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# Diesel Hydraulic Propulsion

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The author describes a small vessel on the Thames which, in its method of propulsion, may perhaps be accounted unique. It adds to the interest and value of the paper that he also gives the result of two years' continuous operation in what is generally acknowledged to be difficult work.

Hitherto, this prototype vessel has received only brief mention in the Press as the author preferred thoroughly to test and prove it in actual operation before making any claims.

He is of the opinion that the test results should be more convincing than any recommendation; indeed, he has endeavoured to be strictly impartial, to allow the figures to speak for themselves and the merit of the installation to be judged on performance and results—the proper and only way in which the value of any new project can be assessed.

## INTRODUCTION

In a paper* read by the author before the Diesel Engine Users' Association about twelve months ago, passing mention was made of a small vessel with an unusual installation. The present paper is intended to give a fuller and more detailed description of this prototype vessel, named *Tom Jay,* a small barge-towing tug on the Thames. In appearance (see Fig. 1, Plate 1) it is the same as any other Diesel tug. There are, however, two special features about it; propulsion is effected by a hydraulic motor, and the hydraulic power is developed by three Diesel engines, with a fourth engine in reserve. Fig. 2 shows the general arrangement of the *Tom Jay* and Figs. 3 and 4 show further details of the installation of the Diesel engines and the hydraulic motor.

It may not be necessary to point out that in a single-engined job a very minor mishap may cause a breakdown. It may be a small matter and, if spares are on board, easily rectified; on the other hand it may be serious, necessitating a long delay, and this is inevitable if there is only one prime mover. Where there are two, as in the Diesel electric tugs *Framfield* and *Robertsbridge,* there is an immediate gain in availability, but not at full power. An increase in the number of engines increases the availability factor. Where, as in *Tom Jay,* there are four engines with full power on any three of them, then availability is at its maximum. It is suggested that for an installation such as that in the *Tom Jay,* there should be a minimum of four prime movers; the greater the number, the smaller percentage of power lying dormant. For example, in *Tom Jay,* with four engines—one of which is in reserve—it is 33 per cent; with five engines and full power on four it is 25 per cent. The percentage decreases as the number of engines is increased.

One then has the choice of an installation with a larger number of engines of small power and small but sufficient reserve, or a smaller number of engines of greater power and a larger reserve. The main idea, whichever method is chosen, is that a prime mover is always in reserve which can be laid off for scheduled servicing or, alternatively, be ready for use should trouble arise on another engine or pump. In this way it is possible to budget for full power all the time. The great advantage of being able to manhandle all the parts of small engines should not be overlooked; heavy lifting tackle is not required.

## DESIGN AND CONSTRUCTION

The main object in designing this prototype was to build a vessel that would give the highest possible availability factor. The economy resulting from this was regarded by the author's company as of major importance, and everything was designed with that in view. This is probably the first vessel to be propelled in this way.

In 1944, the author discussed with Mr. G. F. Jones and Mr. M. G. Petty the design of a tug driven by a hydraulic motor, and prepared a plan in which the layout comprised Gardner engines directly driving radial hydraulic pumps. Mr. Jones has been responsible for the design of the hydraulic plant, which was constructed and erected under the able supervision of Mr. Petty. After careful consideration, the author's company decided to build an experimental tug to this design, of a power between the small 100 b.h.p. dock tugs and the bigger 360/400 b.h.p. river tugs. It was thought

* Mayor, F. J. 1951. "Developments in Thames Tugs". Diesel Engine Users' Association, S.216, July 1951.

that about 200 s.h.p. would give a very useful working tug of medium power, which would suffice to prove the practicability of this layout and method of propulsion.

A fruitless attempt was made to find a secondhand steam tug with a hull in sufficiently good condition, which could be stripped of its boiler and engine and used for the experiment; it was therefore decided to build a new hull. The vessel was built by the well known Lowestoft shipbuilders, Richards Ironworks, Ltd. The main dimensions of the vessel are 77ft. overall, with a moulded breadth of 18ft. and a maximum draught of 9ft. 3in., with scantlings similar to the company's other tugs. However, before any machinery was sent to the shipbuilder, it was decided to erect a mock installation at Park Royal. This comprised a Gardner engine directly coupled to a radial pump, a reserve oil tank, control valve, relay valve, and propulsion motor. A crude form of brake was devised and fitted to the propulsion motor shaft so that a load, similar to that of the propeller, might be applied. The object of this was to test thoroughly the hydraulic mechanism and its manœuvring qualities for going ahead and astern and to discover and remedy any defects before sending the machinery to the shipbuilders. These trials proved to be very useful and informative and resulted in several necessary modifications.

There are certain advantages attached to a multi-engined installation which are well worth consideration wherever it is necessary or desirable to maintain a continuous and uninterrupted service. This might be accomplished in conjunction with electric propulsion or, as in the *Tom Jay*, by Diesel hydraulic propulsion. It was decided to use Diesel hydraulic propulsion for this experimental prototype vessel, as it was felt that, if properly carried out, it had all the essential requirements for a reliable and trouble-free job.

The author was induced to consider favourably the three or four engined installation by the very good service record put up by the two Diesel electric tugs *Framfield* and *Robertsbridge* owned by his company. Each of these tugs is fitted with two engines and two generators; with such an installation the tug is very seldom incapacitated. On occasion each of them has had engine or electrical trouble necessitating the shutting down of one engine, nevertheless the tug has continued in service.

This record led the author to consider whether or not it was possible to design an installation that would have a still greater, or even complete, immunity from total immobilization. There are examples in public transport where it is essential at all times that service should be maintained, which shows that the trend of design has already been governed and conditioned by that idea. In the *Tom Jay* this idea has been put as far as possible into practical form for water transport. The purpose of a tug is to tow barges or other vessels and it is desirable from an owner's point of view that it should be in service as many days in the year as possible.

A high availability record gives the owner a major economy and this was the principal idea in the author's mind in designing the *Tom Jay*. At first, the use of small high-speed engines of 1,500 r.p.m. was considered, to be geared down to a suitable speed for the pumps, but it was finally decided to use larger engines of slower speed, 800 r.p.m., to drive the pumps direct and thus dispense with the need for gear drive. The engine finally chosen, when working at full load, develops about three-quarters its rated load, so it will be seen that the engines are at all times comfortable and never overloaded. The economy of this is reflected in low maintenance costs.

### MACHINERY LAYOUT AND OPERATION

The layout of the plant can be seen from Fig. 2. Figs.

