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SELECTION AND INSTALLATION OF A FISHING BOAT ENGINE

Compiled by

SHINZO YAMAMOTO

Training Department

Southeast Asian Fisheries Development Center

Preface

This textbook on selection and installation of fishing boat engine has been compiled for the Regional Training Course for Extension Officers and also for use by the Marine Engineering Course trainees of the SEAFDEC Training Department.

The spark ignition volatile-fuel engine, excellent as it is, is wasteful when compared with the diesel engine in terms of thermal efficiency. The latter delivers 30~38 percent while the spark ignition engine 22-25 percent, and consequently, it is economical with fuel. It is also a good puller (high torque), reliable and robust and its mechanically accurate metering pump replaces the carburettor and electrical ignition apparatus which is vulnerable in rough sea conditions.

As a matter of fact in the marine field, the diesel engine of even small horsepower has become the main source of power to propel the fishing boat and its auxiliary machinery. Therefore in this text I only touch upon the diesel engine ranging from 3 to 1000 horsepower which is most popular in Southeast Asia.

Although many books have been written about various aspects of diesel engine such as its design, principles, construction, performance, operation and maintenance, it is difficult to find books or articles on how to select a suitable fishing boat engine. I realized during my compilation of information that no ready-made solution can be obtained, because it is difficult to specify which engine is the most suitable for a particular fishing operation.

This does not always mean that there are many possible approximate answers for choosing the engine as much as to say that there are a number of manufacturers producing commodities such as your car or your house at different prices.

Actually there are so-called good engines and not-so-good engines; we can observe this for instance concerning the significant differences in fuel consumption when we compare the same horsepower conducting the same fishing operations. Therefore in order to reach a better answer to these problems, the minimum necessary conditions for such an answer may be considerable. I have tried to summarize them simply and clearly.

The actual installation of the diesel engine is not included in the above mentioned difficulty. The installation can be done by following manuals. Of course the installation parameters should be considered when planning the design of the fishing boat beforehand.

SHINZO YAMAMOTO
Training Department
SEAFDEC

BANGKOK
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1. SELECTION OF FISHING BOAT ENGINE

1.1 Specific features of the fishing boat engine

It is not easy to choose the most suitable diesel engine even though such factors as fishing method, type of boat, speed resulting from the hull shape and the required horsepower of the engine are known. The complex procedure of engine selection can be devided into six phases as shown in Fig. 1*. In this textbook we shall deal only with Phases 5 and 6.

A fishing boat engine is required not only to cruise at an appropriate speed, but also to be capable of being handled by an unskilled operator without developing any malfunctions, even in difficult conditions, such as heavy weather and storms encountered far from the shore.

It is therefore imperative to maintain perfect operational reliability** of the engine.

Operational reliability results from appropriate design, suitable materials, good manufacture, as well as good operation and maintenance. These factors will provide absolute confidence for the fisherman with regard to the safety of fishing operations and will affect the size of catch.

1.2 The necessary conditions for the fishing boat engine

If you want to select an appropriate type of diesel engine for your fishing operation, at least the following ten major considerations have to be taken into account.

(i) Is the engine durable in any operating conditions?

Generally speaking, the load conditions of a fishing boat engine are much more severe than those of other heavy vehicles. For instance, the engine requires a higher torque at a low revolution

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* From "Fishing Techniques", JICA, Dec. 1975

** (1) Operational reliability = Inherent reliability x Use reliability

(2) Reliability is the probability that a part, device or equipment system will perform its intended function for a specified period of time under given conditions.

for trawling operation. At the same time, when the boat cruises it is required to haul a heavy load for a long time until its return to the starting port. On the contrary, engines of road vehicles run most of the time under part-load conditions with only intermittent demand for maximum power accompanied by high acceleration rate. Another type of fishing boat such as for drift gill nets fishing requires hundreds of on-off operations of clutch every day. Then durability of the fishing boat engine is assential.

(ii) Is it reliable, without failures over the expected period?

It is necessary to maintain the performance of the engine under any quick change of loading such as during bad weather, or continued long cruising, without any failure occurring.

(iii) Is it economical in fuel and lubricating oil consumption?

Recently, the fuel and lubricating oil costs have soared so that they account for more than 60-70 percent of the total fishing operation expenditure as shown by a survey.

Therefore the importance of saving fuel cannot be overemphasized. The fuel consumption ratio curve should preferably be as flat as possible whatever the load.

Additionally, the ratio of the lubricating oil consumption against the fuel consumption should be checked.

(iv) Is maintenance work possible in the engine room?

It must be possible to change parts such as piston rings or to make repairs easily in the engine room without dismounting the engine from the boat. Sometimes the costs of dismounting the engine off the boat exceeds the initial installation costs.

(v) Are there many service shops and are spare parts readily available?

It goes without saying that the engine must be repaired quickly when it fails, and moreover, periodical maintenance is needed. For these purposes the number of service shops and abundance of interchangeable spare parts and quick delivery are essential to increase the Availability of the boat. Availability means ratio between the amount required to satisfy the demand and that which can be obtained under planning (operation period). When two or more sources of supply exist the bonus factor is increased.

An abundance of spare parts means that this type of engine has been produced in great numbers or might be mass-produced. Therefore it is often an advantage to buy an engine produced by well-known manufacturers.

(vi) Is it of compact size and of light weight?

A compact, light-weight engine not only requires minimum space for installation but also gives easy maneuverability of the boat, and faster speeds can be obtained. Then we must compare the index of the engine weight (kg) divided by its horse-power (ps); generally the low speed engine shows 20-30 kg/ps and the high speed engine not more than 15 kg/ps approximately.

Of course, there is always a controversial problem of whether a high-speed or low-speed engine is suitable for fishing operations. However, the answer to this is whether the engine meets all your fishing operation needs as well as the overall cost.

(vii) Does it have sufficient capacity and durability of marine gear (clutch)?

In fishing operations the role of the clutch is important; in conjunction with reverse and reduction gearing it transmits power to the propeller. Therefore the capacity and durability of the clutch, including astern transmitting capacity, half-clutching capacity, operating power on-off work, should be ascertained. Some older mechanical clutches require constant adjustment on the clutch plate so that a simple adjusting device is required, but modern clutches generally have hydraulically operated gears. If the capacity of clutch meets all requirement perfectly no adjustments needs to be made between overhauls.

(viii) Is the reduction gear ratio suitable for the hull and fishing operation?

To ensure better efficiency of the propeller and good operation of the boat, an adequate reduction gear ratio should be choosen.

(ix) Does it save man-power and maintenance costs?

The operation of the engine should be done by remote control, not only from the engine room or wheel house but also from another deck. The remote control should be provided with a warning device, if possible. In addition, the period between overhauls should be long such as 5000-8000 hours of service which is guaranteed by the manufacturers, since this will reduce maintenance costs accordingly (replacement of minor parts and overhauling costs).

(x) Does it satisfy the maritime regulations?

There are many regulations for hull, equipment, and engine, which vary from country to country. It is therefore necessary to comply with the regulations. For instance, the crank shaft materials and strength, and the diameter of the propeller shaft are strictly specified by the authorities from the viewpoint of safety of the boat.

1.3 More detailed checking for selection of a suitable engine

After determining the most likely suitable type of engine for fishing operations by the above ten items, a further detailed examination of the actual engine specifications and construction is needed for the successful selection of your engine. If possible, ask the expert or contact a user of the type of engine selected and a sales agent to check the following items which are all of equal importance:

- Check the factory or catalog performance data at a maximum continuous rating, exhaust temperature of mean effective pressure (Pme) that is of a lower value. If possible other factors, such as power factor (Pme x Piston speed), should be checked.

- Check the idling (dead slow) revolution to ascertain that it meets the requirements of your fishing operation and fuel consumption.

- Is the engine engine easy to start?

- Check the anti-corrosion measurement device; does it work effectively and is it easy to maintain?

- Is it easy to check the main moving parts of the engine or bearing in the engine room?

- In the "clutch off" condition there should not be even the slightest transmission of power to the propeller shaft. Slow rotation of the screw-shaft can result in the net or the line being caught in the propeller shaft.

- Does the critical torsional vibration speed coincide with your fishing operation revolution?

- "Surging phenomenon" should be checked if the engine is equipped with a turbo-charger.

- Check the vibration at every stage of the engine revolution.

- Does the engine match your boat (see Installation parameters)?

- It is easy to perform routine checking of the engine such as valve timing, injection timing, change of lubricating oil, cleaning or change of fuel and oil filter elements.

- Is it easy to check the cooling pump system?

  Trouble is frequently caused by plastic substances being sucked into the pump system.

- Is the capacity of the auxiliary power takeoff from the front shaft enough for your fishing gear drive or any other purpose? (generator drive)

- Is the construction simple and easy to disassemble in order to enable your operator to change the parts without using special tools?

- Check the pipe line attached to the engine.

  A failure of the piping system tends to occur easily and is extremely annoying, so the less piping the better.

- Is there a good warning system or device to prevent any failure of the main function which would lead to a critical situation?

- Is there an emergency apparatus or device attached to the clutch system and turbo-charger in case they fail?

- Is the instruction manual provided written in the local language? Is a parts list provided or available at yours agent's shops?

- Is the engine dealer or agents or repair shop able to repair the engine efficiently?

- Are sufficient standard spare parts and tools provided?

- If possible, observe the actual working conditions.

- Check for oil leakage!

  Especially check for leakage of lubricating oil and fuel from the engine. It is possible to say that from my experience engine can be considered good if there is no leakage of any oil under ordinary maintenance conditions.

- Finally try to ascertain from as many users as possible the reputation of the engine used for the same fishing operation which you intend to do.

[The good qualities of an engine are evaluated by the actual results obtained by the user.]

2. INSTALLATION OF FISHING BOAT ENGINE

2.1 Installation parameters - engine room layout

When designing a new boat or when repowering an old one, there are several factors to consider regarding the power plant, which require preplanning in order to ensure a good engine installation. Proper planning will avoid costly revision work which may arise later when troubleshooting. Maintenance and repairs occur. A checklist of points to consider for planning purposes is given below. See the Installation guidance of manufacture (I.G).

Clearance

a. To allow the engine and all accessories to fit in the hull.

b. For accessibility to perform minor maintenance work.

c. For ventilation between engine and hull or adjacent equipment.

d. To allow for future removal and installation of the engines by providing removable hatches or adequate clearance in the entrance hatches.

Inclination and Trim of the Vessel

a. Effect of engine weight and its location.

b. Effect of storage tanks for fuel, lubricating oil, and water.

c. Location of battery packs and other heavy accessory equipment.

Engine Bed Structure

a. Should have strength to support the weight of the engine.

b. Should have rigidity under the torque and thrust loads of the propeller and boat movements.

c. Should allow for engine accessory location and oil pan removal.

d. See I.G. "Engine Foundations".

Location and Routing of Services

a. Lubricating oil filters, fuel filters, engine water filters, and sea strainers must be readily accessible for maintenance and inspection.

b. Piping runs should be direct but as neat appearing as possible. Use a minimum number of elbows and other fittings to avoid flow restrictions and reduce installation costs.

Ventilation

a. Determine capacity required for engine room cooling and air consumption by main engines and auxiliaries. Necessary volume of air is 0.1~0.2 m^3/min/ps for the main engine.

b. Determine flow part of ventilating air to do the most efficient job.

Fuel System

a. Adequate tank capacity, considering vessel operations and availability of fuel and separation of water (good water drainage).

b. Proper tank location in the vessel and fuel level with respect to the engine fuel pump.

c. Proper line sizing, routing and material.

d. Possibilities of future leaks and fire hazards involved.

e. Proper isolating valves where needed.

f. See I.G. "Fuel Systems".

Cooling System

a. Consider whether it should be a heat exchanger or other cooling system, taking into consideration the boat operation and average sea temperatures.

b. Consider need for and location of sea strainers.

c. Consider hull fitting locations and piping paths to them to avoid excessive flow restriction.

d. See I.G. "Cooling Systems"

Exhaust System

a. Determine whether it should be a wet or dry stack system.

b. Determine most direct piping runs. Check the back pressure 250mm/Aq.

c. Determine mufflers to be used and locations.

d. Provide for preventing rain water or sea water from entering the engine.

e. Eliminate fire hazards due to hot-spots in the system.

f. See I.G. "Exhaust Systems".

Starting System

a. Determine whether it should be air, electrical, or hydraulic.

b. Determine whether it should be remote or engine room starting.

c. Consider air pressures or voltages available and required.

d. Consider wire sizes, routing and exposure of connections.

Controls

a. Whether mechanical, pneumatic, hydraulic, or electrical controls should be used will depend on the availability of air or electricity for control and on the vessel operation.

b. Establish location of the operator's controls and ease of cable versus pipe or electric wiring runs.

c. Consider experience and ability of the operator.

d. Sea I.G. "Control Systems".

Vibration and Noise Isolation

a. Decide on method of mounting engine to engine foundation. Use of isolation mounts depends on whether the vessel hull transmits or dampens vibration and whether the vessel is intended for commercial or some other use.

b. Determine possibility of engine room insulation against noise.

c. Use flexible hose and fixtures for all fuel, water, exhaust and other connections between the engine and the hull.

Legal Requirements

a. Check all local, state, and federal requirements regarding marine inspection of commercial and pleasure vessels and adhere to them. It is especially important to check the temperature of exhaust pipe and the heat insulation, as fire is often caused by the fuel leakage.

2.2 Engine installation for small wooden fishing boat

In engine installation, the structure of the engine bed is most important. This is especially true in the case of a wooden boat, where the engine bed has to be made of extra-hard wood.

The recommended dimensions of engine bed are as follows:

Engine	P.S. (HP) -50	50-100	100-250	200-300	300-
Width and thickness of engine bed	27cm	30	33	36	39

Note : The length of the wooden bed is at least twice the engine length.

