen Culture of Shrimp in the Backwaters of Killai, Tamil Nadu: A Study of Techno-economic and Social Feasibility. Rathindra Nath Roy, Madras, India, January 1985.

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