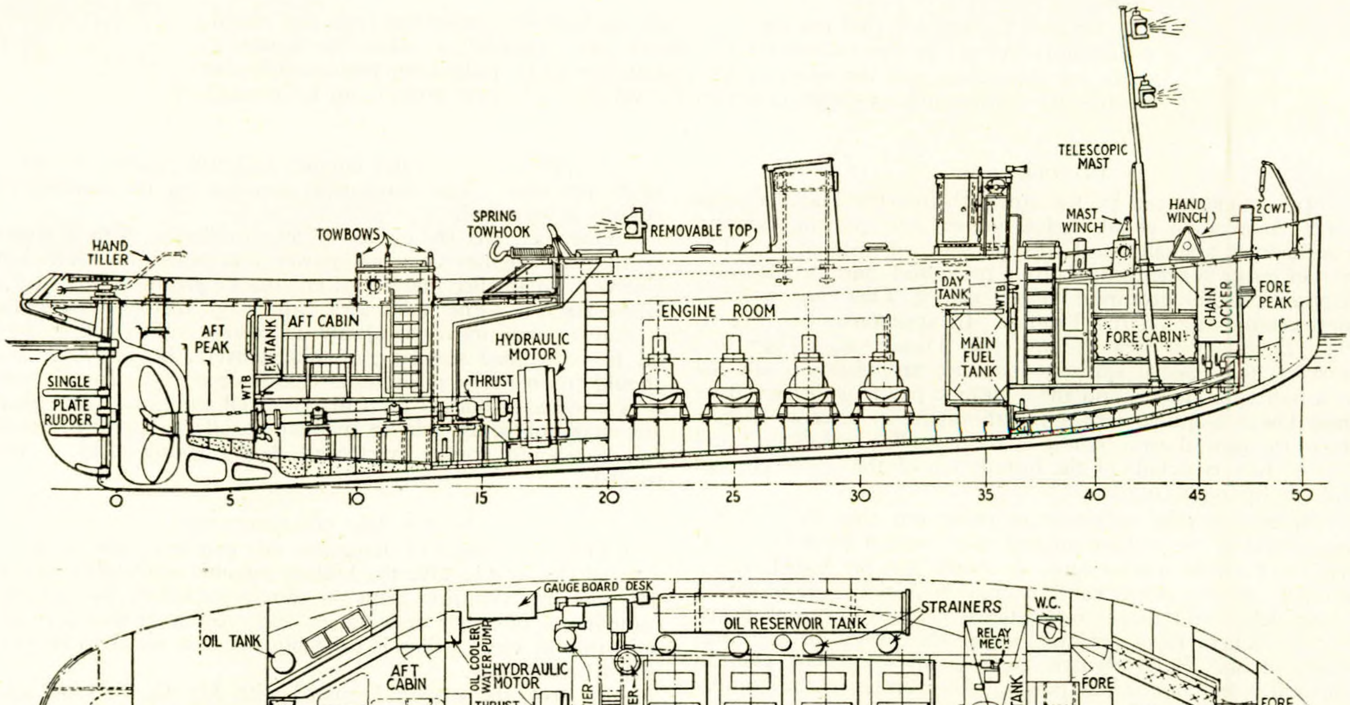


FIG. 2—*Line drawing of the general arrangement of the* Tom Jay

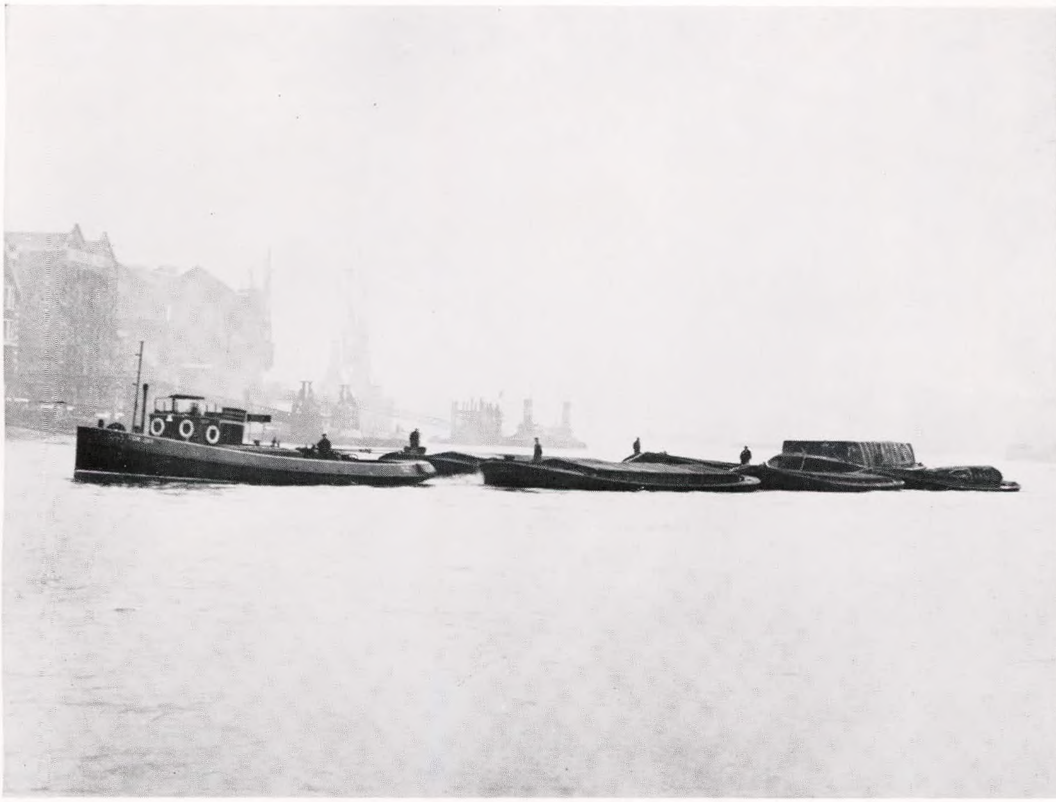

FIG. 1—*View of the* Tom Jay *towing barges*

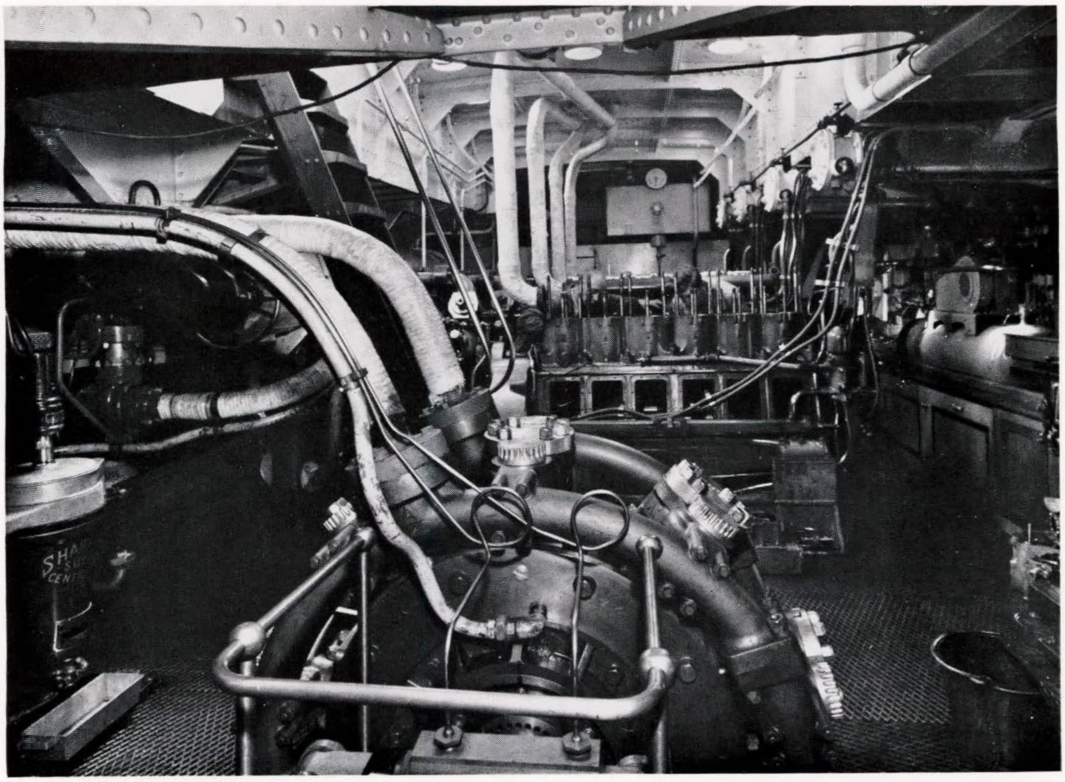

FIG. 5—*View of engine room from aft, showing engine No. 4 under repair while tug is at work on three engines*

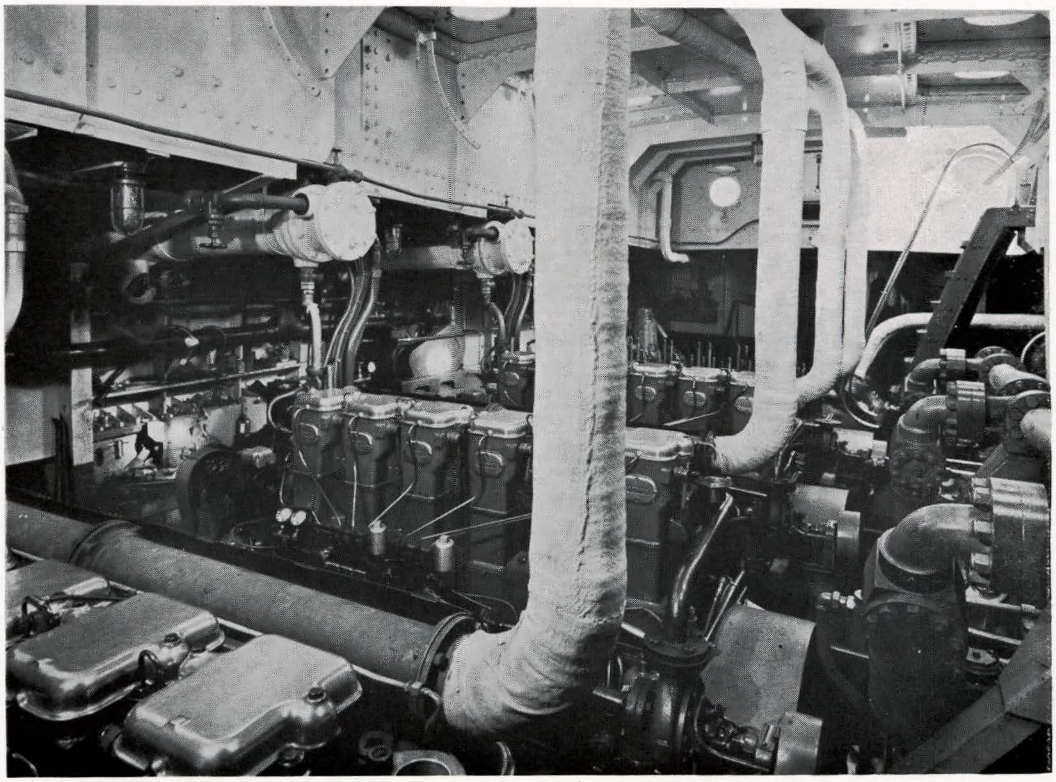

FIG. 6—*View of engine room from forward showing heat exchangers, isolating valves and pressure main*

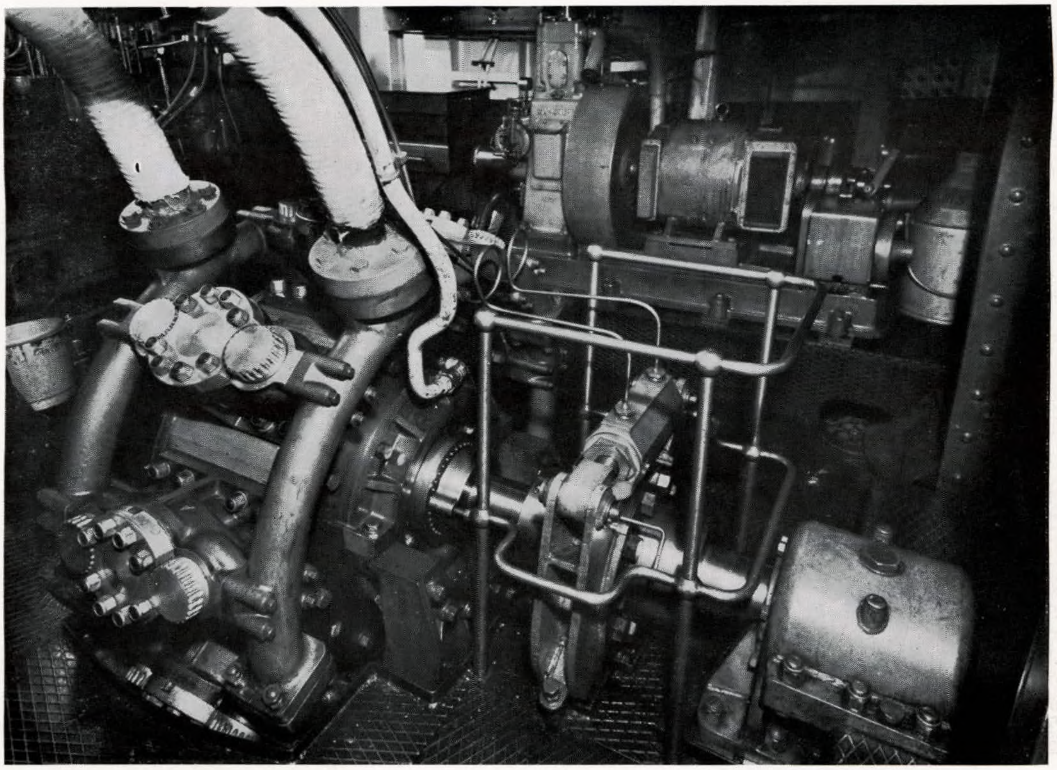

FIG. 8—*View of propulsion motor and hydraulic brake and thrust block, also auxiliary*

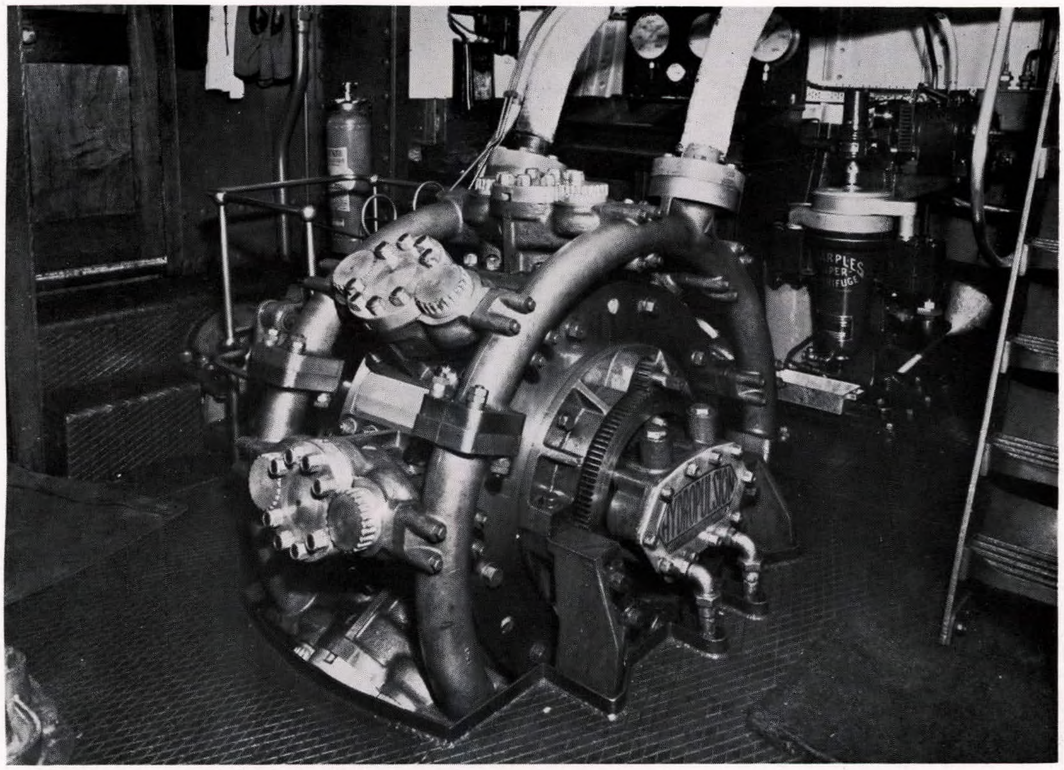

FIG. 9—*View of nine cylinder propulsion motor, two pipes pressure and exhaust, clarifier—control desk and gauge board*

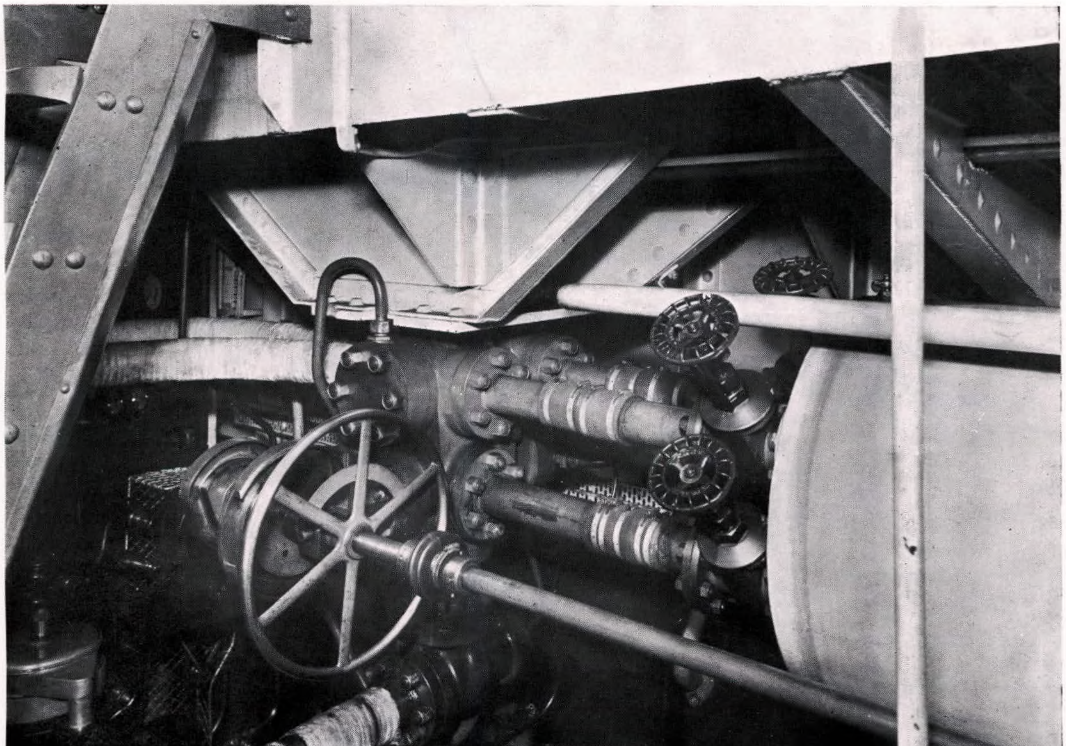

FIG. 10—*View of control valve and discharges to the reserve oil tank and hand control in engine room if necessary—pressure retaining valve below*