Installation manual should be followed for other installation items such as:

(A) Propeller clearance

(B) Engine bed

(C) Alignment

(D) Piping procedure and materials

(E) Wiring & remote control system

(F) Front power take-off

(G) Engine room ventilation

ENGINE INSTALLATION

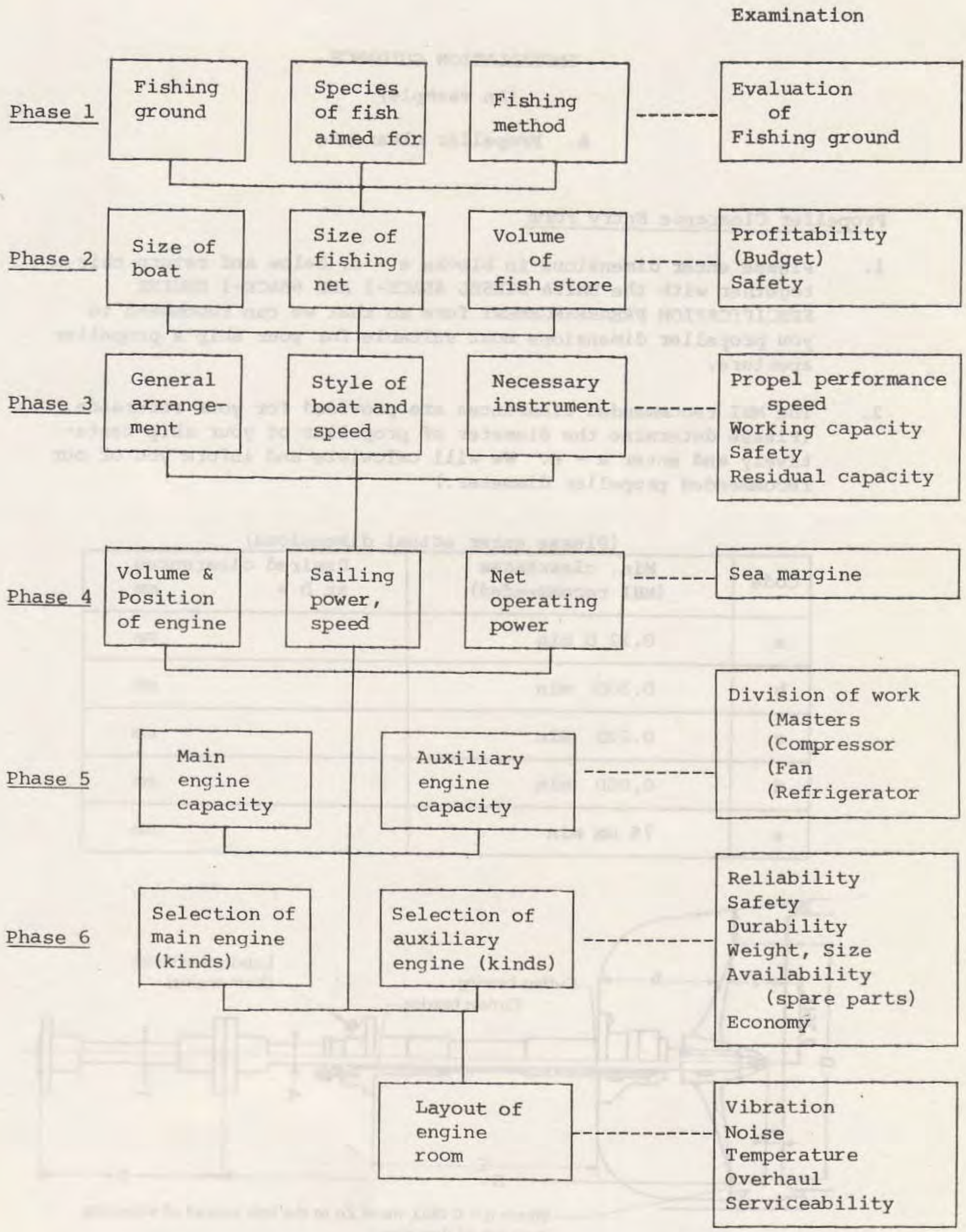


Fig. 1. The procedure in engine selection (from "Fishing Techniques", JICA, Dec. 1975)

INSTALLATION GUIDANCE

(An example)

A. Propeller clearance

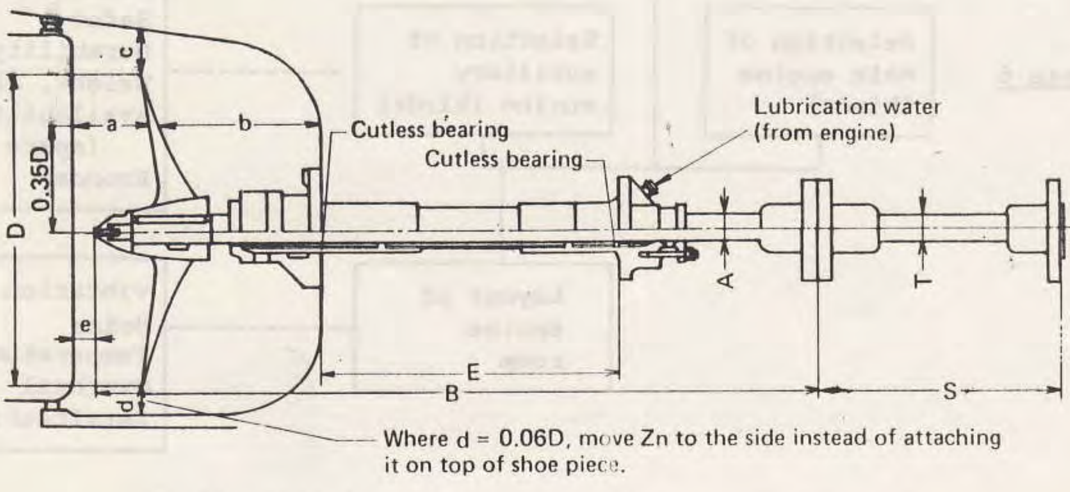
Propeller Clearance Entry Form

1. Please enter dimensions in blocks a - e, below and return this together with the DAIYA DIESEL 4SACE-1 AND 6SACE-1 ENGINE SPECIFICATION PREARRANGEMENT form so that we can recommend to you propeller dimensions most suitable for your ship's propeller aperture.

2. The MHI recommended clearances are provided for your reference. (Please determine the diameter of propeller of your ship tentatively and enter a - e. We will calculate and inform you of our recommended propeller diameter.)

(Please enter actual dimensions)

Code	Min. clearances (MHI recommended)	Desired clearances at D = mm
a	0.12 D min	mm
b	0.30D min	mm
c	0.22D min	mm
d	0.06D min	mm
e	75 mm min	mm



Model	Reduction gear ratio	*Propeller (mm)		**Stern gear dimensions (mm)				
		3 blades D x P	4 blades D x P	A	T	B	S	E
4 SACE-1 500 SHP / 1000rpm	1.92	1350 X 770	1300 X 770	130	115	3500	1500	2000
	2.52	1610 X 900	1550 X 900	140	125	3500	1500	2000
	*3.08	1760 X 1080	1700 X 1080	150	135	3500	1500	2000
6 SACE-1 750 SHP / 900 rpm	1.84	1530 X 840	1470 X 840	145	130	3500	1500	2000
	2.39	1730 X 1080	1670 X 1080	160	145	3500	1500	2000
	*2.83	1930 X 1200	1860 X 1200	170	155	3500	1500	2000

* : Standard reduction gear ratio
Please consult with us when you need the propeller dimensions for trawlers.

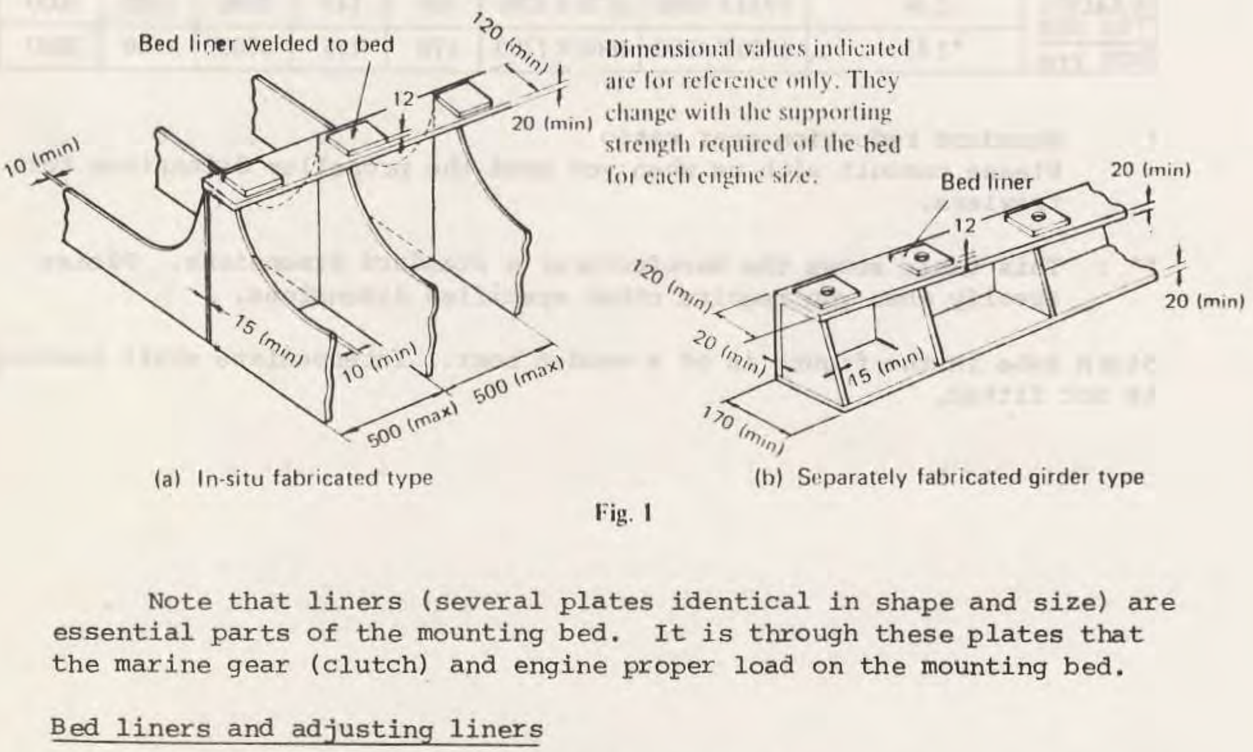
** : This table shows the manufacturer's standard dimensions. Please specify when you require other specified dimensions.

Stern tube in the figure is of a wooden boat. Intermediate shaft bearing is not fitted.

B. Engine bed

Foreword

What we need is not the detailed technical knowledge of an engine application engineer but a general idea of key considerations involved in engine installation work. The discussion to follow, based on the Type-S engine, is under-scored by this objective.



(a) In-situ fabricated type

(b) Separately fabricated girder type

Fig. 1

Note that liners (several plates identical in shape and size) are essential parts of the mounting bed. It is through these plates that the marine gear (clutch) and engine proper load on the mounting bed.

Bed liners and adjusting liners

Bed liners are usually welded to the bed, and their top faces are machined smooth and flush at a certain designated plane. The levelness of their faces is checked with a long straight-edge bar and feeler gauges, as shown in Fig. 2. Each bed liner is sloped outward, presenting a gradient of 1/100 to 1/200, in order to facilitate insertion of adjusting liners.

Mounting bed construction

Roughly speaking, there are two types of bed construction: in-situ fabricated bed, Fig. 1 (a), and separately fabricated girder type, Fig. 1 (b). For steel vessels, the existing structural members, such as bottom strakes, of the vessel serve as a reliable foundation for supporting the bed: this construction is illustrated in Fig. 1 (a).

For wooden vessel, the common practice is to build two girders like the one shown in Fig. 1 (b), and set them parallel on the floor of the engine room.

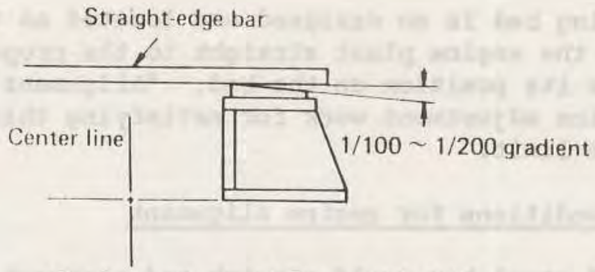


Fig. 2. Levelness and flatness of bed liners

Adjusting liners are sheets sized to match bed liners; they are used to fill the clearance occurring between bed liners and the seating faces of the engine. When the adjusting liners become necessary and how to use them will be discussed in the next section (Engine positioning and alignment).

Instead of using bed liners, the top faces of the bed members may be machined flat and smooth to directly support the engine. This method is economical for small-size engines. In this case, too, the outward slope of 1/100 to 1/200 is required of the top faces for facilitating insertion of adjusting liners.

Bolt hole drilling

After setting up the bed, mounting bolt holes must be drilled through the liners and bed members. Blowing holes through by operating a cutting torch is a sloppy way of working and is not permitted for the engine bed. The hole must be located exactly and drilled true and accurate, so that the radial clearance occurring between mounting bolts and holes will be minimized.

Bolt holes with ugly burrs showing at the edge are evidence of bad workmanship. Normal engine installation work begins with an accurately dimensioned and carefully machined mounting bed, of which the mounting holes are of great importance.

C. Alignment

Engine positioning and alignment

The mounting bed is so designed and located as to point the output shaft of the engine plant straight to the propeller shaft when the engine takes its position on the bed. "Alignment" actually means, in one sense, fine adjustment work for satisfying this requirement within the close limit.

Ambient conditions for engine alignment

A piece of steel bar would stretch and contract as its temperature rises and falls. A load-supporting mechanical member is always in a more or less strained state, and its strain (or distortion) changes with its load. Where there is a stress (which is an internal force), there is a strain.

Though almost imperceptibly small are these physical changes, they have critical bearing upon drive available from the engine through its output shafting. When aligning the engine in place:

(a) The vessel must be in properly ballasted state.

(b) Fuel, water and other tanks or storage spaces must be half-to-3/4 full.

(c) All machinery, weighing more than 450 kg apiece, must be in place.

In other words, the vessel must be in loaded condition, simulating its normal operating state.

Preparatory steps for aligning work

After tentatively mounting the marine gear or clutch and engine proper upon the bed, a total of 16 adjusting brackets (for the Type-S engine considered here) are welded to the bed. See Fig. 1.

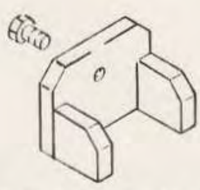


Fig. 1 Adjusting bracket

The adjusting brackets are actually jacking means. They are located at such positions that the engine proper and marine gear can be turned around by very small amounts in seated condition. Fig. 2 is a plan view, showing the jacking screws of the brackets pointing horizontally.

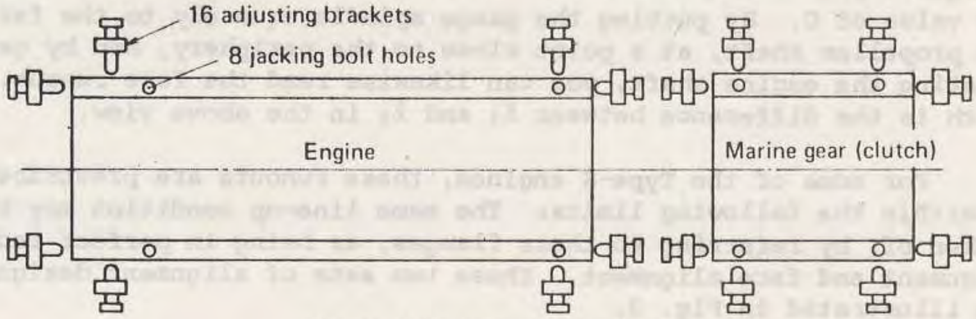


Fig. 2 Adjusting bracket positions

Alignment terminology

When two flanged shaft ends are abutted to each other, with the axes of the two shafts lined up perfectly straight, the two are said to be aligned angularly, vertically and horizontally.

In marine engine work, it appears that radial alignment and face alignment are more commonly referred to because c, ℓ_1 and ℓ_2 are measured in terms of "runout" with an instrument called a dial gauge, which is very handy in measuring small displacements or "runouts." After all, c, ℓ_1 and ℓ_2 are but small displacements.