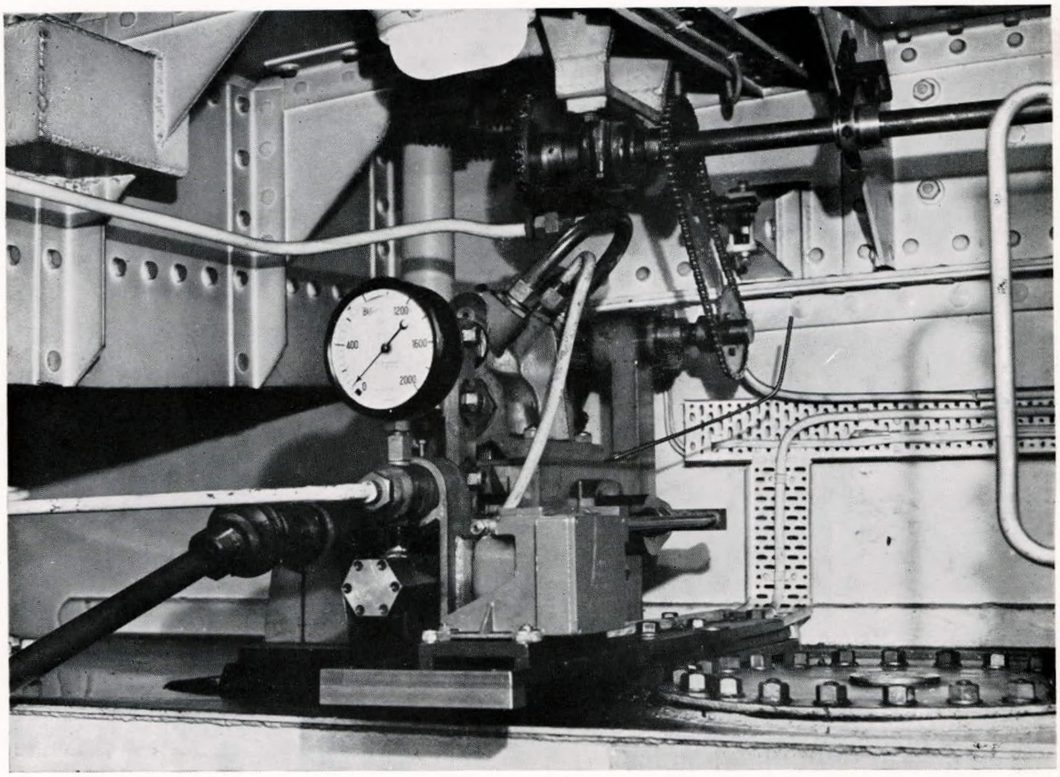

FIG. 11—*View of relay valve and master unit for power rotor*

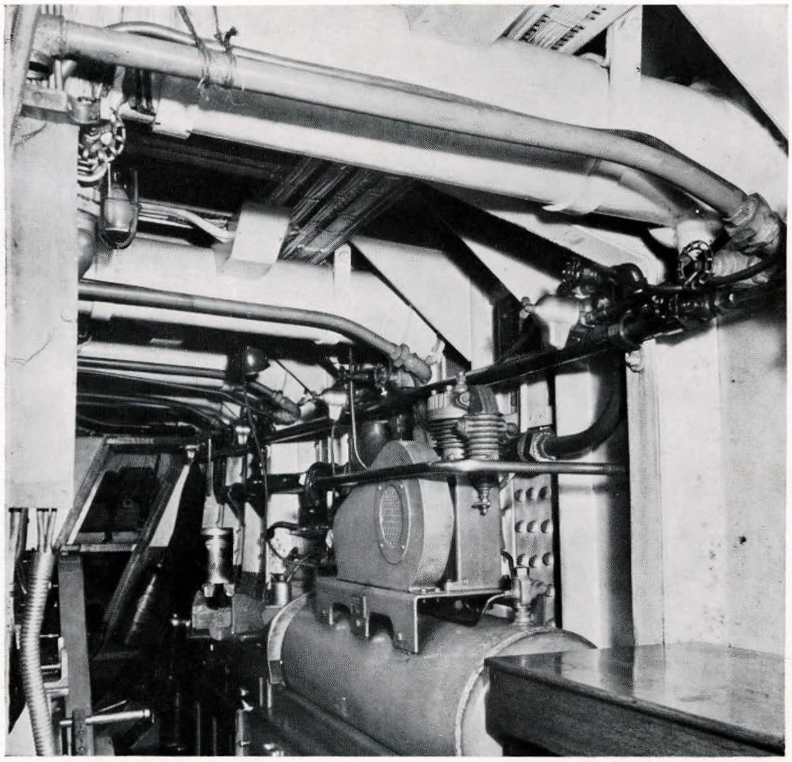

FIG. 12—*View of motor driven air compressor and receiver for whistle air and batteries—piston from No. 4 engine under repair in vice*

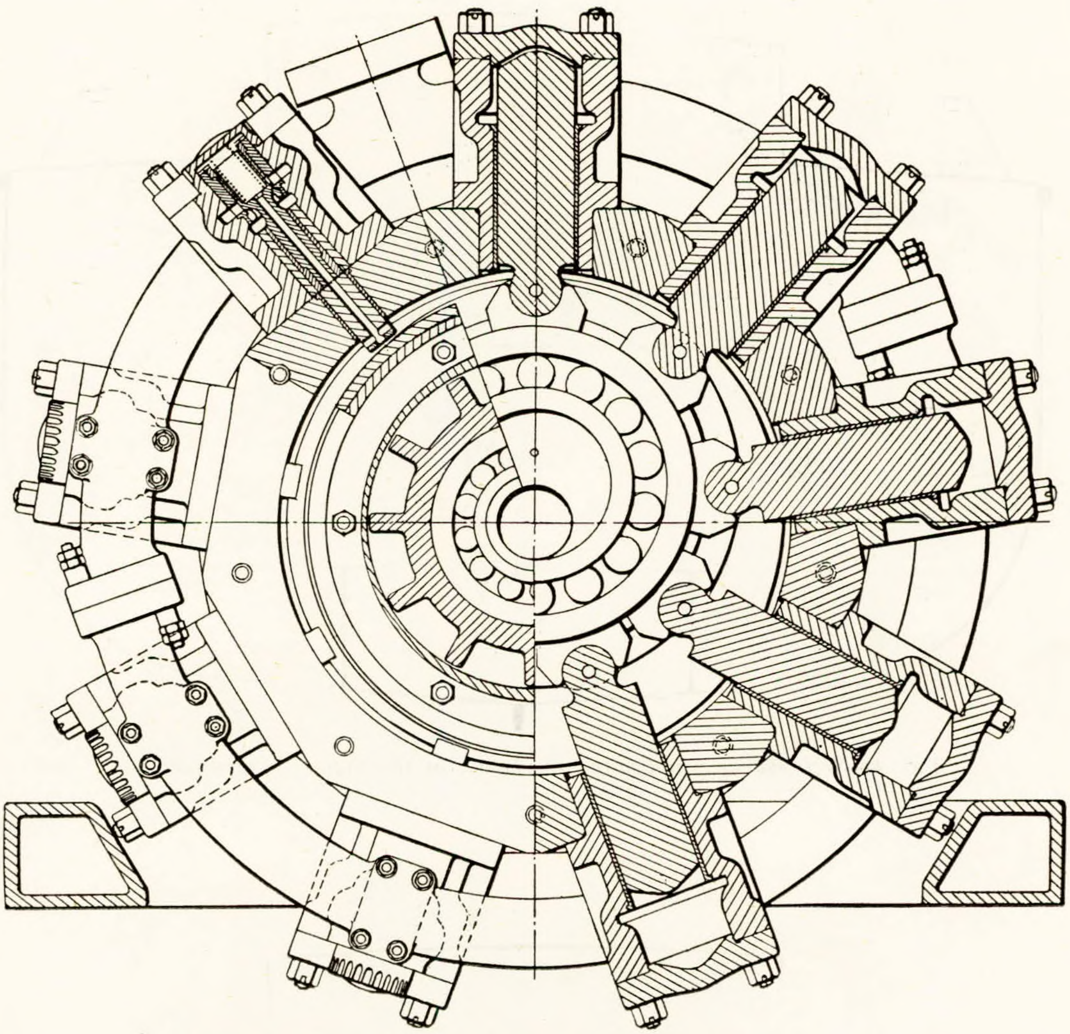

FIG. 3—*Sectional view of the hydraulic propulsion motor*

5 and 6 (Plate 1) show different views of the engine room. Each of the four power units consists of a six-cylinder Gardner L3 compression ignition engine developing 102 b.h.p. at 800 r.p.m. The engines are started by 24-volt electric starting motors, power being supplied by 300 ampere hour Exide batteries, and are fitted with suitable dynamo for charging the batteries.

These engines are directly coupled to seven-cylinder radial oil pumps. The pumps are gravity fed with oil from a tank holding 400 gallons of oil, suitable for hydraulic pumps and motor. A strainer is fitted on the suction line to each pump. The oil is delivered by the pumps to a service main at varying pressures according to the speed of the engines. The pressure will vary with the demand made by the propeller and the load on the tow hook. It will vary from a minimum pressure when the tug is running light to a maximum pressure when the tug is at full speed with a heavy load on the towhook. With the present propeller on the *Tom Jay,* the maximum pressure is 1,250 to 1,300lb. per sq. in. As the load decreases, so also does the pressure decrease.

The oil passes to the control valve by way of the pressure retaining valve. The function of this valve is to retain sufficient pressure, when the pumps are running under no load conditions, to operate the reversing valve.

The control valve is connected to the propulsion motor (Fig. 7) by two pipes, one of which conveys the oil under pressure to the motor when the vessel is going ahead and the other conveys the exhaust oil from the motor. When going astern, these functions are reversed, the pipe that was formerly the pressure pipe when going ahead, becomes the exhaust and the pipe that was the exhaust when going ahead becomes the pressure pipe when going astern.

Figs. 8 and 9 (Plates 2 and 3) show the arrangement of the propulsion motor, hydraulic brake, thrust block and exhaust clarifier. The control valve (Fig. 10, Plate 3) is connected to the relay valve (Fig. 11, Plate 4) by a shaft fitted with universal couplings. The relay valve is in turn connected to the bridge or wheelhouse and is operated by the captain by means of an orthodox ship's telegraph. The captain, when moving the telegraph from stop to ahead or astern, moves not only the hydraulic control valve, but simultaneously controls the speed of the three engines through the engine fuel pumps. This engine control is accomplished by a "power rotor" unit by which a master unit, operated manually by the captain, actuates a slave unit on each engine, which in turn controls the fuel pump. In this way engine control is synchronized and the three engines work in perfect unison with the control valve and each other.

The hydraulic control valve is moved by the relay valve. This is similar in principle to all relay mechanism. The captain operates manually a pilot valve which admits oil under pressure and shifts a piston from its neutral position in one direction or another. By means of a rack and pinion and bevel gear the shaft to the control valve unit is rotated and by means

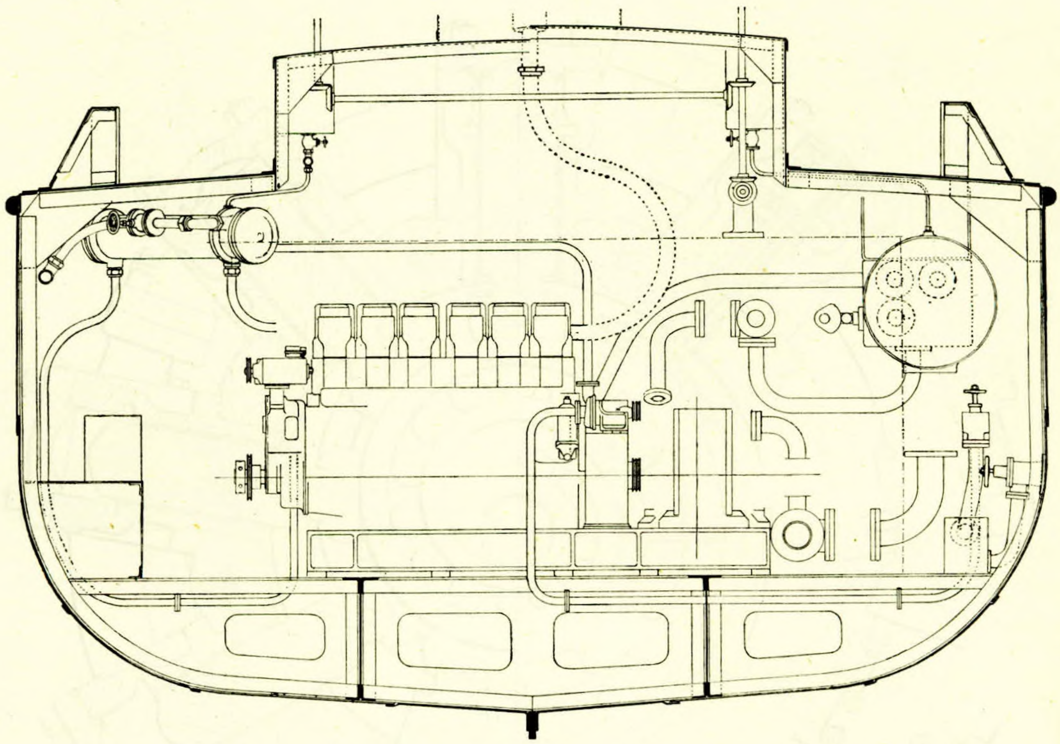

FIG. 4—*Sectional view indicating the layout of the engine arrangement*

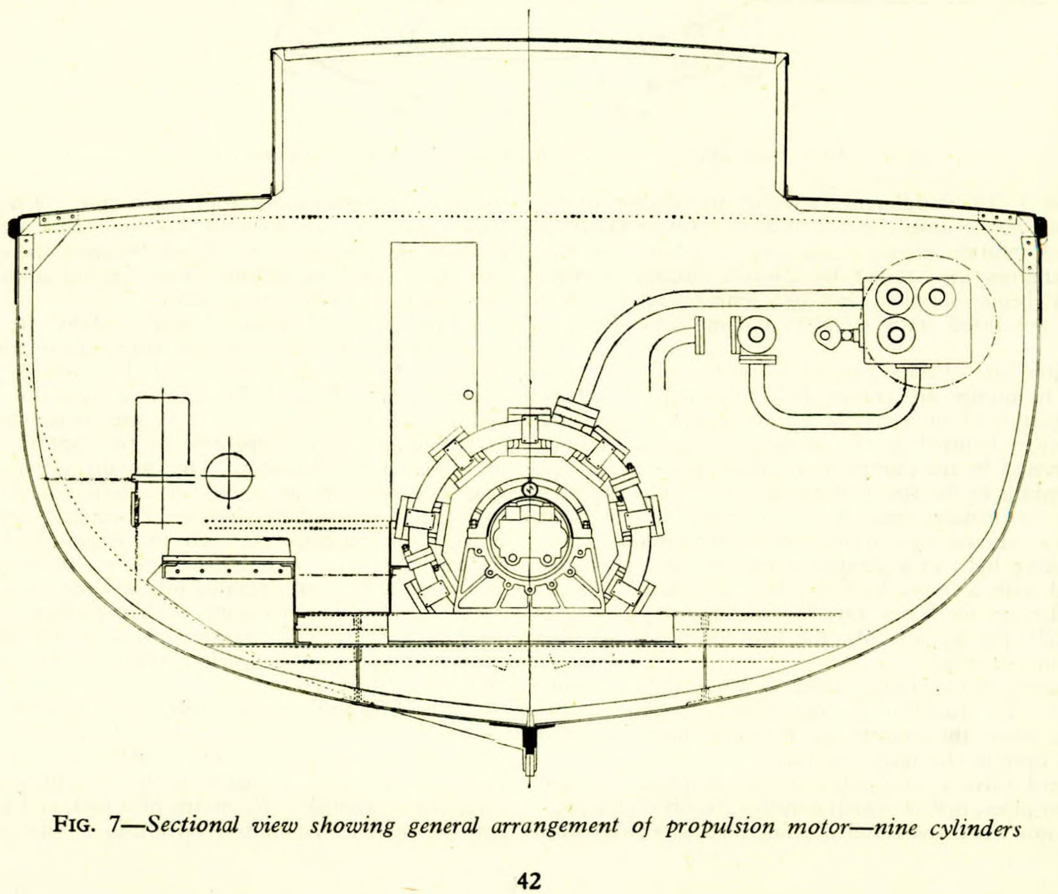

FIG. 7—*Sectional view showing general arrangement of propulsion motor—nine cylinders*

of the double track cams operates the selector valve and main valves in the control unit.

The propulsion motor runs at 103 r.p.m. when the pumps are delivering their full capacity of oil to the motor. The motor is of the radial type and has nine cylinders. These nine cylinders are fitted to a solid forged steel foundation ring, which is machined to take the extension piece on the lower part of each cylinder.

The oil has access to each cylinder through two poppet valves, one admitting oil under pressure from the pumps via the control valve and the other passing the exhaust oil back to the tank via the control valve unit. As already described, the functions of these valves are reversed according to whether the vessel is going ahead or astern.

In the propulsion motor it will be noted that these valves are lifted mechanically. In this they differ from the pumps, the inlet and outlet valves of which are operated by the pressure of the pumps. The valves in the propulsion motor are lifted from their seats by tappets which in turn are moved by two eccentrics on the crankshaft. It is so arranged that there is very little movement between the tappets and the floating ring which lifts them, the greater movement occurring between the floating ring and the eccentric on the crankshaft. The two eccentrics are placed so that the inlet and outlet valves open in proper sequence.

When the telegraph is at full speed, the whole of the oil is passing through the control valve to the propulsion motor. At less than full speed the engines reduce the volume of oil delivered, thereby reducing the speed of the propulsion motor. When the telegraph is at "stop" position the whole of the oil is by-passed to the tank and the motor stops.

The inner ends of the plungers are shaped to fit into bronze slippers which are machined to run on the outer ring of a large ball race. The rocking motion of these slippers is very small.

The crankpin is fitted with a very robust roller bearing, the inner race of which is a press fit on the crankshaft and the outer race takes the slippers already mentioned on the lower end of the pistons. The slippers are kept in close contact with the outer race by means of a floating ring. In the *Tom Jay,* the rams of the hydraulic motor have a diameter of 4⅜in. and a stroke of 4⅜in. The pressure in the cylinder is constant throughout the stroke. The crankshaft runs in self-aligning bearings which are supported in housings.

With the nine cylinder motor there is an impulse every 40 degrees which is conducive to very smooth running. The whole motor can be rotated by means of gear for purposes of access when overhauling or repairs are required. By this means the bottom cylinders and valves can be brought, when required, to a position where they can be easily examined, repaired or removed.

The motor is provided with a gear driven oil pump for lubricating the roller bearings and other moving parts. This pump is reversible in action with the motor, and is supplied with oil from the main reserve oil tank. The oil dealt with by this pump floods the motor casing and bearings and is returned to the main reserve oil tank through an oil cooler. Any heat generated by the moving parts is dissipated by the cooler. Any heat generated by the moving parts of the power pumps is also dissipated by the cooler. The friction of the moving parts running in lubricating oil is so small, however, that it has been found unnecessary to use the cooler in cold weather. The usual working temperature of the oil is from 100 to 110 deg. F. This is found to be a very suitable and economical working temperature.

The hydraulic medium is a very important item in an installation such as this. It should be a suitable lubricating oil of the correct grade and characteristics for this work. Its viscosity should be such that it will flow freely through the valves, pumps and motor and at the same time be a perfect seal against leakage past rams and valves. It should allow the plant to run at full speed on starting up when the temperature of the oil is low and it should allow the pumps and motor, when the temperature of the oil, after several hours' work, has risen to 100 deg. F., to maintain their efficiency without being impaired by leakage past the unpacked rams. In actual practice, there has been no difficulty in finding an oil that fulfils all these requirements and gives perfectly satisfactory service.

It will be noted, for example, that above the rams in the propulsion motor we have oil, when at full speed and load as in the *Tom Jay,* at a pressure of 1,250 to 1,300lb. per sq. in., whilst below the rams in the crankcase chamber the pressure is not more than about 12lb. per sq. in. Any oil that may leak by the rams passes from the high pressure to the low pressure side and eventually back to the main reserve oil tank.

The whole of the hydraulic oil system is closed, the only part of it open to atmosphere being the topping up or header tank, the highest part of the hydraulic oil system. The glands on the shafts of the pumps and the aft end of the propulsion motor are the only places in the whole system where there is any likelihood of oil leakage. These glands are fitted with a carbon type packing suitable for rotary shafts. They are found to be practically drop tight with very little loss of oil and no wear on the shaft. It will be seen from Fig. 2 that a strainer has been fitted on the suction line to each pump. The volume of oil passing through the system in the *Tom Jay,* when engines are running at 800 r.p.m., is 12,500 gal. per hr. and strainers and filters must do their work without impeding materially the flow of oil in any part of the system.

Since the *Tom Jay* has been at work, as an additional safeguard the author has fitted a centrifugal clarifier of standard type to ensure the utmost cleanliness of the hydraulic oil. This deals only with a proportionately small quantity of the oil at a time, which is by-passed through the clarifier. Its initial function is to cleanse the oil and extract any foreign solid matter from inside pipes, valves, castings, etc., and by being switched on occasionally thereafter, to keep the hydraulic oil absolutely clean.

It is not possible to overstress the vital importance of this matter of cleanliness. In the *Tom Jay* all the moving parts of the hydraulic machinery are machined, hardened and ground to very fine limits, and any care, trouble and precautions taken in this very important matter will be well repaid by continuity of satisfactory service and low maintenance costs. In the author's view it would be worse than useless to construct hydraulic plant with such care and precision and then run the risk of impairing its working by neglecting to give equal care to ensuring the cleanliness of the oil which operates it.

It was soon found essential to include in the design one very important feature, a hydraulic brake. The purpose of this is to stop the propeller immediately when the telegraph is in the "stop" position. For instance, when running full speed ahead, and the telegraph and control valve are then put in full speed astern position, the momentum of the propeller would build up an excess pressure that would lift the relief valves, with resulting loss of pressure. To overcome this difficulty, it was arranged for a hydraulic friction brake to come into action automatically when the engines were running and the telegraph was in the "stop" position. The brake is of very simple design and construction and consists of two Ferodo lined shoes. The lower ends of the shoes are hinged to the base and the upper end of one shoe carries an oil cylinder in which works a piston secured to the upper end of the other shoe. When oil under pressure is admitted to the cylinder, it brings the shoes together and grips the coupling situated between the motor and the thrust shafts, and immediately stops the propulsion motor. When the oil pressure is released, a spring forces the shoes apart. The pressure is admitted automatically by the relay valve at the moment oil pressure is shut off from the motor. The brake is firmly bolted down to a very substantial fabricated base of heavy steel plate, which is in turn securely fixed to the ship's floors. The rate of reversing is provided for by means of chokes or nozzles in the ends of the reversing valve chamber; a nozzle can be chosen with an aperture suitable for the time required for reversing. A similar choke or timed nozzle is fitted in the relay gear. These nozzles can be easily fitted and changed either to speed up or slow down the time taken in reversing; too slow a reversal is undesirable, and too rapid a reversal would impose needless shocks on the hydraulic plant. In the *Tom Jay* the time taken to reverse the propeller from full ahead to full astern is 12 seconds, which is quite satisfactory from an operational point of view and very similar to the time taken by the company's other tugs.

The reserve oil tank is a reservoir which feeds the power pumps and receives the exhaust from the propulsion motor and the crankcases of all the pumps. It is 14ft. in length and 2ft. 3in. in diameter, and is constructed of ¼in. steel plate made smooth and bright inside to obviate as far as possible any trouble that might arise from dislodgement of scale or dirt. The main discharges into the tank via the control valve unit are in the aft end at the upper part of the tank. A dividing plate is fitted horizontally the whole length of the tank, secured at the aft end but with ample clearance at the forward end. The object of this arrangement is to ensure that the oil discharged into the tank from the pumps and motor traverses the whole length of the tank above the division plate before it reaches the four pump suctions taken from the bottom of the tank. This results in a good circulation of the oil through the tank and prevents the possibility of those pumps nearest the discharge short circuiting the supply. Incidentally, this tank with its large surface helps materially by radiation to dissipate any heat from the crankcase oil discharged into it.

In the *Tom Jay*, the original intention had been to supply oil to the pumps through a large suction main, but it was decided during the construction of the vessel that it might be better to connect each pump suction directly to the tank in order to ensure that each pump received its full quota of oil. The original method could still be followed and with some installations it might be preferable, provided care was taken regarding the run and diameter of pipes to give equality of distribution.

There is in addition to the tank just described, a small tank called the "header" tank. This is placed well above the reserve oil tank. A pipe connects the bottom of the header tank with the top of the reserve oil tank, which is thus kept quite full of oil with a static head of several feet. Any replenishment of the hydraulic oil is made into the header tank through a fine gauze strainer. The tank is fitted with a bolted cover.

The discharge from the relief valve on each of the four pumps is taken into the header tank, which also receives the clarified oil from the Sharples separator. The delivery from this is made through the top of the tank, the internal discharge pipe being carried nearly to the bottom to avoid aeration of the oil.