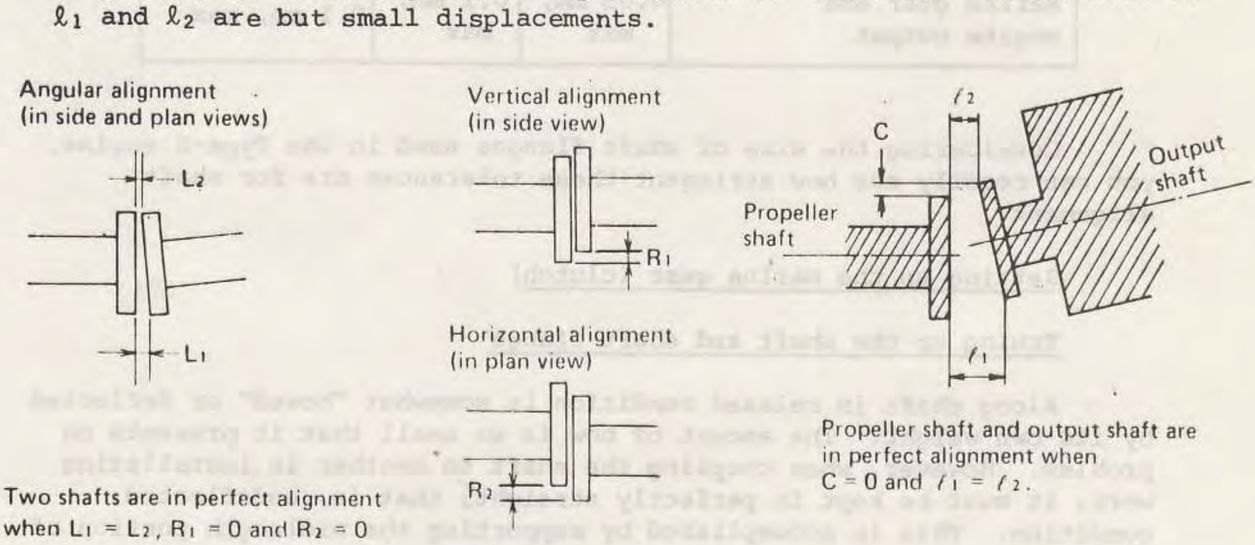


Fig. 3 Alignment terminology

Alignment tolerances

Install a dial gauge on the periphery of the engine output shaft flange, with the spindle of the gauge put squarely to the peripheral surface of the propeller shaft flange, and rotate the engine shaft slowly. In one complete revolution, the gauge indication changes. The maximum indication is the radial runout, which is twice the value of C. By putting the gauge spindle squarely to the face of the propeller shaft, at a point close to the periphery, and by gently rotating the engine shaft, you can likewise read the face runout, which is the difference between ℓ_1 and ℓ_2 in the above view.

For some of the Type-S engines, these runouts are prescribed to be within the following limits: The same line-up condition may be spoken of, by referring to their flanges, as being in perfect radial alignment and face alignment. These two sets of alignment designations are illustrated in Fig. 3.

Coupling	Radial alignment		Face alignment
	Value of C	Radial runout	Face runout (= $\ell_1 - \ell_2$)
Propeller shaft and marine gear	0.05 mm, max	0.1 mm, max	0.1 mm, max
Marine gear and engine output	0.05 mm, max	0.1 mm, max	0.1 mm, max

Considering the size of shaft flanges used in the Type-S engine, you can readily see how stringent these tolerances are for shaft alignment.

Setting up the marine gear (clutch)

Truing up the shaft and shaft flange

Along shaft in relaxed condition is somewhat "bowed" or deflected by its own weight. The amount of bow is so small that it presents no problem. However, when coupling the shaft to another in installation work, it must be kept in perfectly straight, that is, undeflected condition. This is accomplished by supporting the midlength portion of it in the manner illustrated in Fig. 4. To "true up" in this sense too is called "to align."

The shaft associated with the marine gear must be aligned in place before it is coupled. The alignment is checked by reading its radial runout at unsupported portions and at its flange. The flange must be checked also for face runout. The shaft is ready for coupling when all these runouts are not greater than 0.1 mm and its flange aligned accurately to its partner flange.

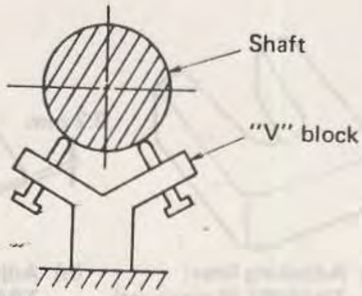


Fig. 4 Supporting a shaft for "truing up"

Checking the coupling alignment with straightedge and feeler gauge

It is the marine gear (clutch) that takes its position first. To align its shaft to the propeller shaft, the coupling flanges may be checked for alignment with a straightedge and feeler gauge, instead of a dial gauge, in the manner illustrated in Figs. 5 and 6.

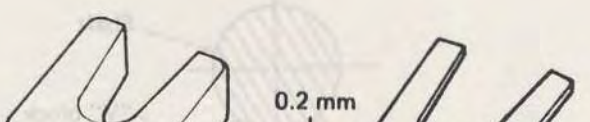
Fig. 5 Checking radial alignment

Fig. 6 Checking face alignment

Use of adjusting liners

To align the marine gear to the propeller shaft, the gear unit must be adjusted, that is turned or lifted or angled on the bed by small amounts. After making sure that the coupling flanges are properly matched in the manner already explained, the clearance between each bed liner or the bed top and the gear unit must be filled by driving a properly sized adjusting liner into the clearance. Care is required so that the liners driven in will not disturb the alignment.

Adjusting liners are usually supplied in two kinds, which are shown in Fig. 7. Note that one is relatively thick while the other is very thin.



(a) Adjusting liner: TB48082 (8-piece set) (b) Adjusting liner: TB48083 (40-piece set)

Fig. 7 Adjusting liners for the marine gear

Securing the marine gear and alignment logging

With the adjusting liners fitted, the marine gear is now sitting solidly on the bed. The next step is to secure it in the manner illustrated in Fig. 8. The same method is used in securing the engine.

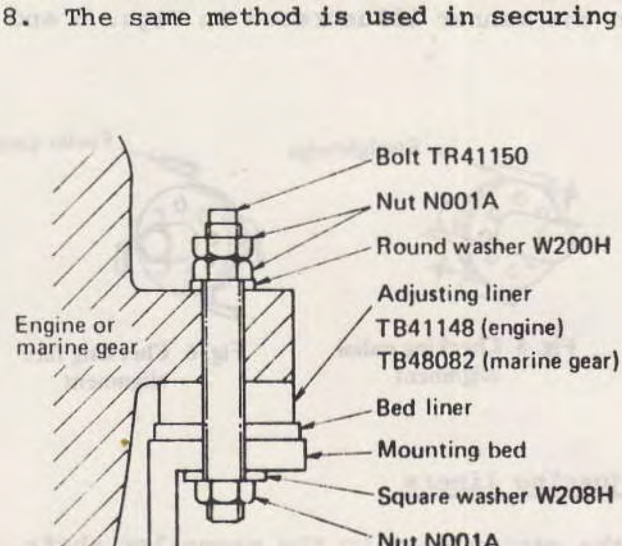
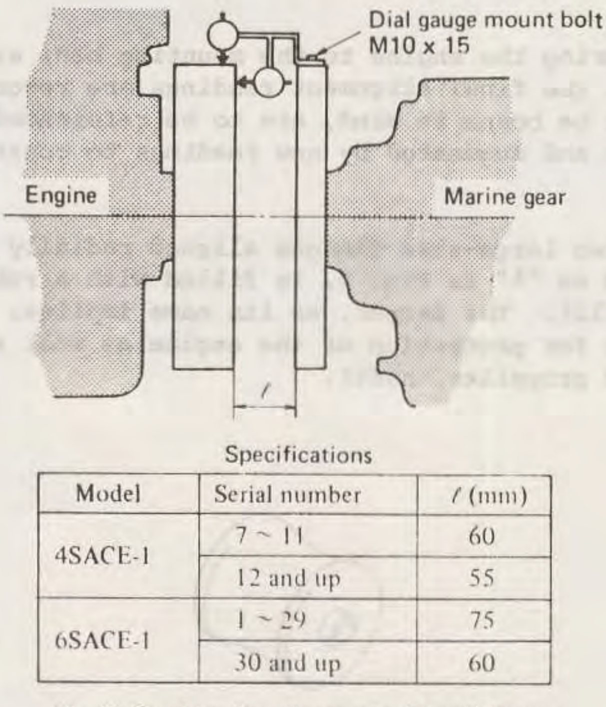


Fig. 8 Bolting to the mounting bed

The mounting bolts must be tightened gradually and uniformly, while checking the coupling alignment from time to time. If any misalignment occurs in the process, additional adjusting liners should be put in or the existing liners should be replaced. In short, this bolting is a delicate job demanding the highest skill and mental concentration on the part of installing mechanics. The job is completed by recording the final alignment readings for certifying and future-reference purposes.

Setting up the engine

With the marine gear set and aligned to the propeller shaft, the next step is to set up the engine. This job is not much different from that of installing the marine gear. The main difference is in the size of the coupling flanges, which are large for the connection between engine shaft and marine-gear shaft. The usual practice is to use a dial gauge instead of a straightedge, feeler gauge and the like. Fig. 9 shows two dial gauges rigged up on the marine gear flange. Actually, only one dial gauge is used: it is repositioned from time to time, now checking radial alignment and then checking face alignment.

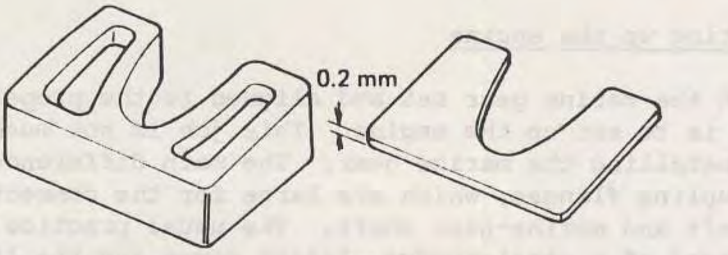


Specifications

Model	Serial number	ℓ (mm)
4SACE-1	7 ~ 11	60
	12 and up	55
6SACE-1	1 ~ 29	75
	30 and up	60

Fig. 9 Checking the alignment with a dial gauge

The engine standing on the bed is so heavy that it is a big job to reposition or adjust the engine to bring its flange into perfect alignment with that of the marine gear. The process of checking the radial and face alignments alternately has to be repeated a number of times while moving the heavy engine just a little at each time. The adjusting liners used on the engine, too, are in two kinds, as shown in Fig. 10.



(a) Adjusting liner: TB41148 (16-piece set) (b) Adjusting liner: TB41149 (32-piece set)

Fig. 10 Adjusting liners for the engine

After securing the engine to the mounting bed, as in the case of the marine gear, the final alignment readings are recorded. These records, it must be borne in mind, are to be referenced at each subsequent inspection and augmented by new readings to constitute an alignment log.

With the two large-size flanges aligned radially and axially, the space (indicated as "ℓ" in Fig. 9, is filled with a rubber damper (shown in Figs. 11 and 12). The damper, as its name implies, dampens or absorbs torsional shocks for protection of the engine as well as the drive line (marine gear and propeller shaft).

Fig. 11 Damping element of the damper

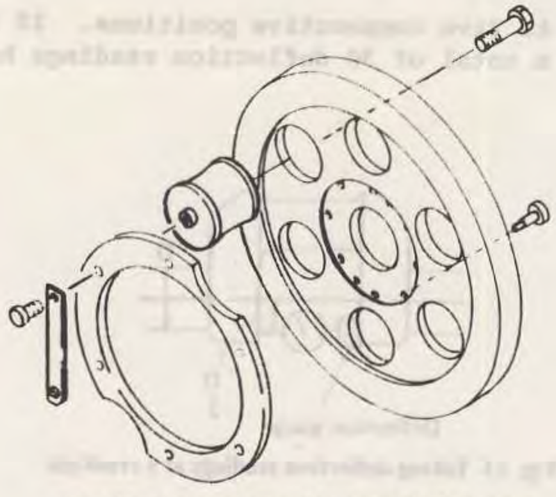


Fig. 12 Damper assembly in exploded view

Deflection measurement

This topic is not related directly to engine installation work, but is of great importance and remains so for the life of the engine.

It will be recalled that, where there is a stress, there is a strain. No vessel is perfectly stiff and rigid and no piece of steel, as an engine crankshaft, is perfectly stiff and rigid. The vessel in service is subject to all kinds of stresses - bending stress, tensile stress, compressive stress, torsional stress, etc. Some stresses are of cycling type and others are persisting type, depending on the loaded, cruising or weather conditions.

The crankshaft of a marine engine in service has to withstand all these stresses, particularly bending stress, which could be so severe at times to produce a permanent deflection or "bow" in it. Because of this possibility, the engine is periodically opened and its crankshaft checked in place for bow. The usual practice is to check once a year.

Not only the crankshaft but also the shafts in the marine gear and the coupling flange (next to the engine flywheel) are similarly checked and recorded. The method of checking the crankshaft for deflection is shown in Fig. 13. Note that a gauge block and a dial gauge are used at each crankpin to take five readings at different angular positions. This means that the crankshaft must be "barred" to bring the crankpin to five consecutive positions. If the engine is a 6-cylinder unit, a total of 30 deflection readings have to be taken.

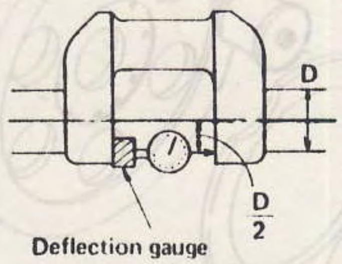


Fig. 13 Taking deflection readings at a crankpin

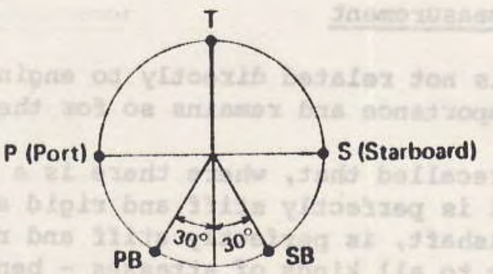


Fig. 14 Angular positions at which readings are taken

The format for logging the alignments (mentioned previously) and crankshaft deflection; it can be used on engines before and after installation aboard vessels.