It is important that every measure be taken to abstract air from the hydraulic system. The run of piping should be so arranged that there are no air pockets, and venting should be provided at any high spot. For efficient and quiet working there should be no visible air in the oil. On initial starting up it may take some time to rid the oil of air and provision has been made on the pump cylinders for bleeding the oil until it is shown to be clear of air bubbles.

The thrust block is an important feature in any installation and the block in *Tom Jay* was specially designed. The roller thrust bearing is of the spherical roller type. The thrust is applied to the bearing through a split collar fitted in the recess between the two seats. Provision is made for limited self alignment, and fore and aft movement has been kept to 0·003 inch. The capacity of this bearing at the full speed of the propeller is 60 tons, which gives this thrust block a safety factor of nearly twenty.

Owing to difficulties in delivery for castings, the housing of the thrust block was fabricated from heavy steel plate. The block was firmly bolted down after special care had been taken in alignment. It is satisfactory to note that throughout the whole period the tug has been in service the thrust block has not given the slightest trouble.

Distilled water in a closed circuit is used for cooling the engines with a separate heat exchanger for each engine, so that isolation of any one engine does not affect the others. A small "header" tank is also fitted to this circuit. A belt driven centrifugal pump on each engine pumps sea water through the heat exchangers to cool the distilled water. Each hydraulic pump can be isolated from the pressure main when necessary by a strongly made full way valve designed for high pressure, and another ordinary gate valve is fitted on the suction line.

The auxiliary is a Gardner single cylinder engine developing 6·65 b.h.p. at 700 r.p.m. It is directly coupled to a battery charging generator and is clutch-coupled to a bilge and general service pump. This is connected to a suction distribution box to pump from sea, fore cabin, bilge, engine room bilge and also to a deck connexion for suction hose.

The delivery distribution box has connexions to the engine sea cooling system through the heat exchanger, delivery overboard, engine room fire and washdown hose.

The peak tanks are pumped up by means of the deck hose and the after peak tank is pumped out by means of the deck salvage suction hose.

Provision is made for whistle air by a self-contained set comprising a motor driven compressor mounted on top of a small receiver (Fig. 12, Plate 4). Twenty-four volt batteries supply the power for the motor. Delivery of air is automatically governed by the pressure of air. There are two receivers, one above and the other below the bench, the two being connected. A valve permits the two receivers to be isolated or connected. The receivers are 15 inch diameter by 48 inch long, which gives a total capacity of 10 cu. ft. The compressor is belt driven at 700 r.p.m. by a 1 h.p. 24-volt motor at 1,400 r.p.m. Maximum air pressure is 150lb. per sq. in.

The propeller is a principal part of any installation and should have the correct proportions for the job. The diameter is more or less determined by the draught of the vessel, and the pitch within the usual pitch ratio limits. The surface, number of blades, set back, and revolutions are matters which will receive the careful consideration of the propeller expert, with the view of obtaining the most efficient propeller for its particular work. It should be able to use economically the horsepower transmitted from the active prime movers.

The volume of oil passing through the motor at the full speed of 103 r.p.m. is a known calculable quantity. The pumps are designed to supply easily this quantity of oil, and the engines are capable of running the pumps at full load and full speed comfortably and continuously.

The load on the towhook, combined with the speed, directly affects the pressure. The propeller characteristics are also important factors. Increase of the diameter, pitch, or surface all directly affect the pressure of the hydraulic medium.

The hydraulic plant in the *Tom Jay* has been designed to work up to a maximum pressure of 2,000lb. per sq. in.

The engine room is noisier than the author would like, but it is anticipated that in the near future a considerable improvement may be effected in this respect.

### MANŒUVRING AND HANDLING QUALITIES

The design of the hull, rudder and steering gear, together with the time taken in reversing the propeller from full ahead to full astern, is important and it is the happy combination of these that makes a tug handy when manœuvring. In the *Tom Jay* these essential features have been retained, with the result that it is equal in this respect to the company's other tugs.

### SERVICING

Accessibility for repair has been a dominant feature in the design of the *Tom Jay*. On one occasion it was necessary to open up and overhaul one of the hydraulic pumps; it was arranged for the tug to come under the crane at high water when the pump was removed to the shops and the tug, still in full power, was away again to work in forty-five minutes.

A schedule for servicing the engines has been compiled and posted in the engine room, with a copy in the office, and the shore staff effect overhaul and servicing while the tug is at work.

OPERATIONAL RESULTS

The following figures record the results of some trials made after the tug had been continuously at work for more than two years. A representative of Norris, Henty and Gardners, Ltd., the engine builders, was aboard during the standing pull test in Millwall Dock to check the fuel consumption of the three engines during the test. He reported that "for engines of this age, and under these conditions of temperature and load, we would estimate a specific fuel consumption rate of 0·365lb. per b.h.p. per hr.". The specific gravity of the fuel, B.P. Gasoleum, was also checked; it was 0·84.

A special set-up was constructed to ensure accurate measurement of fuel. The time taken to consume a given quantity of fuel with the engines on full load was measured; 5 gallons were consumed in 31 min. 24 sec.

The b.h.p. of the engines was computed on the figures given above.

The Siemens-Ford torsionmeter was fitted on the intermediate shaft and readings were taken by a representative from the manufacturers. The torsionmeter recorded 192·5 h.p. on standing pull. Engine b.h.p. on fuel consumption basis = 219·87 b.h.p., therefore the mechanical efficiency of hydraulic transmission $= \frac{192 \cdot 5}{219 \cdot 87} = 87 \cdot 55$ per cent.

Tom Jay—*Standing pull trial in Millwall Dock, 23rd October 1951*

Standing pull, 3 tons 8 cwt.: three engines, Nos. 2, 3 and 4.

| | |
|---|---|
| Shaft horsepower by torsionmeter | 192·5 |
| Engine horsepower by fuel consumption ... ... ... | 219·87 |
| Efficiency ... ... ... ... | 87·55 per cent |
| Hydraulic pressure ... ... | 1,400lb. per sq. in. |
| Propeller revolutions ... ... | 101 |

On the following day a towing trial was made on the Thames and corresponding figures for fuel consumption and shaft horsepower were taken. The mechanical efficiency calculated on the same basis works out at 78 per cent.

*Towing two barges, 24th October 1951*

| | |
|---|---|
| Total weight ... ... ... | 529 tons |
| Shaft horsepower by torsionmeter | 161·6 |
| Engine horsepower by fuel consumption ... ... ... | 207·1 |
| Efficiency ... ... ... ... | 78 per cent |
| Hydraulic pressure ... ... | 1,250lb. per sq. in. |
| Propeller revolutions ... ... | 103 |
| Speed over measured mile both ways ... ... ... ... | 4·86 knots |

With regard to the difference in efficiency figures quoted between 87·55 per cent for the standing pull and 78 per cent for towing 529 tons, probably the explanation is that the friction of all the working parts of the pumps and motor and the oil throughout the hydraulic system remains practically constant whatever the load. It therefore follows that efficiency is greatest on heavy load and decreases as the load is reduced.

No special measures were taken to overhaul the engines for these tests; they were in ordinary everyday working condition.

*Repairs.* The following figures are taken over a period of two years and compared with other types of tugs in the fleet, Diesel direct drive, Diesel reduction reverse, and Diesel electric. In order that they should be comparable, the two-year period is as nearly as possible the same in each case.

| Vessel | Type of engine | Period | Percentage |
|---|---|---|---|
| *Tom Jay* | Diesel hydraulic ... | 1950-51 | 14·9 |
| *Wortha* | Diesel direct ... ... | 1949-50 | 100 |
| *Irande* | Diesel reverse reduction | 1949-50 | 46·4 |
| *Framfield* | Diesel electric... ... | 1949-50 | 102·9 |

The Diesel direct reversing type has been taken to represent 100 per cent and the other types are relative. The figures represent cost of *labour, materials and establishment charges only.* The time the tug was out of service is not taken into consideration, but any spares or parts repaired ashore and afterwards fitted to the vessel are included.

*Fuel Consumption.* The following table gives the relative powers of five tugs with various transmissions and the fuel consumption, taken over a long period:

| Vessel | Type of engine | Maximum available s.h.p. | Average fuel consumption per hr. | Period |
|---|---|---|---|---|
| *Tom Jay* | Diesel hydraulic ... | 192·5 | 3·99 gal. (3 engines) | 26.9.49-25.9.51 |
| *Framfield* | Diesel electric... ... | 400 | 12·08 gal. (2 engines) | 15 years |
| *Robertsbridge* | Diesel electric... ... | 400 | 12·1 gal. (2 engines) | 13 years |
| *Wortha* | Diesel direct ... ... | b.h.p. 360 | 104·4 gal. (per tide) | 16 years |
| *Irande* | Diesel reverse reduction | 330 | 7·26 gal. (per hr.) | 4 years |

Taking the hourly fuel consumption of *Tom Jay* as the yardstick at 4 gal. per hr., proportional fuel consumption of the other tugs according to their h.p. (allowing 9 hours' work per tide for the tug *Wortha*) should be:—

| | |
|---|---|
| *Wortha* ... ... | 7·4 instead of 8·7 |
| *Irande* ... ... | 6·2 instead of 7·26 |
| *Framfield* ... ... | 8·3 instead of 12·1 |

*Availability Factor.* The availability factor is computed as follows:—

| | | |
|---|---|---|
| | | 365 |
| Less Sundays | 52 | |
| Less holidays | 6 | |
| | | 58 |
| | | 307 working days |

$$\text{Availability factor} = \frac{\text{Number of days } \textit{actually} \text{ worked}}{\text{Number of days } \textit{possible} \text{ to work (e.g. 307)}}$$

| Vessel | Availability factor, per cent | Period |
|---|---|---|
| *Tom Jay* ... ... | 95·5 | 2 years |
| *Wortha* ... ... | 74·9 | 16 years |
| *Irande* ... ... | 88 | 4 years |
| *Framfield* ... ... | 78·1 | 16 years |
| *Robertsbridge* ... | 82 | 13 years |

It is anticipated that with ordinary care the high availability factor of the *Tom Jay* can not only be maintained, but will be improved, as the first two years includes a few stops due to teething troubles inevitable in any new type of installation, but which it is now felt with reasonable confidence will not recur.

*Powers.* The comparative powers and propeller speeds for the various types of installation are shown below:—

| Type of engine | Horsepower | Propeller revolutions |
|---|---|---|
| Diesel electric ... | 530 engine h.p. to give 400 s.h.p. | 100 |
| Diesel hydraulic | 207 engine h.p. to give 161 s.h.p. | 103 |
| Diesel reverse reduction ... | 330 engine h.p. to give 307 s.h.p. | 275 |
| Diesel direct ... | 360 engine h.p. to give 349 s.h.p. | 275 |

*Personnel in Engine Room.* The personnel required by each type of installation is as follows:—

| | |
|---|---|
| Diesel hydraulic... ... ... | 1 man |
| Diesel electric ... ... ... | 1 man |
| Diesel with reverse reduction ... | 1 man and assistant |
| Diesel with reverse reduction and remote control ... ... | 1 man |
| Diesel direct drive ... ... | 1 man and assistant |

### CONCLUSION

It may very properly be asked what is the advantage of an installation such as that in the *Tom Jay* over the ordinary simple single engined direct Diesel tug? The advantage is mainly higher availability, an advantage which can reasonably be claimed to be of major importance.

The author wishes to make it quite clear that the tug was not designed to give any greater speed or pull, or show superiority over any other tug of similar shaft horsepower save in one thing, the most important factor of availability. The record of the first two years shows this to have been substantially realized. The records also show a gratifying economy in repair and fuel consumption. Apart from hydraulic propulsion, the development of the required power in several small engines instead of a single large engine, is a valuable contributory factor. The *Tom Jay* has merely put into actual practice the idea first suggested by Sir Harry Ricardo in 1931.

The everyday work of a Thames barge towing tug is difficult and exacting. As mentioned earlier in the paper, the owner may not be very concerned about the technicalities of the tug and its machinery, but he is vitally interested in, and appreciative of, its earning capacity. An installation from which he can expect and obtain 100 per cent service, or as near as possible, is one which will undoubtedly commend itself to him.

Multi-engine hydraulic propulsion in the *Tom Jay,* which even in the first two years has given such a good availability record, should give equally good results in trawlers, coasters, inspection vessels, ferries, or other similar vessels where the lay-off time must be kept to an absolute minimum.

The author trusts that the foregoing description of this prototype vessel, together with the record of two years' service, has been of interest. If it has been shown that it can successfully and economically do the difficult work of a Thames tug, it may well be considered as a practical proposition for other and larger vessels with less arduous duties, always provided, of course, that the owner considers a high service or availability factor to be a matter of importance.

### ACKNOWLEDGEMENTS

The author wishes to acknowledge with many thanks the valuable assistance of Constants, Ltd., the naval architects, who watched with this accustomed skill and care the construction of the *Tom Jay.*

Finally, a tribute is due to the Thames Steam Tug and Lighterage Co., Ltd., who, by the same courageous enterprise they showed in pioneering the Diesel tug on the Thames in 1929-30, made the building of the *Tom Jay* possible.

# Discussion

Mr. C. P. Harrison (Member of Council), who opened the discussion, said that Mr. Mayor had had so wide an experience of tugs of all types that one hesitated to make any comment on the paper. It seemed like teaching one's grandmother to suck eggs. Many questions were prompted by the paper, but he would restrict himself to four.

First of all, what was the normal range of engine speed? He took it that there was an idling speed and—as the author had explained in presenting the paper—the revolutions went up with the power demand.

Secondly, had any trouble been experienced in keeping three engines at equal speeds? The author said that there had been no difficulty, and that must be accepted. But if they did not keep at the same speed was there any surging or hunting trouble in the hydraulic system?

Thirdly, it was difficult to understand the figures for fuel consumption, in spite of the remarks made by the author. How did the figure of 5 gallons consumed in 31 min. 24 sec. (see "Operation Results", page 45) compare with 4 gallons per hour for service consumption? It was very difficult to understand the difference between 4 gallons for 200 s.h.p. (in round figures) for the Diesel hydraulic and 12 gallons for 400 s.h.p. in two or more other cases. The discrepancy was something like 50 per cent.

Fourthly, he assumed that repair costs were for the engine-room only. Could the author say what proportion was for the engines and what proportion was for the electrics in the Diesel electric or for the hydraulics in the Diesel hydraulic machinery?

It seemed a little unfair, in relation to the figures given on page 45 of the paper, to compare a two-year old with a sixteen-year old in the matter of repair costs, fuel consumption and availability.

This availability factor applied, presumably, to the whole tug and included routine overhauls and maintenance on engines *and* hull. The availability factor, therefore, was not an absolute indication of engine and transmission reliability. He understood that in some tugs, perhaps on different duties, it was possible to do all that was necessary in the way of engine maintenance while the vessel was laid up for dry docking or some other regular maintenance or survey stoppage. This was the situation in a Diesel electric tug now twenty years old which had an availability figure last year of 94 per cent, so one might claim that the Diesel electric machinery itself was 100 per cent available. If this state of affairs could be achieved with a Diesel electric tug having two engines, there would appear to be no real case for the first cost of three or four units, although this could be done quite as easily with Diesel electric as with Diesel hydraulic. The transmission losses with the Diesel hydraulic appeared to be more than with the Diesel electric, especially at partial load, and one would expect efficiency to fall still further with age, whereas the electrical efficiency was maintained.

He was much intrigued by the hydraulic brake and the controlled rate of reversal of the propeller, both of which were necessary to protect the hydraulic system. He had always understood that manœuvrability was the answer to the tugmaster's prayer and was provided by electric propulsion; moreover, he believed that it was still so. Evidently some limitation had had to be accepted on the hydraulic system.

Apparently this system was far from simple. The movement of the telegraph moved a relay valve which operated the hydraulic control valve. This altered the engine speeds through a master and slave rotors and applied a hydraulic brake at the "off" position of the telegraph. These units must have a busy time during manœuvring!

He must offer his apologies to the author if, in the light of the author's convictions and in spite of his great experience, he appeared to be a little challenging. He could, of course, judge only by the paper, not having had the benefit of seeing the gear. Perhaps he was biased, but at the moment he felt that he would have an answer to the next man who told him that Diesel electric propulsion was complicated.

Mr. J. D. Thorn said that he had no doubt that the section of the paper which would arouse most interest and provoke most discussion, both at the Institute and elsewhere, would be that dealing with comparative data on the various systems of drive ("Operational Results", page 45).

The previous speaker had already referred to the figures for fuel consumption, and he himself was glad that Mr. Mayor had made something of a disclaimer about these figures. So far as the reverse reduction gear drive and the hydraulic drive were concerned, however, it was possible to make a reasonably accurate comparison on the basis of the efficiencies quoted in the left-hand column on page 45. The hydraulic system achieved 87·55 per cent transmission efficiency on standing pull trial and 78 per cent when towing two barges. With a reduction gear at loads equivalent to those two conditions, one would expect about 95 or 96 per cent efficiency. There was a clear margin, therefore, of at least 10 per cent if not nearly 20 per cent in favour of the reverse reduction gear. The fuel consumption data in the paper suggested that the opposite was the case, and the discrepancy must obviously be due to some extraneous factor, which Mr. Mayor had indicated was likely.

It was very interesting to note that since entering service, the *Tom Jay* had been fitted with a centrifugal clarifier for the hydraulic oil. He heartily agreed that scrupulous cleanliness was a virtue that could hardly be pushed too far. It would, for instance, benefit a good many engines which he knew if the lubricating oil were treated with considerably more care than was customary. In the case of Mr. Mayor's hydraulic oil, however, he was not sure whether to praise him for being so thoroughgoing or to sympathize with him for finding it absolutely essential to use a centrifuge. It would certainly appear that a little adventitious dirt could cause havoc with the hydraulic machinery.

Mr. W. A. Green drew attention to the author's statement that the function of the pressure retaining valve was to ensure that pressure was always available for operating the control valve. Did this mean that there was a spring loaded relief valve in the main delivery from each pump through which all the oil passed all the time? That would seem to be the implication. If so, what was the pressure at which these valves lifted? Whatever it might be, it would put extra work on the engines and pumps continuously, whether any work was being done by the propulsion motor or not. It did not seem to be a very efficient way of obtaining the pressure oil that was required in quite small quantities to effect the reversing of the controls.

He had intended to ask whether the engines were governed, but he gathered that they were and that the speed was controlled by adjusting the governor springs.

Under "Operational Results" (page 45), the author remarked that the difference between the mechanical efficiency figures obtained in the dock test and the towing test would be accounted for by the fact that the losses in the transmission were more or less constant. But his own (the author's) figures refuted that, because in the case of the dock test the difference between the engine b.h.p. and the s.h.p. was 27·4, whereas in the towing test it was 45·5—well on the way towards double. This was a surprising difference. Could it be that the losses in the transmission system were affected largely by the temperature of the oil circulating in the system? In view of the effect of oil temperature on engine performance it seemed possible.

Apart from this, was it legitimate to evaluate the b.h.p. of the engines by measuring actual fuel consumption per hr. and dividing it by the assumed consumption in lb. per b.h.p. hr. He would have thought that the figure given—0·365lb. per b.h.p. hr.—was what might be expected from engines under the optimum conditions, whereas difference in temperature of the jacket water or the lubricating oil would make a considerable difference to the consumption figure. One might well get a very much higher consumption figure under unfavourable conditions. This would help to account for the apparent difference between 27·4 and 45·5 h.p. loss in the transmission in the two different conditions.

Two speakers had already referred to the differences in fuel consumption between the different tugs. He himself looked at this matter in rather a different way. He had converted the figures given for consumption in gallons per hour and the s.h.p. into lb. per s.h.p. hour. This was a simple calculation, assuming the specific gravity of the fuel to be 0·85. The result was surprising. Assuming the full h.p. of 192½, the consumption of fuel for the *Tom Jay* was 0·17lb. per s.h.p. hr., an impossible figure. The only explanation was that the engine was not working at anything like the rated power most of the time.

The *Framfield, Robertsbridge* and *Wortha* came out at 0·27 and the *Irande* at 0·19. These figures were only approximations, but frankly he was mystified, and he wondered whether Mr. Mayor could throw any light on them. He would have expected them all to have about the same value.

There was one point which seemed to have some bearing here. Fig. 1 showed the *Tom Jay* towing six barges. He had had a number of runs on the *Framfield,* and he believed that her normal load was also six barges. One had two tugs, therefore, one of 200 and one of 400 h.p., both of which appeared to do the same amount of useful work. He would like to have Mr. Mayor's comments on this also.

Finally, he was very much interested to note that the *Tom Jay* had indirect cooling for the engines and that distilled water was used. On the rare occasions on which he was on an internal combustion engined ship, he was always horrified at the low cooling water temperature. Usually the outlet temperature seemed to be round 100 deg. F. To a land oil engine man that was a terrible figure. He wanted at least 140 to 160 deg. F. Did the author take advantage of the fact that the use of distilled water allowed him to run higher temperatures? He should gain in reduced wear and improved fuel consumption.

Mr. R. J. Welsh, Wh.Ex. (Member), congratulated Mr. Mayor on remaining a pioneer after fifty years' service in tug work. His pioneering spirit was shown in the statement that the use of small high speed engines was considered, but it was decided to use larger engines of slower speed, 800 r.p.m. (page 40). Having listened to various discussions at the Institute about engine speeds, he thought he could say that in classing 800 r.p.m. as a slow speed Mr. Mayor had given himself away as rather go-ahead!

Some of the points he had intended to raise had been dealt with adequately by other speakers. With regard to the control valve, however, other speakers had perhaps not made it quite clear that the hydraulic drive was a fixed ratio gear. The control valve only allowed the "clutch to slip" when idling. When the speed of the engine varied, it was merely on account of the propeller speed varying. The speed was varying with the power in accordance with the ordinary propeller law.

The performance of the tug was comparable to that of a direct driven rather than a Diesel electric tug. For example, the draw-bar pull was not particularly high. The author gave a figure of 30 cwt. per 100 h.p., but he was a little unfair because he was quoting that per s.h.p. actually developed when doing the pull.

With an ordinary direct-driven tug the figure given for pull per b.h.p. was generally that related to the rated b.h.p., and when tied to a bollard one did not get more than 70 per cent engine revolutions. The actual b.h.p. developed by the engine was thus only about 70 per cent of the rated power. Allowing for this, Mr. Mayor's figure of 30 cwt. was no better than 21 cwt. under the more usual nomenclature. Taking the ordinary standing pull figure for a direct Diesel tug as 25 cwt. per rated b.h.p., it would seem that on this job one was about 16 per cent lower.

This also accounted, to some extent, for the difference in fuel consumption between the Diesel electric and the Diesel hydraulic. The Diesel hydraulic being, in effect, a direct gear job, could not do full power all the time. When it was running light it gave a low torque. When it was towing its revolutions dropped. It never achieved full power. With Diesel electric, on the other hand, one could arrange to take full power from the engine all the time, both when running light and when towing, so that the total fuel consumption might well be higher.

He would like to hear from Mr. Mayor regarding the adjustment of the motor poppet valves. These had to deal with an incompressible fluid, so that the inlet and exhaust must be changed over very accurately at the right moment at the end of the stroke, otherwise there would be a knock in the cylinder. Equally, there must be no overlap between the opening of the valves, otherwise high pressure fluid would escape down the exhaust, and the efficiency would suffer. The valves were operated by eccentrics, presumably with half a stroke clearance; but there must also be some adjustment to take account of wear, and the setting must be rather critical.

With regard to the previous speaker's remarks on measuring, he would suggest that working from the fuel consumption of the engine introduced considerable uncertainty into the figures. A fuel consumption of 0·365lb. was remarkably good for an 800 r.p.m. engine at two-thirds load. He would not like to criticize a competitor or to say that it was impossible, but it was remarkably good. Nevertheless, if one assumed the fuel consumption at any higher figure, one did not need to go very far before achieving an apparent hydraulic efficiency of over 100 per cent, which raised grave doubts as to the whole method of measuring.

He suggested that the comparative figures for availability and maintenance cost did not necessarily prove that the Diesel electric was worse than the Diesel hydraulic but showed rather that new ships were better than old. The availability figures fell into a nice curve conforming closely to the law.

Availability percentage = $100 - 6\sqrt{\text{age in years}}$. It was difficult to form a judgement on the maintenance costs because the author did not say by what figure he had divided the total maintenance costs to arrive at the cost per h.p. The h.p. of the *Tom Jay* was a somewhat movable feast. It had 400 h.p. engines, so one might call it a 400 h.p. ship. On the other hand, only three were used at a time, so it might be called a 300 h.p. ship. Then again they were rated at 200 h.p., so it might be a 200 h.p. ship. If it cost £200 to maintain in a year, was that called 10s. per h.p. or £1 per h.p.?

When all was said and done, however, the fact remained that this was a new type of installation which had been successfully tried out, and after two years of service the owners were still obviously pleased with it. Any installation which could achieve that result clearly deserved both notice and commendation.

Mr. M. G. R. Petty (Associate) quoted paragraph 4 on page 43 of the paper:

> "When the telegraph is at full speed, the whole of the oil is passing through the control valve to the propulsion motor. When at less than full speed, the control valve allows part of the oil to go through to the motor and part is bypassed back to the reserve oil tank. When the telegraph is at 'stop' position the whole of the oil is bypassed to the tank and the motor stops."

He would like to expand that explanation as follows.