ALIGNMENT RECORD

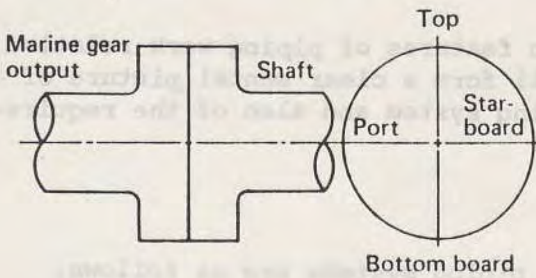
Type: ______________________

Month	Day	Year

Serial No.: ______________________ Agent: ______________________

Installed by: ______________________

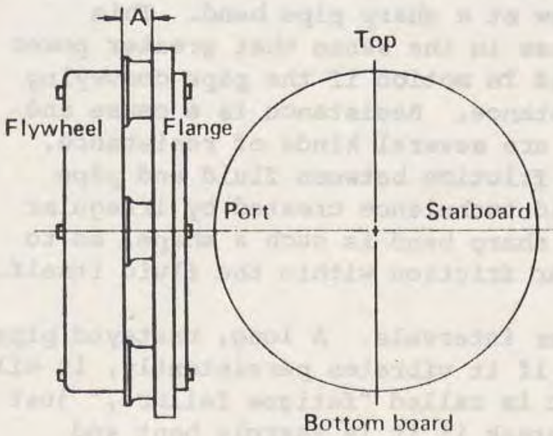
1. Marine gear to shaft (land or aboard)



Readings $\frac{1}{100}$ mm

Posi-tion / Alignment	Top	Port	Bottom board	Star-board
Radial				
Face				

2. Flywheel to flexible coupling (land or aboard)

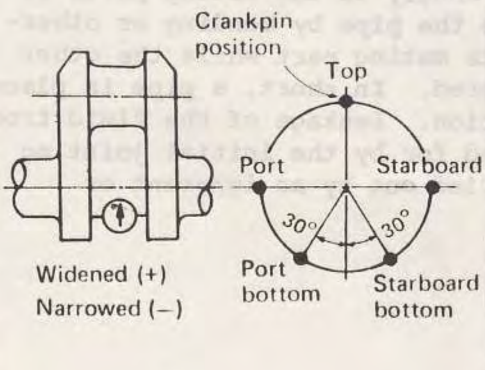


Readings $\frac{1}{100}$ mm

Posi-tion / Alignment	Top	Port	Bottom board	Star-board
Radial				
Face				
Separation "A"				

3. Crankshaft deflection (land or aboard)

When checked: (hours) Ambient temperature (°C) $\frac{1}{100}$ mm



Cyl / Position	Bow 1	2	3	4	5	Stern 6
Starboard bottom						
Starboard						
Top						
Port						
Port bottom						

D. Piping procedure and materials

Piping work

The maze of pipe lines that you see in the engine room consists of five major kinds: namely, fuel piping, lube oil piping, air piping, exhaust piping and water piping.

This section discusses the main features of piping work relative to the Type-S engine, so that we shall form a clear mental picture of the functions and nature of each piping system and also of the requirements on pipe installation work.

Piping work requirements

The requirements common to all piping systems are as follows:

(a) Avoid sharp bends. The fluid flowing inside encounters a greater resistance to flow at a sharp pipe bend. This resistance is called a loss in the sense that greater power is needed to set the fluid in motion if the pipe conveying it offers a greater resistance. Resistance is a cause and loss is a result. There are several kinds of resistance, such as those due to the friction between fluid and pipe wall surface, to the fluid turbulence created by irregular shapes of its passage (a sharp bend is such a shape, so to say), and to the molecular friction within the fluid itself.

(b) Stay a long pipe at proper intervals. A long, unstayed pipe is prone to vibrate and, if it vibrates persistently, it will break in time due to what is called "fatigue failure," just as a piece of wire will break if it is sharply bent and straightened alternately for a number of times.

(c) Pipes in place must be in relaxed condition. When installing a piece of pipe, a conscientious worker will make sure the two ends of the pipe will fit snugly to the mating parts or connections; he will not force the pipe by bending or otherwise to fit the pipe end to its mating part while the other end is already bolted or anchored. In short, a pipe in place must not be in stressed condition. Leakage of the fluid from a pipe joint is often accounted for by the initial jointing job, which happened to be carried out by an ignorant or irresponsible worker.

(d) Flush each pipe line completely, making its internal passage absolutely clean. Piping materials must be cleaned before installation. Pipe joints are often made by welding and, in such a case, splatters of metal inside the pipe must be removed by flushing (forcing a flushing liquid through the line with a blowing speed). This requirements must be met with the best possible thoroughness if the fluid conveyed is the lube oil.

(e) Piping materials must be of the specified quality. There are a host of technical standards and specifications governing all kinds of piping materials.

The piping designer specifies the metal grade and size of each piping material according to its duty requirements - operating pressure and temperature, flowrate, and the physical and chemical properties of the fluid, etc. Piping work is often the responsibility of the engine purchaser but, even in such a case, the engine supplier is seriously concerned with this work because the capability and performance of the engine stated in the contract presuppose that all piping systems are designed and installed to meet the specifications submitted by the engine supplier.

How the piping work is specified is a topic of importance to our business, and will be treated in its briefest form.

<u>Outline of piping work specifications</u>

Table 1 indicates the piping materials to be procured locally by the engine purchaser. The materials are to be worked on and turned to the shapes and lengths indicated in the piping work drawings.

Fuel piping

The fuel line from the service tank to the injection pump, through a settling tank, fuel filter and feed pump, is a low-pressure line. From the injection pump to each injection nozzle is a high-pressure line. Besides leakage-free pipe connections, a minimized number of pipe bends or elbows and also high strength in the high-pressure lines, the important requirement on the fuel system is cleanliness of the pipe interior and the fuel oil itself.

Fuel oil in the main tank contains more or less contaminants, such as water (dissolved or in droplet form), gritty particles and perhaps some lints. Water can promote rust formation on metal surfaces in the pipe; gritty and rust particles can foul up the close-tolerance moving parts in the pumps and injection nozzles. Because of these possibility, fuel reaching the feed pump flows through the settling tank, in which water droplets are removed from fuel, and the Unicus filter, in which solid particles are separate from fuel.

Too small a fuel tank is as undesirable as too large a fuel tank. It is sized for each vessel on the basis of the fuel consumption and the working hours and conditions. Fuel consumption is stated for the engine and the service tank is sized to accommodate that consumption. The graph of Fig. 1 is such a statement, and shows the rates at which two Type-S engines burn fuel.

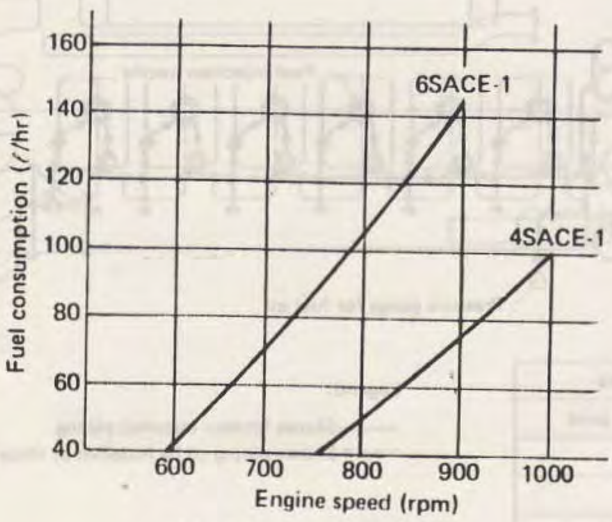
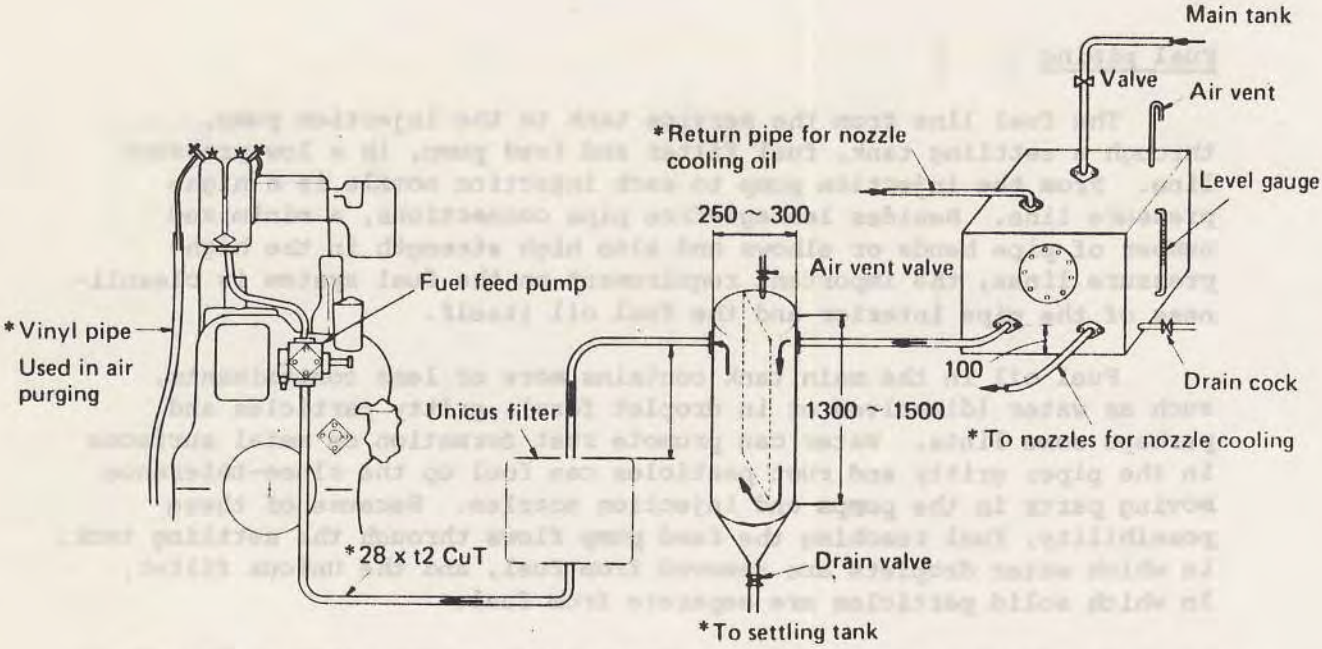
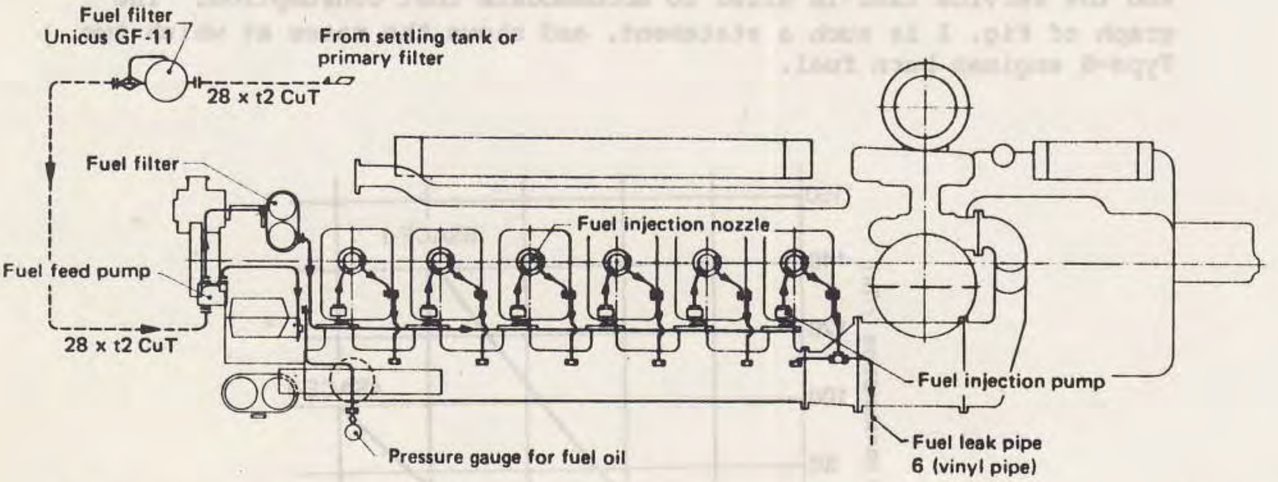


Fig. 1 Fuel consumption



Note: Parts marked * are meant to be installed at shipyard.



Unit: mm

Piping symbols	
	Union collar joint
	Flange joint
	Cap nut
	Two way cock
	Stop valve
	Three way cock
CuT	Copper pipe

Legend:
——— Shows factory-installed piping
- - - - Shows piping to be installed at shipyard

Fig. 2 Fuel piping (EY23570)

Lube oil piping for the rocker mechanism

In the Type-S engine, the rocker mechanism is lubricated with oil supplied through its own system independent of the other lubrication systems of the engine. Fig. 3 shows the scheme of sending lube oil to the rocker arms.

NOTES: 1) In this example, the 20-liter tank is located 200 tc 500 mm below the pump inlet, and the pipe between tank and pump is limited to 2500 mm.

2) The return line from the top of the cylinder head is made as short as possible.

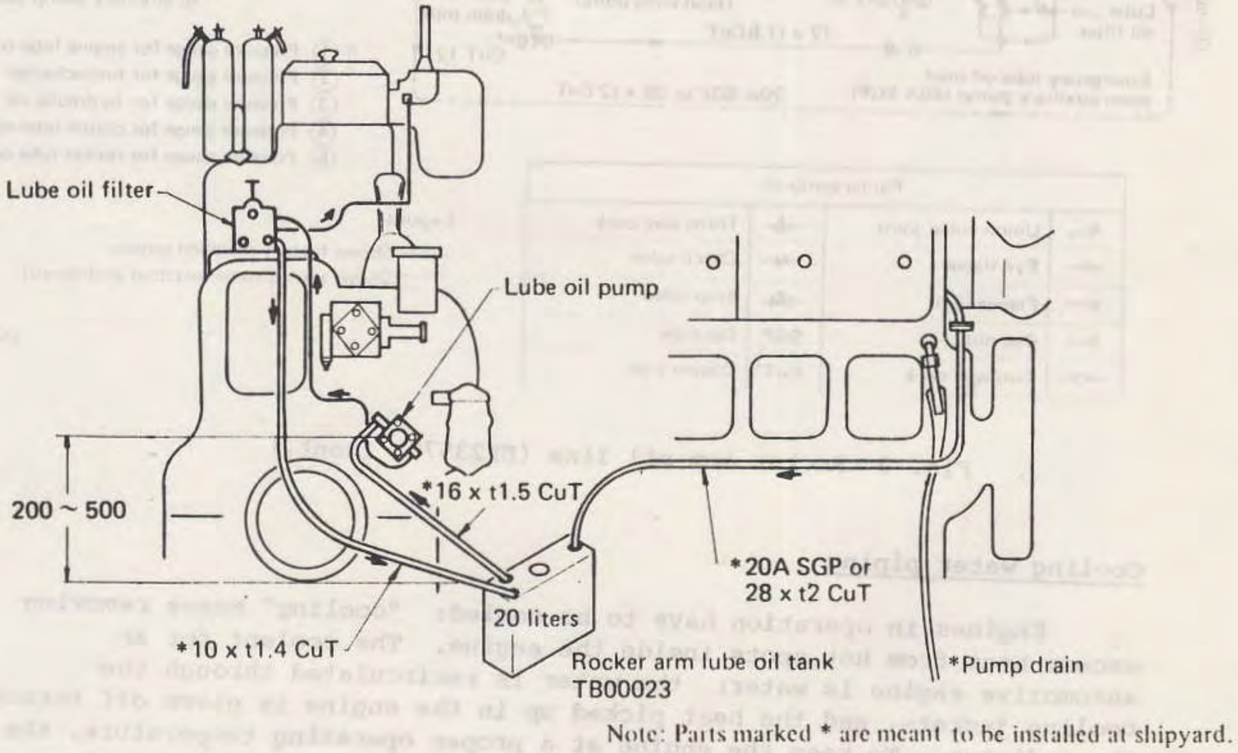
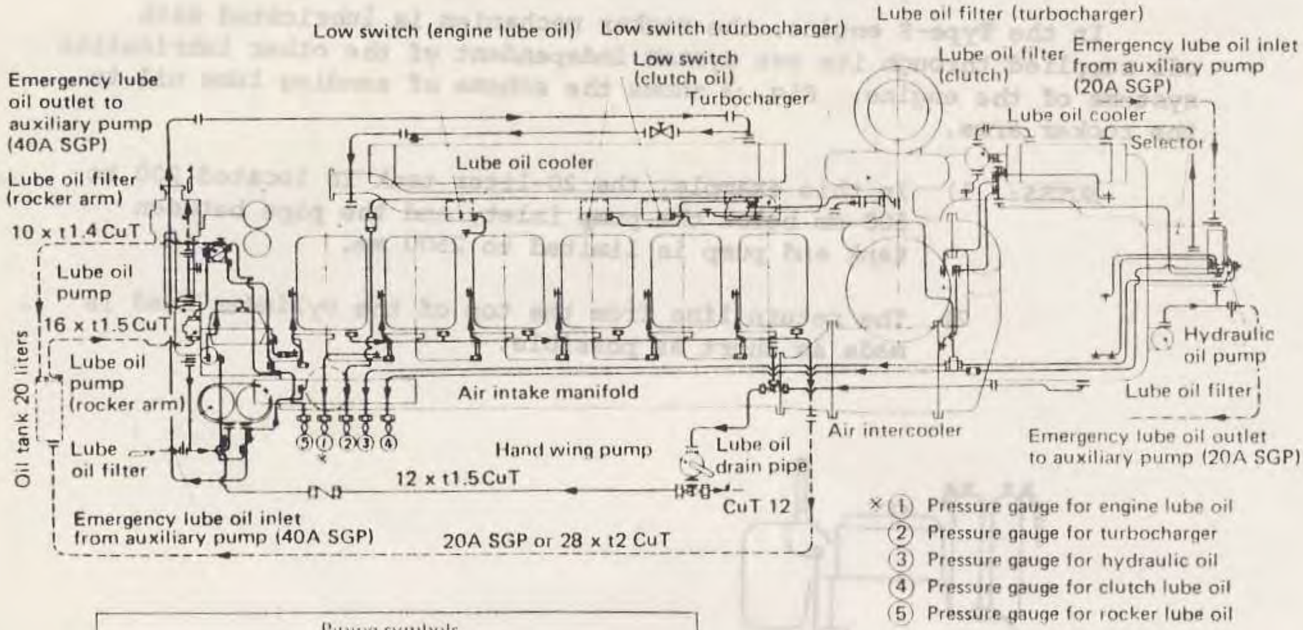


Fig. 3 Rocker arm oil line (EY23570)



Piping symbols			
╫—	Union collar joint	—◆—	Three way cock
─╢├─	Eye flange	—N—	Check valve
‖—	Flange joint	—⋈—	Stop valve
⊟—	Cap nut	SGP	Gas pipe
—◇—	Two way cock	CuT	Copper pipe

Legend

——— Shows factory-installed piping

- - - Shows piping to be installed at shipyard

Unit: mm

Fig. 3 Rocker arm oil line (EY23570) (cont.)

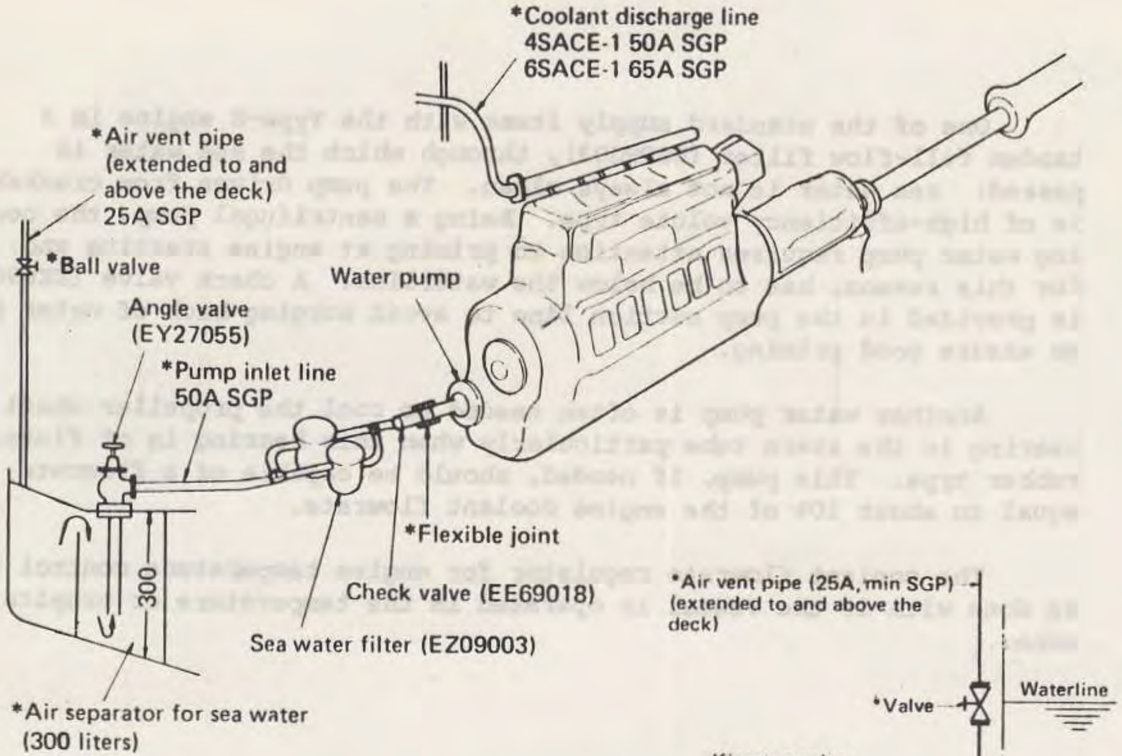
Cooling water piping

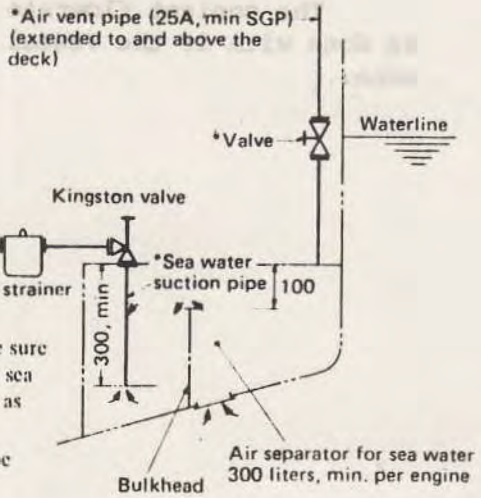
Engines in operation have to be cooled: "cooling" means removing excess heat from hot spots inside the engine. The coolant for an automotive engine is water: the water is recirculated through the cooling jackets, and the heat picked up in the engine is given off through the radiator. To keep the engine at a proper operating temperature, the recirculation flowrate is automatically controlled by a thermostatic valve. In the Type-S engine, however, no radiator is used; sea water is admitted through the hull plate into the intake chamber; it is then pumped into the engine; and its flowrate is regulated by a device operating in response to the engine temperature. This device is selected and installed at shipyard.

One of the standard supply items with the Type-S engine is a tandem full-flow filter (EZ09003), through which the sea water is passed: sea water is not always clean. The pump driven from crankshaft is of high-efficiency volute type. Being a centrifugal pump, the cooling water pump requires attention to priming at engine starting and, for this reason, has to be below the waterline. A check valve (EE69018) is provided in the pump suction line to avoid surging back of water and to assure good priming.

Another water pump is often needed to cool the propeller shaft bearing in the stern tube particularly when this bearing is of fluted rubber type. This pump, if needed, should be capable of a flowrate equal to about 10% of the engine coolant flowrate.

The coolant flowrate regulator for engine temperature control can be done with if the vessel is operated in the temperature or tropical zone.





Piping symbols	
⊣⊢	Union collar joint
⊣|⊢	Eye fange
‖—	Flange joint
⊟—	Cap nut
—◇—	Two way cock
—◇—	Three way cock
—N—	Check valve
SGP	Gas pipe
CuT	Copper pipe

Remarks

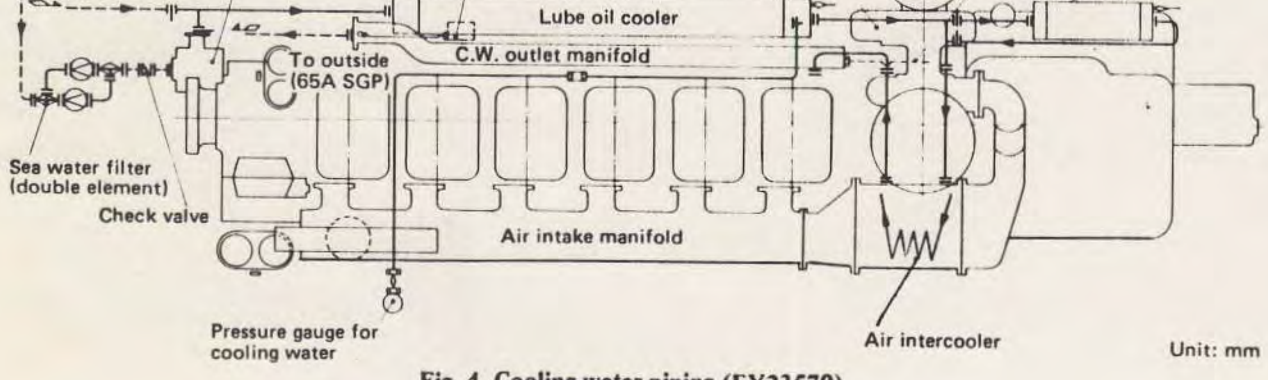
When mounting the engine, be sure to install the air separator for sea water at the bottom of a boat as shown in the illustration.

Parts marked * are meant to be installed at shipyard.

Legend:

——— Shows factory-installed piping

- - - - Shows piping to be installed at shipyard



Unit: mm

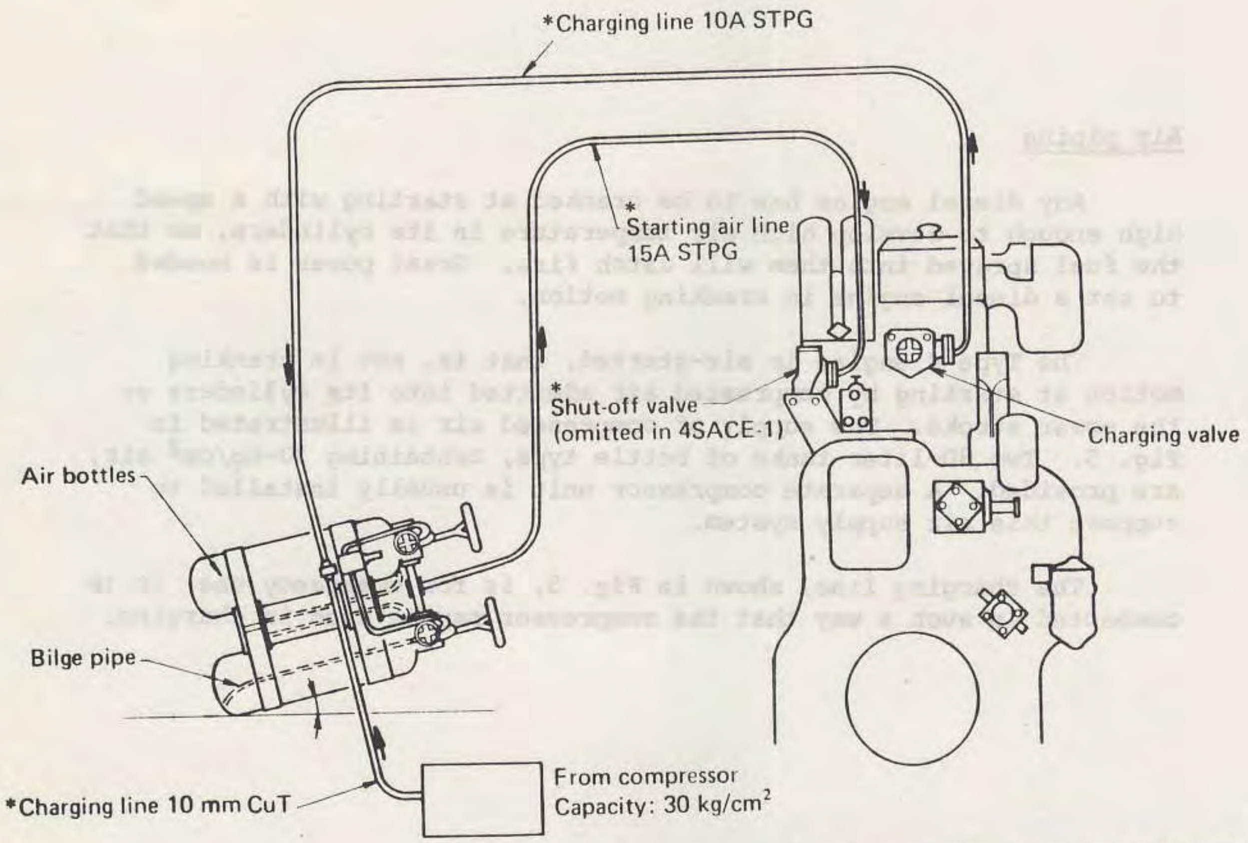
Fig. 4 Cooling water piping (EY23570)