The first movement of the telegraph handle brought the servo relay mechanism into action and this, by means of a shaft, moved the track cam on the main control unit, the first operation of which was to select either head or sternway position. Close behind the direction valve was the full way circulating valve, whose function was to allow the delivery from all the pumps to circulate to the reservoir against no pressure, when the propeller was at rest. When the circulating valve was closed—that was to say, immediately the direction had been selected—the delivery from all pumps was piped to the hydraulic motor, which started to revolve. During this cycle, the Diesel engines remained at idling speed, about 200/50 r.p.m., and upon further movement of the telegraph the master unit of the servo relay moved three slave units connected to the governor bars of the Diesels, and all three engines increased in speed together. Thus, the volume of the hydraulic medium delivered by the pumps was increased, and as volume to the hydraulic motor was revolutions so the speed of the propeller revolutions was increased.

The next point was one which he wanted to make quite clear. At no time in the whole circuit—and this could not be too strongly emphasized—did the control unit bypass any live hydraulic fluid, with the resultant generation of heat which on many occasions had been the downfall of many hydraulic power transmission systems.

No mention was made in the paper of the method of supplying high pressure fluid for the actuation of the control mechanism. This was a small separate circuit comprising a very small seven-cylinder radial pump which delivered approximately 1½ gall. per min. at 1,600lb. per sq. in. One of these pumps was incorporated in tandem with each main propulsion pump, and these small units all delivered into a common main, provision being made so that one or any number might be used as desired. This main was connected via an adjustable relief valve to the main servo unit, so that a high pressure supply of small volume was available as soon as the engines were started. In practice, it had been found that only one of these pumps was necessary for the whole duty, which comprised the operation of the servo and control unit and also the application of the hydraulic brake fitted to the propeller shaft.

With regard to the figures for the trial in Millwall Dock and the subsequent towing trial, previous speakers had anticipated most of what he had intended to say. He would like to make quite sure, however, that these figures were not misunderstood. He had found it very difficult to accept them as being accurate. The standing pull trial figures approximated very closely to the theoretical calculations. They were within 2 h.p., which was a very narrow margin. With regard to the second figures, Mr. Green had already made the point that there was a drop of 27·37 h.p. in the first case and a drop of 45·5 h.p. in the second case, when the duty was lighter. As it might be taken that the frictional losses were almost constant throughout the range, the additional loss of h.p. must occur through leakage or hydraulic slip. He had yet to encounter a hydraulic system where the leakage increased as the pressure decreased, and it might well be that these figures would bear a little further investigation.

Mr. E. G. Warne (Member) said that Mr. Mayor had made a new approach to the subject of engine operation. He believed that safety lay in numbers. In his paper there was no search for efficiency other than that of finding a means to keep a tug at work, which was a commendable aim in itself, though a very specialized task and one to which the author had given much thought over a period of many years.

When the author's proposition was examined, it was found that he began with four engines of 102 b.h.p. apiece, or 408 b.h.p., and ended with three, totalling 230 b.h.p. It was explained that the machinery was derated to 75 per cent of the normal full load. One would expect that with a spare engine being carried around, the rest of the outfit might put up a bolder front! The brake mean effective pressure at 102 b.h.p. was 91lb. per sq. in., which was perhaps on the high side for continuous load, and yet no more was expected of these engines, which were intermittently loaded, than operation at 68lb. per sq. in. b.m.e.p.

Working along the author's lines, it appeared that no more than 56 per cent of the total available power was being used. Taking into account the losses sustained in employing hydraulic transmission, it would be seen that on the towing trial, with two barges loaded with 529 tons, the shaft horsepower by torsionmeter was 161·6. It could not be overlooked that the ship was fitted with engines of over 400 b.h.p., and to find that less than 40 per cent appeared at the propeller end of the installation was apt to give rise to some misgiving. Could the owner of any ordinary commercial craft afford to consider such a proposition? Even allowing for the use of only three engines, the author was not getting much over 50 per cent kick from his mule. He was making a bid for reliability, or to use his own word "availability", but the price seemed rather stiff.

Other speakers had commented on the estimation of the engine power in relation to the fact that the tug had been in service for two years. He would merely add, therefore, that if the consumption of fuel was estimated at 0·365lb. per b.h.p. hr., the engine builders were to be congratulated that an engine with a cylinder diameter of 5½ inch should be credited with such a figure, to the third place of decimals, after two years' service, with no special measures being taken for overhaul.

Eng'r Com'r H. J. Nicholson, R.N.(ret.) (Member of Council) thought that Mr. Mayor and his company were to be congratulated on the bold step that they had taken in installing Diesel hydraulic machinery as a propulsion unit for the *Tom Jay*. There was nothing new about hydraulic transmission, or power transmission by hydraulics. But it could safely be said that this was the first occasion on which it had been used for propulsion.

One feature that had struck him on reading through the paper was the absence of heat. Most hydraulic systems with which he had come into contact, particularly when using oil, had suffered from serious overheating of the hydraulic fluid. In the present case, it was evidently unusual.

He agreed with the author's remarks on the care of the hydraulic medium if oil were used. What was required, of course, was a chemically stable oil having as flat a viscosity curve as possible. It was also necessary to keep it clean and dry. He had crossed swords, so to speak, with the author on this subject before. He thought Mr. Mayor spent a lot of money in his desire to keep this hydraulic medium in tip-top condition. It seemed to be—should he say?—an over-refinement to employ or install a centrifuge on this job. He himself would much prefer to put in magnetic filters, because on this type of system the greatest troubles came from solids, usually pipe scale, or scale from castings and sometimes silica. Magnetic filters in the suction line would be much more useful than a centrifuge, though he did not wish in any way to detract from the usefulness of centrifuges, particularly if moisture were present. In this case, he believed there was very little moisture, because the system was well designed. Furthermore, the pipe problem had been well taken care of inasmuch as there were very few sharp bends or changes of direction of the oil, particularly under pressure, a condition which usually resulted in turbulence in aeration.

He would be interested to know what quantity of solids was extracted during the operation of the centrifuges and whether there had been any trouble with moisture in the hydraulic medium; or any aeration.

MR. W. E. HOBKIRK said that the subject matter of the paper as applied to ship propulsion was not within his own calling. Although he was not devoid of marine experience, he was interested in enterprises outside his own scope. The principles outlined in the paper, however, must surely be attractive to many engineers other than marine engineers. He referred, of course, to the theme of the whole paper, availability.

In water undertakings, availability usually meant installing three Diesel engine pumping sets to do the work of one. In theory, this meant one working, one standing by and one being overhauled; for it must be borne in mind that availability meant that the consumers must have water at their taps every hour of the day throughout the year. In view of the importance of this condition and of the area involved, water undertakings could extend their availability by interconnecting pumping stations by means of pumping mains, which was done apart from triplicating the units at the different stations.

He mentioned this only as a contrast to the author's problem in ensuring availability in such a small and confined space as a tug boat. He was, indeed, greatly impressed by the whole layout of the *Tom Jay*.

To turn to the paper proper, he fully appreciated the author's reference to single engine tugs, for although serious breakdowns were rare, when they did occur the whole ship was out of action. For this reason, he himself would prefer a twin propulsion arrangement, but this design might not be suitable for tugboat manœuvring. He was not an expert on the subject, however, and he would leave its elucidation to those who were. He certainly appreciated the difficulty of twin propulsion design in a ship of this size, especially in view of the enormous size of the propellers. They might foul the side of docks and vessels during work.

It was puzzling that the author provided four engines, each driving a radial oil pump, to produce the power to drive the one and only hydraulic propulsion motor. To his mind this greatly reduced the percentage of availability, especially as in this particular case ball or roller bearings were being used. Ball or roller bearings were very delicate under certain conditions and to fit them in certain pieces of machinery on ships was not one of the best conditions. They were prone to what was called static vibration. A ball or roller race could become affected when standing idle in the machine which in itself was a stand-by unit, as a result of vibration caused by the running of the adjacent set or sets. Minute fretting occurred on the surface of the balls or rollers where they came into contact with the inner or outer tracks, and that was the beginning of trouble —not what the engineman thought was the cause of trouble, such as starvation of lubricant, malalignment or overloading. He would therefore like to hear from the author whether trouble had been experienced, and if so, what measures were taken to rectify it.

Reverting to the subject of twin propulsion and the difficulty of such an arrangement in a tugboat, he would like to put forward for what it was worth the idea of two propellers of different diameters on the same shaft centre. There would, of course, be two driving shafts, one rotating within the other, driven by separate units. In the case in point, they would be hydraulic motors. He could see no difficulty in the design. The availability from the propulsion point of view would be increased, and the layout would be most suitable to fit into a small area. Furthermore, the two propellers, being of different sizes, would be found to be very useful, working singly or in unison, according to the demand.

He could not agree more with the author concerning a useful size of engine, all parts of which could be manhandled and interchanged in a ship of this size. This would enable one to dispense with block and tackle work, rapidity of repair being the keynote.

There was a further requirement in choosing an engine— accessibility. There were still many engines that required a contortionist to remove the big-end bearings and other parts. Good access to any engine meant good, efficient and quick fitting, whereas lack of accessibility produced careless and bad fitting.

Apart from the machinery which was involved, some thought should be given to the man who had to run and maintain the machines, for he was a vital tool in the complete gear wheel and deserved every consideration.

MAJOR-GENERAL A. E. DAVIDSON, C.B., D.S.O. (Member), said that although he was a retired army officer, many types of tugs had been offered to him for inspection and trial at Scandinavian yards he had visited. Of these, Diesel pneumatic transmission seemed to have stood the quickest reversals. The reverse lever could be pushed straight over; there was no waiting.

Applications of hydraulic transmission to solve problems on land had been numerous and on the whole successful, so there was no reason why this idea should not be happily applied to certain types of marine propulsion. The application best known to naval and military officers was perhaps the variable speed gear system used for the movements of guns and their mountings. It might come as a surprise to many to hear that just on fifty years ago, it was intended that half the few petrol lorries owned by the army should be fitted with Hall's hydraulic transmission, as fully described and illustrated in the "Automotor Journal", Vol. 9, 1904. This was another example of variable throw motor and pump but with a limited torque range and separate reverse. Money was not available at the time for its necessary development, and he had not heard of its being used again for road transport. However, three years later Dr. Hele-Shaw reported that it had shown no wear at all, although the filters were possibly not so good in those days, and operating conditions on road vehicles were very difficult.

Subsequently, turbine type hydraulic transmissions, such as the Leyland Lysholm Smith, had been used on road vehicles to a great extent and were much liked by some users; the Swedes still made considerable use of them in their bus services.

Other types of hydraulic transmission were now on the market to fill the expressed need for a variable torque all-mechanical drive, with a view to eliminating the intervention of electricity.

Mr. Mayor's experimental tug transmission therefore had been launched into a world receptive to, and even enamoured of, hydraulic drives. With the experience already gained and reported, further operating results would be awaited with deep interest.

MR. A. F. EVANS (Member) said that he had known Mr. Mayor since the building of the *Wortha* and the *Irande* and he was impressed, even in those days, to find the customer, Mr. Mayor, engaged on the redesign and partial reconstruction of these engines. In fact, Mr. Mayor had been called upon to show the oil engine manufacturers how to make oil engines. It would appear that he was still so engaged!

MR. J. H. TRICKEY (Member) whose contribution was read in his absence by Mr. Thorn, wrote that he had read with great interest Mr. Mayor's excellent paper. Whilst he had had no opportunity of comparing first costs, he would nevertheless consider that the simplicity of the single engine installation would make it a less expensive proposition.

With regard to maintenance also he felt that a single four-cylinder engine, giving the same service h.p. as the engines on the *Tom Jay*, running at about 500 r.p.m. with 172 r.p.m. on the part of the propeller, would be easier to maintain than four six-cylinder engines running at 800 r.p.m. This was evidently the opinion of the author, for he stated that it was originally proposed to use smaller engines running at 1,500 r.p.m., but on consideration slower speed engines were used.

It was early days to consider maintenance after only two years' service. Availability was tied up with maintenance and therefore the figures for availability were subject to some limitations.

However, he preferred the simplicity of the single engine installation with wheelhouse control as fitted on the motor tug *Sun 18*. This vessel, which was owned by W. H. J. Alexander, Ltd., was fitted with an engine rated 500 h.p. with 3/1 reduction gear giving 142 r.p.m. on the propeller. The combined engine and gearbox control was operated direct by the tugmaster on the bridge with ordinary telegraph controls. It might well prove, in course of time, to have more availability than the small multi-engine installation, however ingenious, with numerous parts working at a higher speed.

## Correspondence

Mr. K. C. Barnaby, O.B.E., B.Sc. (Member), having been connected with the building of the four previous tugs mentioned by Mr. Mayor, naturally found his description of the fifth—the *Tom Jay*—of special interest. There was no doubt that from the technical angle the installation was a complete success and reflected great credit on its sponsors.