Air piping

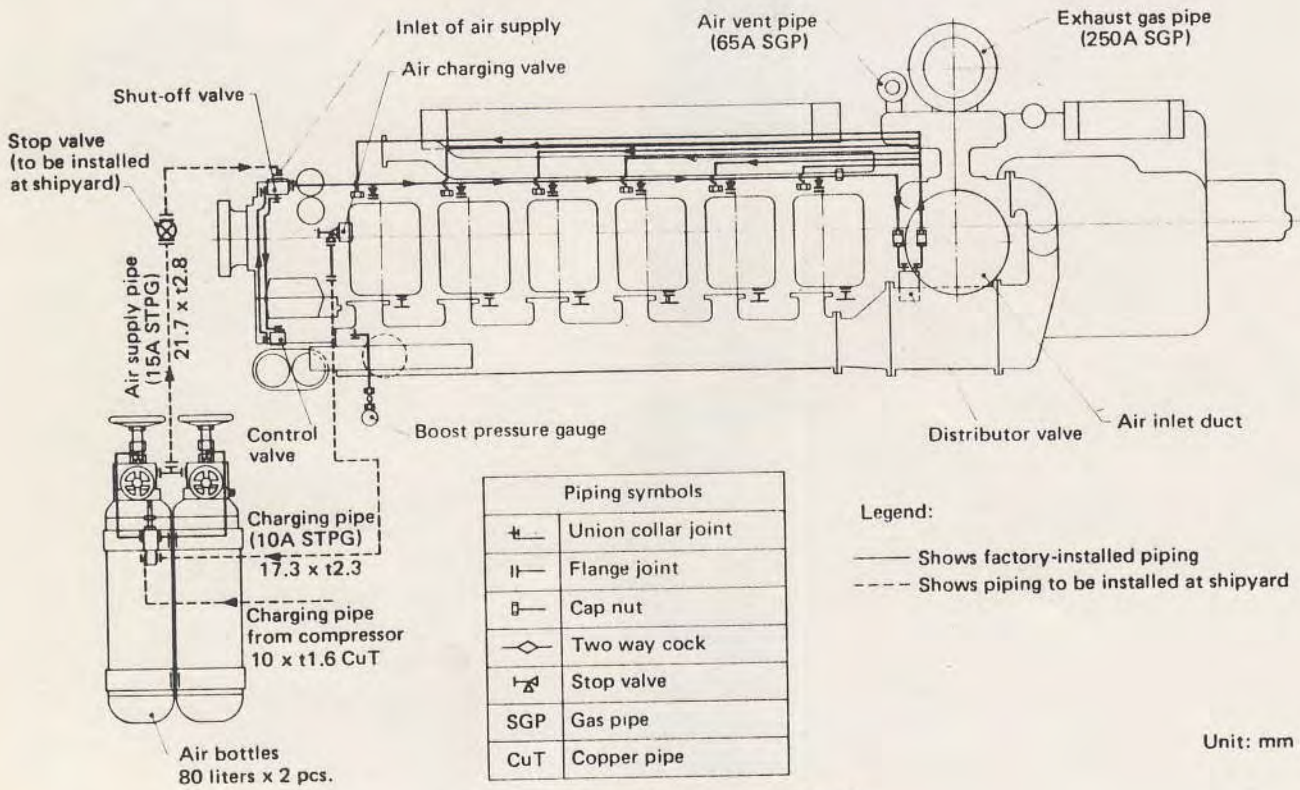
Any diesel engine has to be cranked at starting with a speed high enough to develop high air temperature in its cylinders, so that the fuel sprayed into them will catch fire. Great power is needed to set a diesel engine in cranking motion.

The Type-S engine is air-started, that is, set in cranking motion at starting by compressed air admitted into its cylinders on the power stroke. The supply of compressed air is illustrated in Fig. 5. Two 80-liter tanks of bottle type, containing 30-kg/cm^2 air, are provided. A separate compressor unit is usually installed to support this air supply system.

The charging line, shown in Fig. 5, is for emergency use; it is connected in such a way that the compressor may be used in charging.



Note: Parts marked * are meant to be installed at shipyard.



Piping symbols	
	Union collar joint
	Flange joint
	Cap nut
	Two way cock
	Stop valve
SGP	Gas pipe
CuT	Copper pipe

Fig. 5 Starting air piping (EY23570)

Exhaust piping

The pipe connected to the turbocharger gas outlet or exhaust manifold of the engine is sized large in diameter and made short enough in length to minimize resistance due to back pressure. High back pressure interferes with fuel combustion and, if the engine is equipped with a turbocharger, reduces the turbocharging efficiency, resulting in a higher exhaust temperature and an appreciable reduction of output power. Back pressure is measured with a simple device tied into the exhaust manifold and read in terms of so many millimeters of water column. Normally, the maximum permissible back pressure is 250 mm at full load.

Back pressure measurement may be dispensed with if the straight portion of the exhaust pipe is not longer than 7 meters, with the number of bends being less than four.

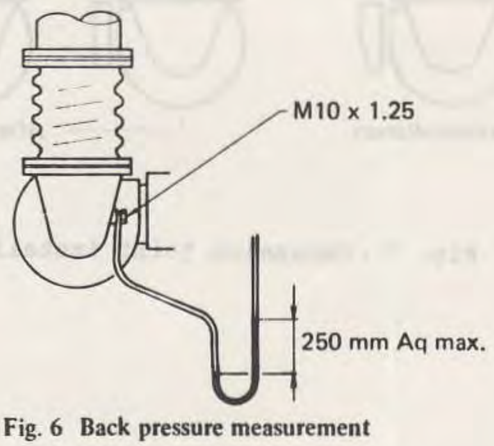


Fig. 6 Back pressure measurement

A straight vertical exhaust pipe and a horizontal exhaust pipe with two bends are shown in Fig. 8. Note that the pipe is anchored and supported at several places, and that the expansion joint is protected by lagging. The horizontal exhaust pipe arrangement is often necessary for engines installed in such as ferry boats. If the straight horizontal portion is long, an expansion joint may have to be used at a mid-length point.

An expansion joint is used in the connection between the exhaust pipe and the exhaust manifold or, in a turbocharged engine, the outlet of the turbocharger. It is supplied with the Type-S engine as a part (EX91005).

This joint is installed in a pre-stressed condition, so that, when the engine gets hot, it will become relaxed due to thermal expansion of the exhaust pipe and engine itself. Fig. 7 illustrates how this joint is fastened to the exhaust pipe in cold state.

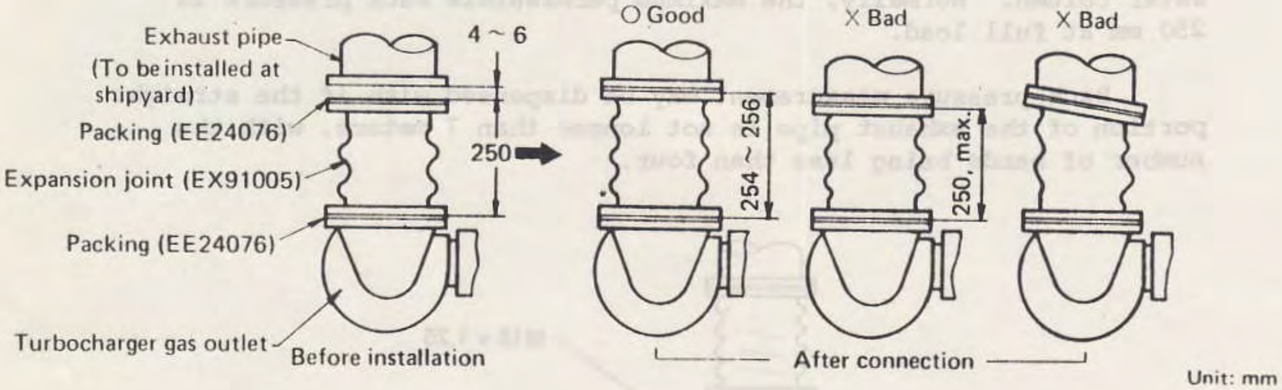
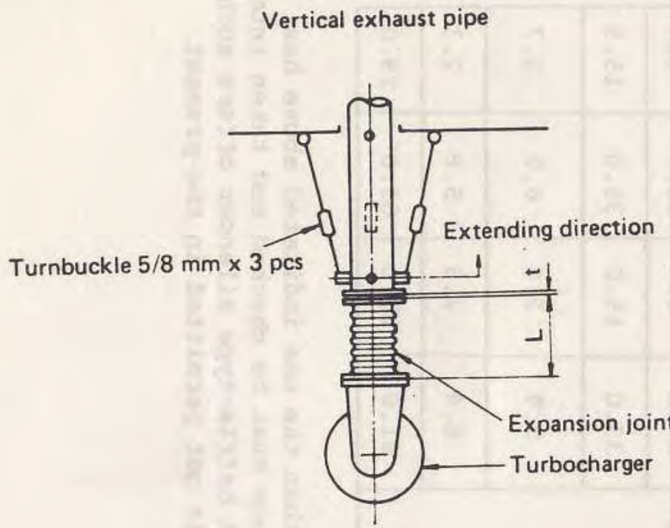
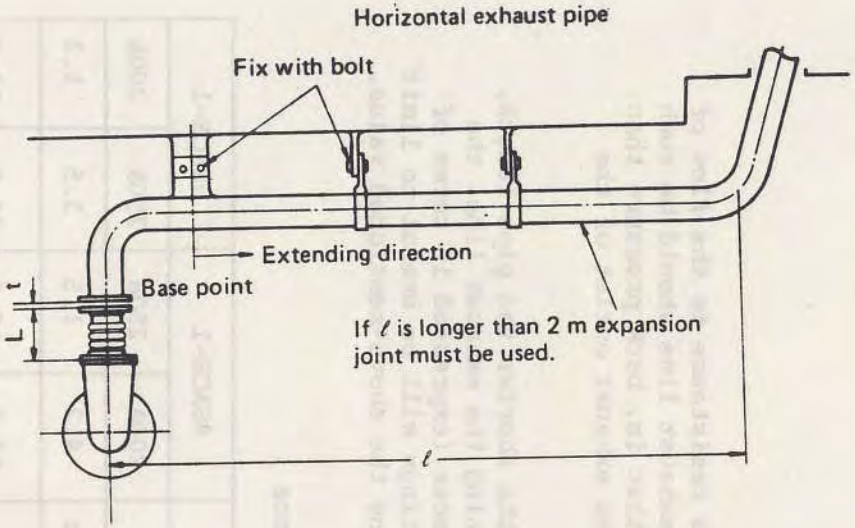
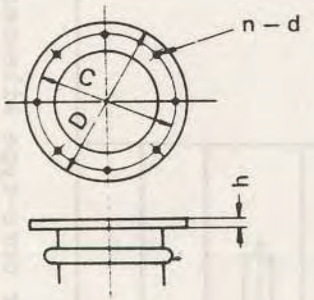


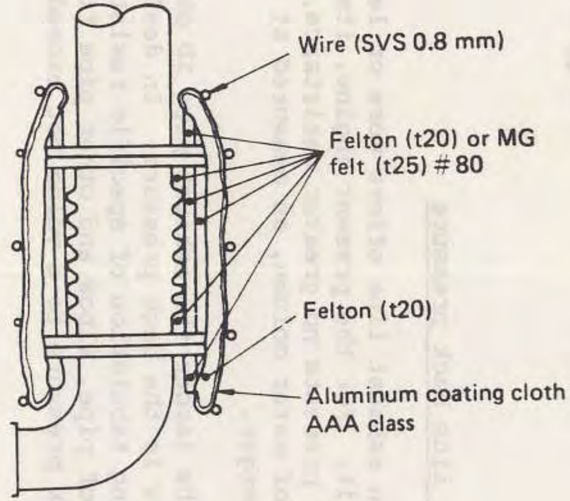
Fig. 7 Expansion joint installation







Exhaust pipe diameter	Length mm	Extending length mm	Setting clear-ance mm	D	C	n	d	h	Exapnsion joint part number	Drawing No.
200A	250	± 10	4 ~ 6	320	280	8	23	20	EZ91002	EY27041A
250A	250	± 10	4 ~ 6	385	345	12	23	22	EZ91005	EY27041B



Expansion joint lagging details

NOTES: 1) Loosen bolts once and tighten again during operation to remove stain of expansion joint.

2) Lag the expansion joint as shown above.

Fig. 8 Exhaust piping details

Exhaust line back pressure

An exhaust line offers more or less resistance to the flow of gas in it. For the present engine, its exhaust line should be such that it presents no greater resistance, that is, back pressure than 250 mm of water column, as measured at the exhaust outlet of the turbocharger.

The larger the exhaust pipe ID or the shorter the pipe length, the less is the back pressure. In designing the exhaust line, the following tabulation of specific resistances (expressed in terms of mm Aq) of pipe, elbow and other pipe fittings will be useful to limit the back pressure to a value not exceeding the above-mentioned value.

Specific resistance

Model			4SACE-1		6SACE-1	
Exhaust pipe diameter			200A	250A	250A	300A
A	Straight pipe	mm Aq/meter	4.2	1.5	3.5	1.3
B	Square elbow	mm Aq/1 pc	54.6	25.5	59.5	26.0
C	Standard 90° elbow		27.3	12.0	28.0	12.7
D	Long 90° elbow		22.6	9.8	22.8	10.4
E	45° elbow		12.2	5.4	12.6	5.6
F	Flexible joint		33.0	15.0	35.0	15.5
G	Opening piece		5.9	2.6	6.0	2.7
H	Core-type silencer		6.4	2.5	5.8	2.3
I	Connector		61.0	27.0	63.0	28.0

NOTE: If any other core-type silencer than the one indicated above has to be used, its specific resistance must be checked and taken into account in designing the line. A baffle-type silencer offers such a large resistance that its use is not permitted in the present case.

Example of back pressure calculation (4SACE-1)

Pipe size 200A is assumed. Apply the specific values listed above to the elements of the line, and totalize the individual mm-Aq values:

(1) Totalized length of straight pipe portions = 250 + 1200 + 3000 + 750 = 5200

(2) Resistance of straight pipe portions A = 4.2 x 5.2 = 21.9

(3) Resistance of flexible joint F = 33.0 x 1 = 33.0

(4) Resistance of standard 90° elbow C = 27.3 x 1 = 27.3

(5) Resistance of long 90° elbow D = 22.6 x 1 = 22.6

(6) Resistance of core-type silencer H = 6.4 x 1 = 6.4

(7) Resistance of opening piece G = 5.9 x 1 = 5.9

Totalized resistance, P = A + F + C + D + H + G = 117.1 mm Aq

This example is satisfactory for the present engine because it offers a back pressure not greater than the stated value, namely, 250 mm Aq.

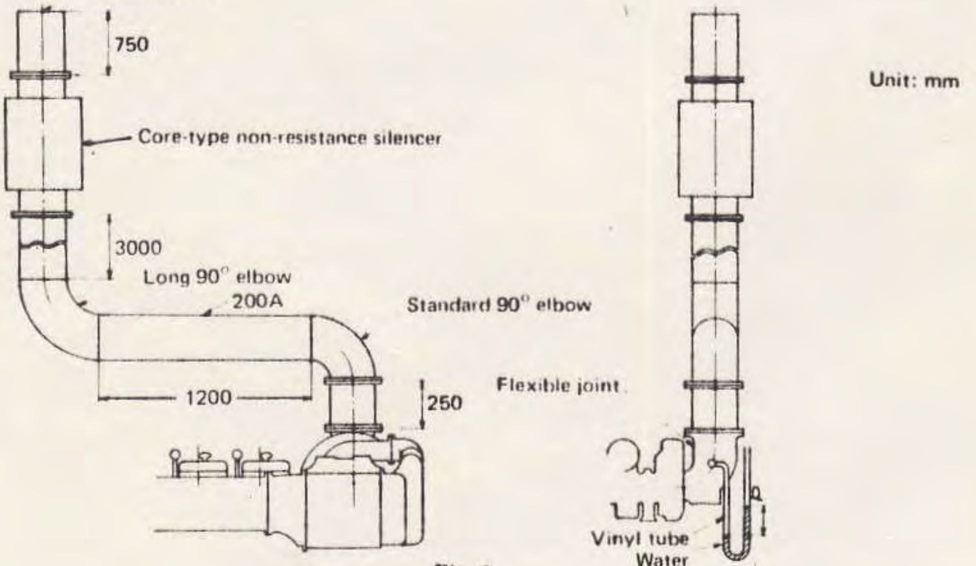


Fig. 9

Breather piping

This piping is for keeping the pressure inside the engine crankcase at the atmospheric pressure and serves to vent out the blowby gas in order to keep the engine-room air clean. The outer end of the breather pipe sticks outboard. Where two engines are installed, each engine has its crankcase breathing through its own breather pipe.

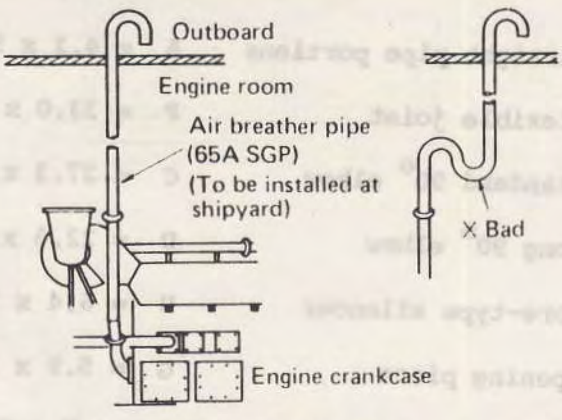


Fig. 10 Air breather piping

There should be no pocket in any part of the breather pipe; it should extend straight out, with its open end turned back, as shown.

E. Electrical wiring procedure

Two kinds of electrical wiring in the engine room are for the alarm system and control system. For the former, alarm circuits are provided to detect and indicate various lube-oil pressures (engine, turbocharger and marine gear) and coolant temperature. Sensors are switches of pressure-actuated and temperature-actuated types. In the event of abnormal condition, alarm is sounded off and warning lamps are lighted.

The condition of the marine gear is electrically supervised. Limit switches are installed in the marine gear (clutch) to indicate the clutch position. It is by referring to this indication at the control panel that the clutch is controlled in driving the propeller shaft.

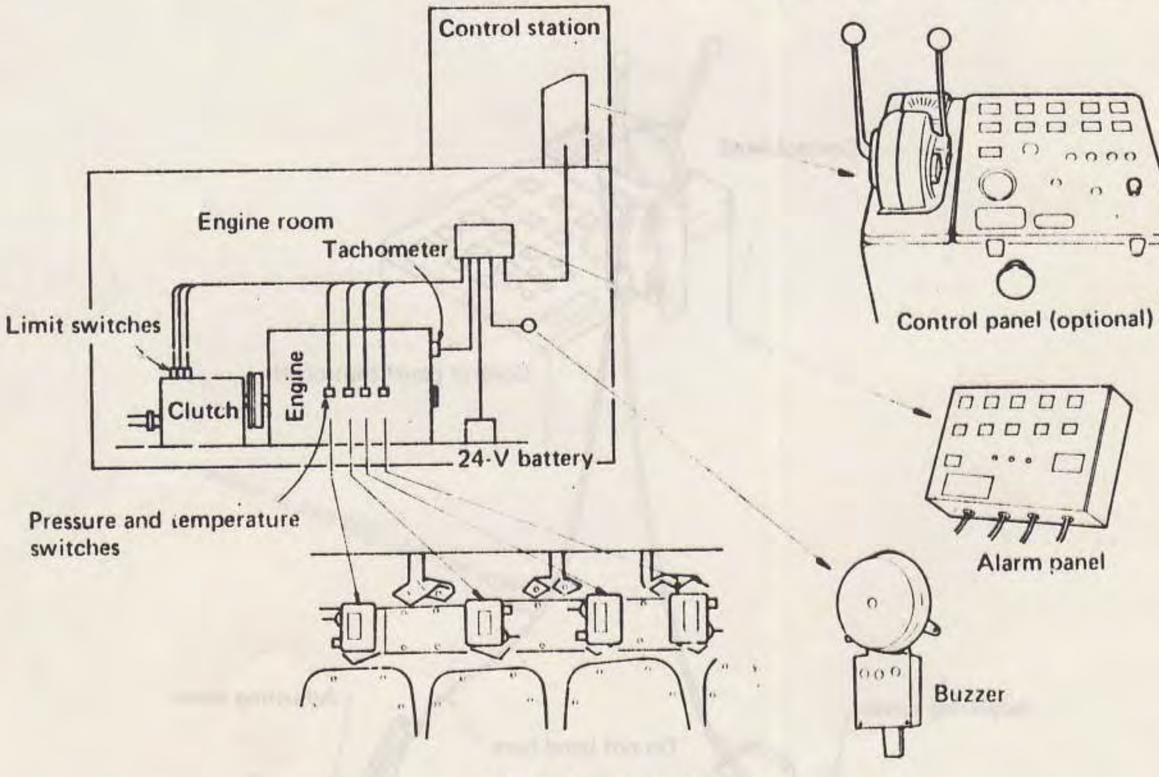


Fig. 1 Wiring diagram

Remote control system (wire type)

The engine governor and the marine gear are remotely controlled through push-pull cables from the control head located to one side of the control panel, as shown in Fig. 1. For the given distance between the control panel and the engine, these cables are made as short as possible. Push-pull cables longer than 13 meters are unreliable for transmitting control motions accurately. Special cables are used if the cable line is longer than 13 meters.

The remote control system of the Type-S engine, arranged as described, is very simple and easy to operate. The cables are routed straight or nearly straight, with its bend, if any, not sharper than 200 mm in radius of curvature. Fig. 1 shows the cable interconnection between the control head on the one side and the governor and clutch on the other. Note that the governor and clutch can be locally controlled in the event of cable failure.

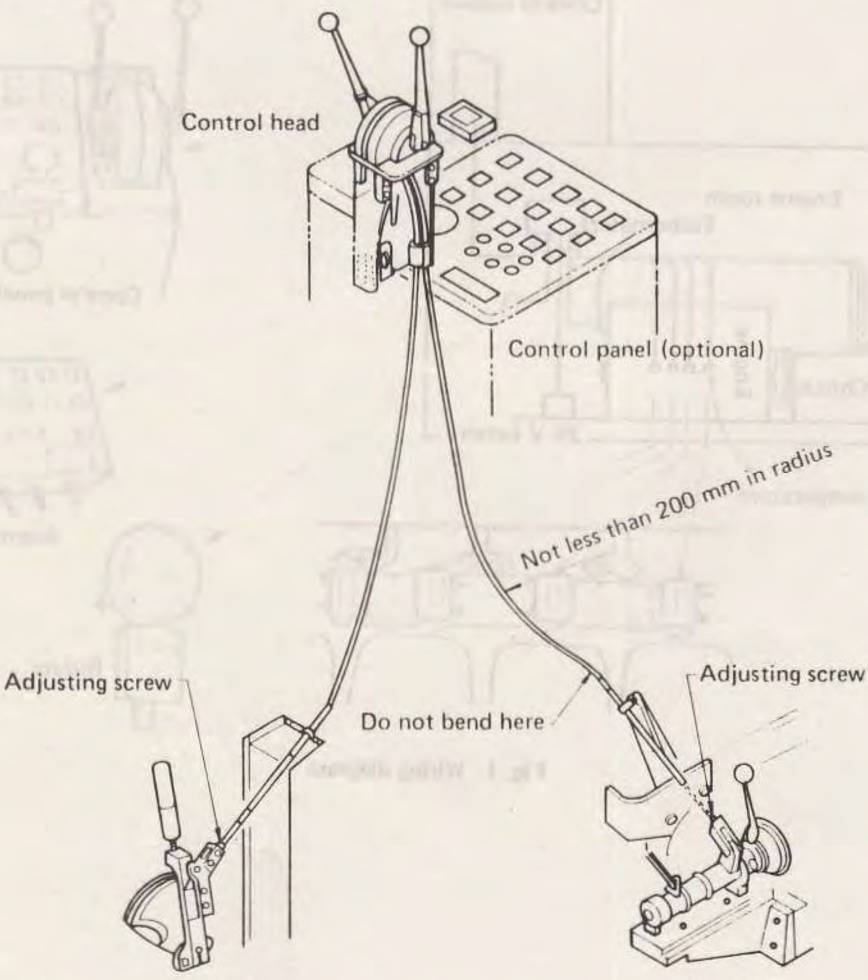


Fig. 1 Remote-control cable lines

Model BT35H

Operation

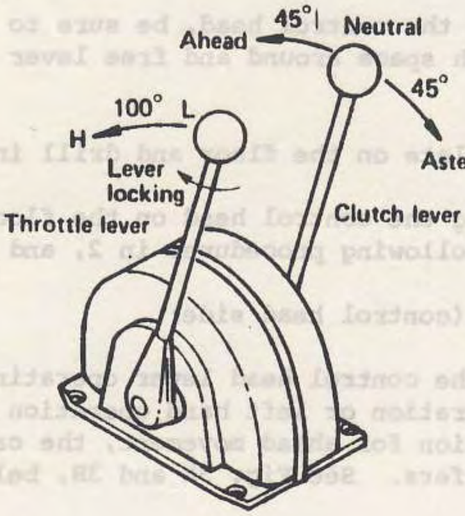


Fig. 2

Tabulated data

- Capacity

	Clutch		Throttle	
Stroke	Ahead	40 mm	High	97 mm
	Astern	40 mm	Low	97 mm
Lever shifting direction	See Fig. 2, above.			
Load at engine side	Max	30 kg	Max	20 kg
	Normal	10 kg	Normal	16 kg
Max proof load for locking	-		20 kg	

- Weight 4.9 kg
- Cable HI-LEX C54D (Series # 100 clamp type, stroke 100 mm)

Installation

1. Control head (remote)

For installing the control head, be sure to select a location where there is enough space around and free lever shifting operation is guaranteed.

Apply the template on the floor and drill installing holes.

Before securing the control head on the floor, install control cables in the head following procedures in 2, and 3 below.

2. Clutch cables (control head side)

a. Depending on the control head lever operating manner, whether right hand operation or left hand operation or whether pulling or pushing operation for ahead movement, the cable installing side (1) or (2) differs. See Fig. 3A and 3B, below.

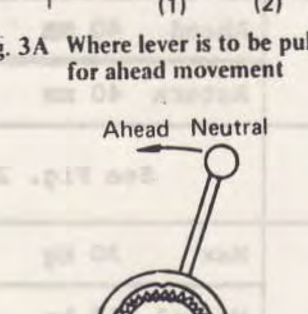


Fig. 3A Where lever is to be pulled for ahead movement

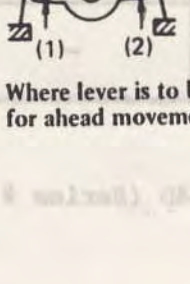


Fig. 3B Where lever is to be pushed for ahead movement

b. There are three connecting holes provided on both sides of the clutch operating plate. Select ones according to the clutch stroke of your engine.

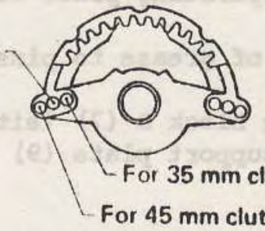


Fig. 4

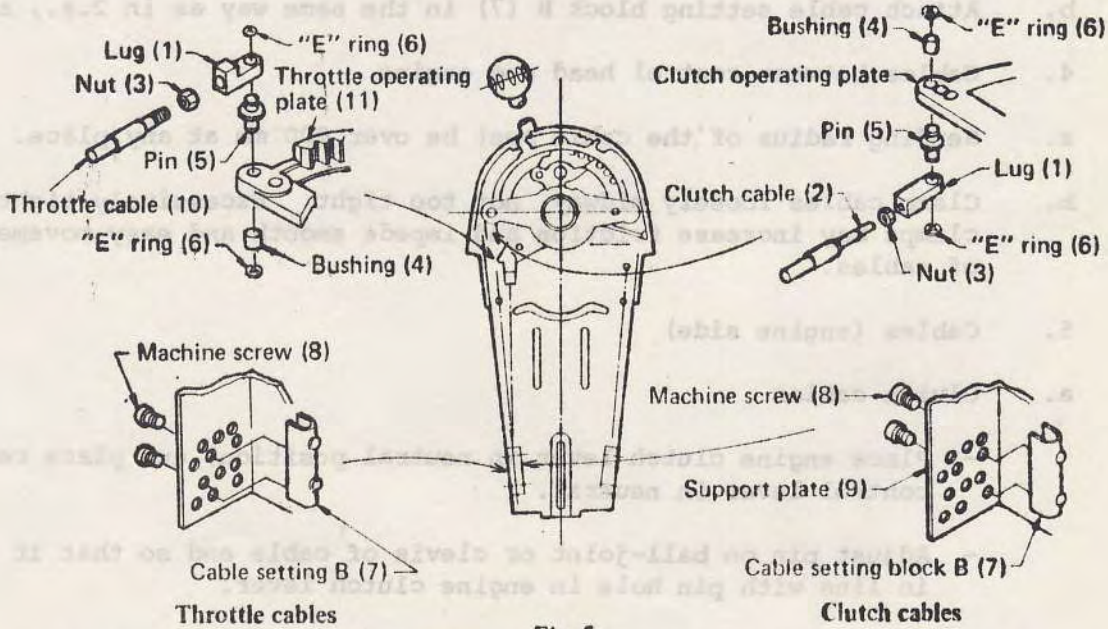


Fig. 5

c. Insert clutch cable rod (2) into lug (1) until the rod end appeares in its stepped part and secure it by tightening nut (3).

d. Insert bushing (4) into the connecting hole of the clutch operating plate as selected in b, above from the front side, and insert pin (5) into bushing (4) from the back side. Secure lug (1) and the clutch operating plate with "E" rings (6).

NOTE: Apply a coat of grease to pins (5) before assembling.

e. Attach cable setting block B (7) (either for right hand or left hand operation) to support plate (9) and secure it by tightening machine screws (8).

3. Throttle cables (control head side)

a. Connect lug (1) to throttle cable rod (10) and insert pin (5) into throttle operating plate (11). Secure lug (1) and throttle operating plate (11) with "E" rings (6).

NOTE: Apply a coat of grease to pins (5) before assembling.

b. Attach cable setting block B (7) in the same way as in 2.e., above.

4. Cables between control head and engine

a. Bending radius of the cable must be over 200 mm at any place.

b. Clamp cables loosely midway, not too tight. Excessively tightened clamps may increase friction and impede smooth and easy movement of cables.

5. Cables (engine side)

a. Clutch cables

- Place engine clutch lever in neutral position, and place remote control lever in neutral.
- Adjust pin on ball-joint or clevis of cable end so that it is in line with pin hole in engine clutch lever.
- Place engine clutch lever in ahead gear position and place remote control lever in ahead position. At this point, check whether pin on ball-joint or clevis of cable end is in line with pin hole in engine clutch lever.

- Place engine clutch lever in astern gear position and place remote control lever in astern position. Also at this point check in the same way as above.

- After adjusting the pin so that pin and pin hole are in line with each other in each of ahead, neutral and astern positions, secure each cable to engine.

b. Throttle cables

- Place both engine throttle lever and remote control lever in "LOW."

- Secure each throttle cable to engine after adjusting the pin on clevis of cable end so that it is in line with pin hole in engine throttle lever.

6. Inspection after installation of control cables

After installation, check whether the control cables can be operated without any undue force.

F. Front power take-Off

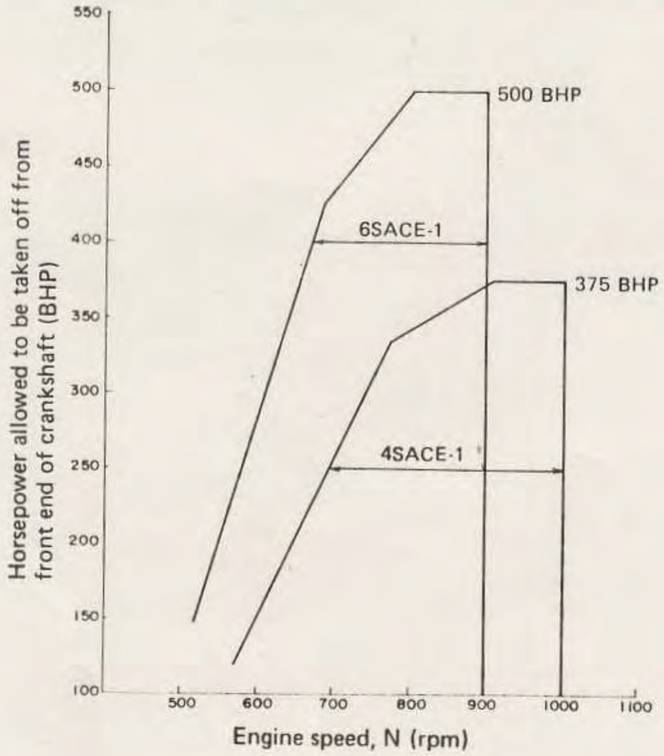
Total PTO horsepower

1. The graph, below, indicates the maximum horsepower output that is permitted to be taken from the front end of the engine through a power take-off (PTO) consisting of a flexible coupling and a pulley supported at two points.

2. If the power output available from the front end has to be used for cross drive, limit the output to the value determinable in the graph given in the following page.

3. Where the PTO of Item 1 and that of Item 2, above, have to be jointly provided at the front end of the engine, then the total power taken off must be within the limit shown in the graph below, and the cross-drive power as part of the total must be limited according to the graph of the following page.

4. It is highly essential that the PTO shaft in place should exhibit no more radial runout than 0.024 mm. Check this by taking deflection readings in the usual manner.

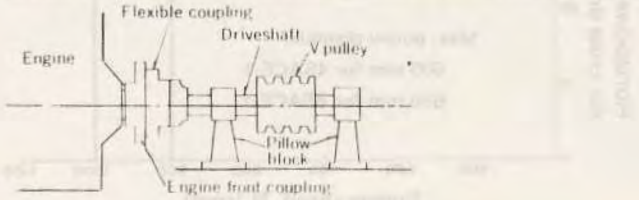


Front power take-off for medium power

Support the driveshaft and V-pulley with two pillow blocks (with bearings) and use a flexible coupling for connection.

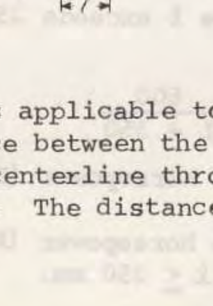
Allowable Output

Model	Torque	Output
4SACE-1	Max. 269 kg·m	Max. 375 BHP/1,000 rpm

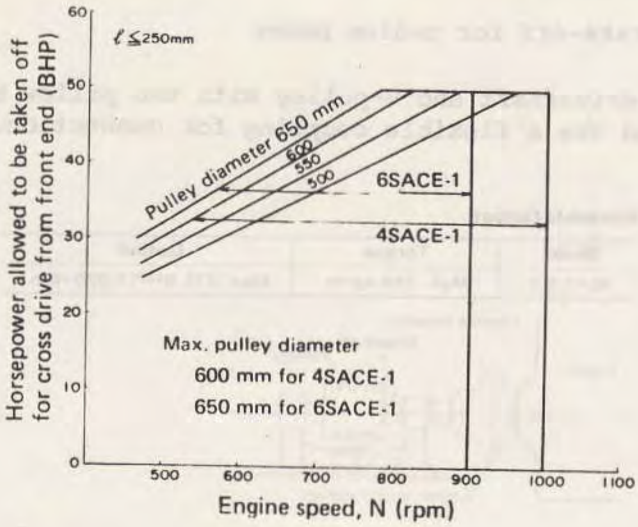


Horsepower allowed for cross drive

1. The front-end PTO preferred for the subject engines consists, mainly, of a flexible coupling and a pulley whose shaft is supported at two points. Taking power off for cross drive in the manner indicated here is permissible, though not preferable, provided that the cross-drive power be limited according to the graph given below.



2. The graph, below, is applicable to the cross-drive arrangement in which the distance between the coupling flange face of crankshaft and the centerline through pulley groove is not greater than 250 mm. The distance is indicated as ℓ in the above sketch.

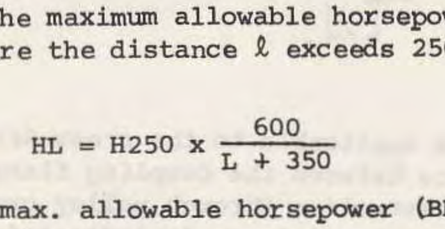


For low power

Install the V pulley directly to the engine front coupling.

Allowable Output

Model	Torque	Output
4SACE 1	Max. 36 kg·m	Max. 50 BHP/1,000 rpm



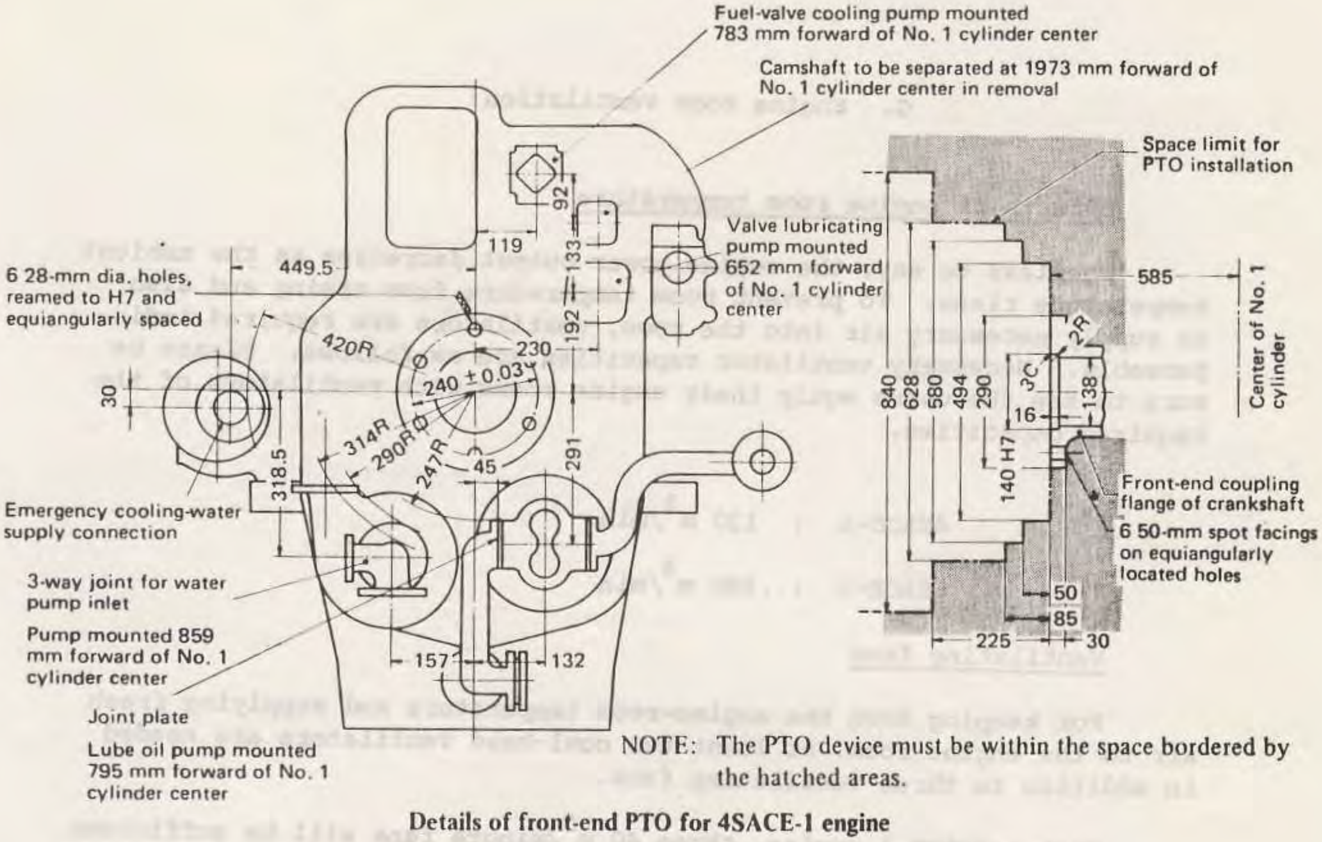
3. Calculate the maximum allowable horsepower according to this formula where the distance ℓ exceeds 250 mm:

$$HL = H250 \times \frac{600}{L + 350}$$

where HL = max. allowable horsepower (BHP) for ℓ = L mm, and

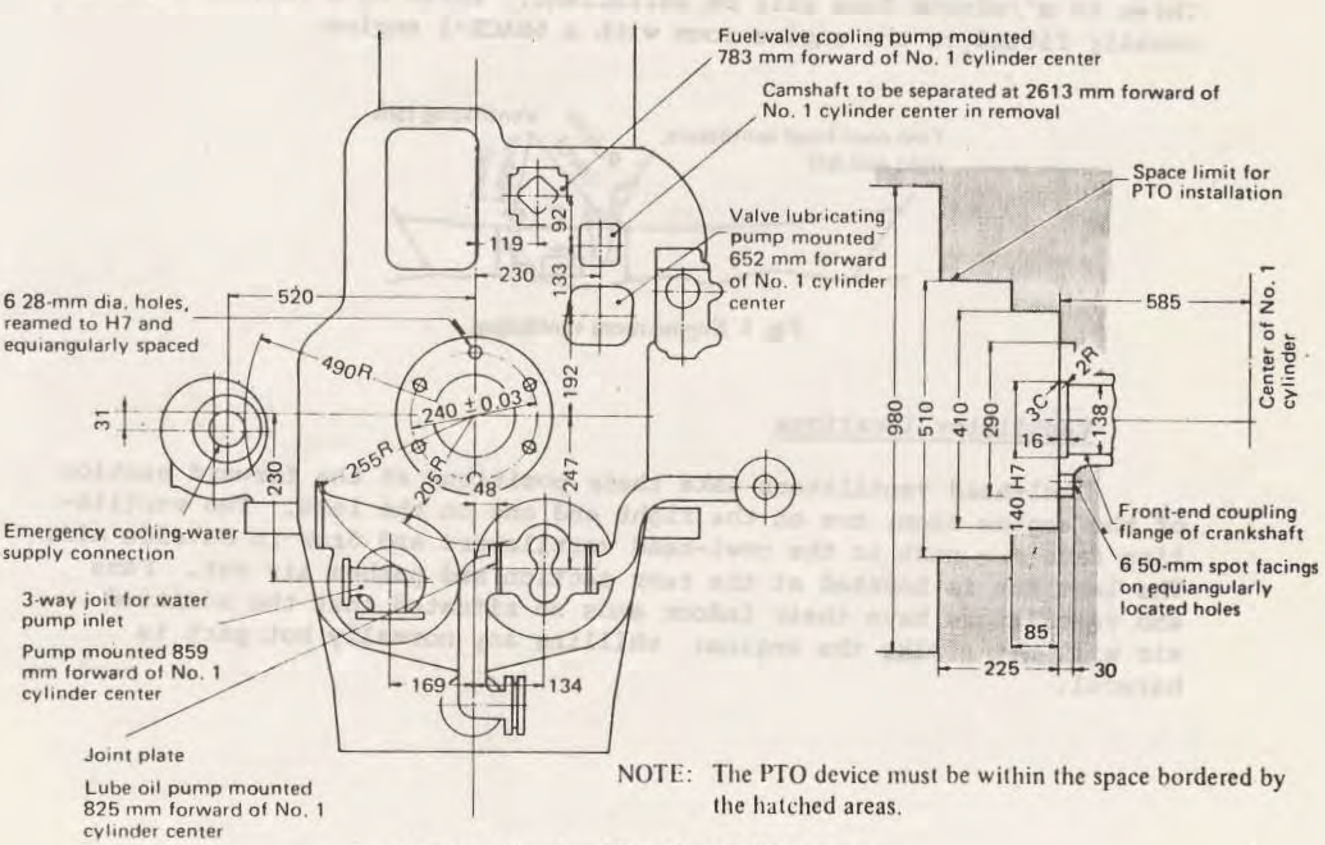
H250 = max. allowable horsepower (BHP) determinable in the graph for ℓ ≤ 250 mm.

4. Be sure that the cross-drive PTO has its shaft exhibiting no more radial runout than 0.024 mm with the belt tensioned. Adjust the belt tension as necessary.



NOTE: The PTO device must be within the space bordered by the hatched areas.

Details of front-end PTO for 4SACE-1 engine



NOTE: The PTO device must be within the space bordered by the hatched areas.

Details of front-end PTO for 6SACE-1 engine

G. Engine room ventilation

Effects of engine room temperature

Needless to say, the engine power output decreases as the ambient temperature rises. To prevent room temperature from rising and also to supply necessary air into the room, ventilators are required indispensably. Necessary ventilator capacities are as follows. Please be sure to see the users equip their engine rooms with ventilators of the required capacities.

4SACE-1 : 120 m^3/min

6SACE-1 : 180 m^3/min

Ventilating fans

For keeping down the engine-room temperature and supplying fresh air to the engine room, at least two cowl-head ventilators are needed in addition to three ventilating fans.

With a 4SACE-1 engine, three 40 m^3/minute fans will be sufficient. Three 60 m^3/minute fans will be sufficient. Three 60 m^3/minute fans are usually fitted to the engine room with a 6SACE-1 engine.

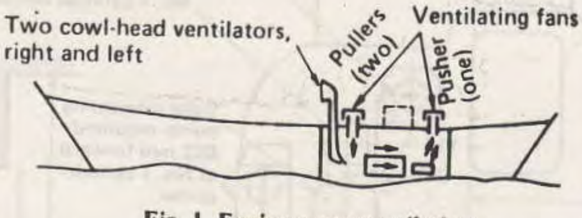


Fig. 1 Engine-room ventilation

Ventilator locations

Cowl-head ventilators take their positions at the forward section of the engine room, one on the right and one on the left. Two ventilating fans are next to the cowl-head ventilators and draw in outside air. The last fan is located at the rear section and pushes air out. Fans and ventilators have their indoor ends so situated that the admitted air will not strike the engine: chilling any normally hot part is harmful.