One point that occurred was whether the gain in availability factor was worth the increased first cost. The average age of the four other tugs was about eighteen years. During this period, engine builders had made great strides and it would seem pretty certain that with more modern Diesels, the availability factor would have been greatly improved.

Owing to the relatively low power of the *Tom Jay* and the low r.p.m., it had been possible to give this tug a much more efficient propeller than was feasible on the *Wortha* or *Irande*. On these tugs the high r.p.m. of about 275 necessitated propellers of about 0·5 pitch ratio and of smaller diameter than on the *Tom Jay*. Tugboat skippers did not like small fast running propellers on account of the reduced backing and manœuvring power. Mr. Mayor's courage in adopting these small propellers was fully as remarkable as in persuading his owners to adopt the highly novel system of the *Tom Jay*.

Mr. A. K. Bruce thought that the paper by Mr. Mayor provided the corrective for a common impression that technical enterprise was not so marked in Great Britain as it was formerly. Mr. Mayor would, however, be the first to acknowledge that what he had done was to employ known principles in a novel combination. The thing specially remarkable was that the results obtained with the prototype should, from the outset, have proved so successful. He could remember the valiant effort made many years ago by the late Mr. Mavor in the sphere of Diesel-electric propulsion. This was then before its time, though the attempt had a place in marine engineering history. Mr. Mayor had chosen the right moment and, incidentally, he had shown what could be accomplished by the use, in a new application, of certain well-tested elements.

In a patent dated 31st March 1795, Joseph Bramah described his direct hydraulic system as devised "for the purpose of communicating the properties of motion and force from one machine to that of another, where their local situations preclude the application of all other known methods of connexion". Mr. Mayor was not quite in the situation described by Bramah, but he had the courage to use Bramah's method as an alternative to those others which he had tried and which he described in his paper. That was a measure of his enterprise and they must applaud him for taking a forward step.

The idea of a plurality of oil engines for ship propulsion was—as Mr. Mayor went out of his way to declare—derived from Ricardo, and by uniting hydraulic transmission with a multiple-engine installation, there was produced the *Tom Jay*. It could not be put quite so simply as that, since study of the paper revealed how much development and hard work must have been expended in arriving at an installation valid for so arduous a service as tugboat propulsion.

It seemed to him that the cardinal requirement in almost any power producing installation was that it should be reliable in service, and reliability was closely bound up with low maintenance cost. A point which occurred to him was that so far as the transmission system was concerned, the main thing was to keep the oil free from particles likely to cause abrasive wear. That was, indeed, stressed by Mr. Mayor himself. In regard to the propulsion motor, it would be interesting to know whether the roller bearings, and particularly the races, remained in pristine condition over long periods. This would take time, but on the experience he had had with heavy rotors on ball and roller bearings, indentation of the races could, under certain circumstances, prove a nuisance. He would suppose that while the risk of an oil fire was doubtless small, provision was made for coping with it should such a thing occur. In the case of the *Tom Jay* there were naturally a large number of points through which oil could, in the course of time, make its way, so that he would imagine that some equipment was provided whereby—as by foam or other means—a fire could be quickly suppressed. There could certainly be no fire due to electrical apparatus or connexions nor would there be marked likelihood of serious damage to equipment if fire extinguishing means were brought into use.

The outstanding attraction of the propelling machinery in the *Tom Jay* lay surely in the exceptional degree of availability which had been reached, and one did not need to be connected with tugboats to realize that that was their primary service requirement.

Mr. W. A. Green, in addition to his remarks in the verbal discussion, wrote that one of the speakers in the discussion had drawn attention to the fact that Mr. Mayor's installation gave in effect a constant speed reduction ratio. In view of this, he would ask Mr. Mayor whether he had considered an installation consisting of four engines coupled through fluid couplings to a mechanical reduction gear. This seemed to offer all the advantages of his present installation and would appear at first sight to be simpler. Any of the engines could be isolated by emptying its fluid coupling.

Perhaps Mr. Mayor made his choice on account of the greater convenience of the layout possible with hydraulic transmission. Would he say whether he had considered an alternative layout such as that suggested and if so, why he turned it down?

Mr. T. Hornbuckle, M.B.E., B.Sc.(Eng.), maintained that the operation of any type of power unit on regular scheduled services demanded the highest possible standard of reliability, since any failure in service might result in serious financial losses. An important factor in securing this reliability was efficient maintenance, a well organized system of examination and repair by a well trained and fully competent staff would ensure that such failures were reduced to a minimum.

However reliable the prime mover and however efficient the maintenance service, the standard of dependability would be increased if the power equipment could be duplicated. An added advantage of such duplication was that a considerable part of the work could be performed with only one unit in operation while the removal of power equipment for overhaul and its replacement would be facilitated.

Having adopted this policy on Thames tugs, Mr. Mayor had proceeded a stage further by installing four Diesel engines, three of which were capable of providing the maximum power required. This arrangement had important advantages; the operation of the tug at full power was better assured while examination and repair of the Diesel engines could be carried out during normal working hours. Under these conditions this work was likely to be performed more efficiently than was the case when it had to be carried out during limited periods at night or at weekends. It was also possible to maintain a higher average standard of working efficiency than was the case when only one power unit was installed.

In order to obtain a satisfactory layout in the tug for four Diesel engines, a novel type of transmission had been adopted. In the application of this transmission, Mr. Mayor had displayed considerable ingenuity which had doubtless been an important factor in the success achieved.

The particulars given in the paper of the working results of the *Tom Jay* and other Thames tugs were of special interest. In comparing these results it must be appreciated that while the *Tom Jay* had the advantage of newer engines, it was at a disadvantage in being the first of its type; consequently it was unlikely to have been entirely free from teething troubles and less experience was available regarding its operation and maintenance.

However attractive new devices might appear from the point of view of soundness in principle and economies to be effected, the possibility of failure with consequent financial loss could never be disregarded. Departure from established practice therefore involved hard work and mental anxiety on the part of the engineer responsible and a spirit of enterprise on the part of the directors who were taking the risk of financial loss. Acceptance of such responsibilities was essential to progress; for this reason both Mr. Mayor and the directors of the Thames Steam Tug and Lighterage Company deserved high commendation for the courage and enterprise shown in putting into service the *Tom Jay*.

MR. C. C. JEVES wrote that some time ago he was privileged to be a member of a party on board one of Mr. Mayor's Diesel electric propelled tugs during a working trip, towing lighters laden with timber, from the vicinity of the Tower Pier to Brentford Docks.

At the end of the journey it was especially interesting to observe the—no doubt highly deceptive—ease with which, without apparent fuss or bother, the skipper shepherded his unwieldy charges alongside the wharves in the extremely restricted waters at Brentford Docks. This experience prompted him to suggest that a diagrammatic sketch of the control arrangements between the bridge, hydraulic motor and Diesel engines of *Tom Jay* be included in the paper to clarify the written description of this gear.

With the Diesel hydraulic installation, and especially with a single screw, the hydraulic pumps and motor were, of course, the vital links in the propulsion system. It would be interesting to know Mr. Mayor's views on the dependability and life of these accessories as compared with the generator and motor of the Diesel electric system; some figures of comparative weights of the two systems would also be of interest.

In his conclusion, the author referred to the possibility of the adoption of the Diesel hydraulic system for larger vessels. In this respect, it seemed doubtful whether the coupling of a larger number of engines and pumps to the hydraulic motor would not involve an unduly heavy and unwieldly hydraulic system and whether, with a higher load factor and higher powers on long voyages, the fuel consumption would be as attractive as that quoted for the *Tom Jay*.

The author was to be complimented on the information he had given in the paper, and in the paper read in 1951 to the Diesel Engine Users' Association, and on focussing attention on the all too little known fact that the prosaic and unspectacular exteriors of the latest Thames tugs concealed well installed, well kept propelling machinery and auxiliaries of the most modern types.

G. T. SHOOSMITH, M.A. (Member) had witnessed some of the trials of this tug on the Thames and could fully confirm Mr. Mayor's remarks as to her manœuvring powers. In fact, he would go further than Mr. Mayor and state that the *Tom Jay* had the smoothest and best manœuvring of any Diesel powered vessel he had ever boarded.

However, he could not see this form of propulsion being adopted commercially for the average small vessel, due both to the very high first cost and to the difficulty of maintaining over a long period a very complicated installation.

The excellent illustrations in the paper did not do justice to the multiplicity of pipes, gauges, valves, relays, coolers, cables, tanks, etc., which met the jaundiced eye of the maintenance engineer when he descended into the engineroom of the *Tom Jay*.

It was obvious that the greatest care and skill, both in design and construction, had been put into the installation but he could not help suggesting that the freedom from trouble and high availability during the first two years' work of this tug had been in some measure due to the very special skilled attention of supervisory staff to a prototype job, and if he were right, he suggested further that the actual cost of this skilled supervision had not been debited against the tug.

He was at a loss to understand the fuel consumption figures given in the paper. Assuming that the Diesel engines of the five tugs mentioned were all in reasonably good condition, then the specific consumption of fuel per b.h.p. hour would be practically the same for all the engines concerned, and the Diesel electric and Diesel hydraulic units were bound to suffer to the extent of the transmission losses involved.

Due to the wide and rapid variation in power demand on a Thames tug, Mr. Mayor would, he was sure, agree that fuel consumption per hour over an extended period was not a real guide since there was no provision for assessing the actual s.h.p. which had been developed.

On the question of availability it must be borne in mind that a tug must, of necessity, be out of service for two or three weeks every year for general hull attention. One hundred per cent availability from the machinery would, therefore, not give one hundred per cent availability for the tug herself.

He suggested that a more economical and efficient solution to the problem of high availability was the provision, in the case of a small tug, of a spare engine unit ashore which could quickly be changed over with the engine in the tug at a moment's notice. The provision of a spare main engine would not, he suggested, cost as much as the hydraulic transmission and if the spare engine could be utilized for a number of tugs, the economy in first cost was obvious.

Mr. Shoosmith had 100 h.p. launch tugs in his own company's fleet in which the change over of the main engine could be completed in 24 hours without any difficulty; it was much easier to overhaul and maintain a spare engine in a shore based workshop than aboard a vessel. The same principle could be adopted with engines of greater power.

Possibly the introduction of multi-engine, Diesel electric, Diesel geared and Diesel hydraulic drives was a reflexion on the reliability of the average marine propulsion Diesel engine of small boat size, say, in the range of 100 h.p. to 600 h.p. and it was high time that marine superintendents brought home to manufacturers the unsatisfactory position today.

With one or two exceptions, all the marine Diesel engines of this size manufactured today were considerably overrated by their makers and the workmanship left much to be desired. It should be noted that this fault applied just as much to the engines of an indirect drive vessel as to a direct drive vessel. Many marine superintendents were now adopting the practice of purchasing engines of up to 25 per cent greater catalogue horsepower than they would be called upon to develop in service and this made utter nonsense of the manufacturers' claims for their engines.

He would suggest, in conclusion, that instead of the adoption of the high cost and great complication of the multi-engine propulsion units with indirect drive, a better line of attack for small craft Diesel propulsion was a realistic rating of engine output and much greater attention to cleanliness and quality of workmanship during manufacture of the straight direct drive marine engines.

# Author's Reply

The author, replying to Mr. Harrison, said that the range of speeds of the Gardner L-3 six-cylinder engines was 800 r.p.m. full speed, down to a tick-over speed of 250 r.p.m. The engine revolutions were controlled from the bridge or wheelhouse by means of the "Powerotor" and slave units on engines connecting to fuel pumps. No difficulties arose regarding synchronization of the engines once the slave units had been adjusted.

It must be explained that the fuel consumption table was not intended to represent the fuel consumption of the main engine only at full speed but the average fuel consumption per hour of the whole installation, including auxiliaries, over a long period. This was a record which should be of special interest to the owner. It had been assumed that what might be best described as the "power factor" was the same for all the tugs mentioned. In other fleets it might be greater and due allowance should be made if that were the case.

It was, of course, impossible at the present time to give more than a two years' record of the *Tom Jay*; if the records of the other tugs had been confined to the first two years they were in use rather than the longer period when all teething troubles had been surmounted, they would have appeared in a still more unfavourable light.

The availability record for 1951 of the twenty-year-old Diesel electric tug was excellent. Could it be assumed that records for the previous nineteen years were equally good? It was important that comparisons of availability should all be on the same basis. Usually the time required for overhaul and repair of hull was well within that required for overhaul and repair of machinery. In *Tom Jay* the installation had been so designed that repairs and maintenance of engines and pumps could be effected whilst the tug continued work at full power. In no other tug, at present, was it possible to do this. The only need for stopping was to scrape and paint the hull, which would, unless there was damage, take a minimum time during which overhaul of the hydraulic plant could be made if necessary.

He could not agree that transmission losses were less with Diesel electric than with Diesel hydraulic. On the contrary, their experience and figures proved the opposite. Diesel electric transmission had many advantages; the high efficiency of the large slow running propeller more than compensated the acknowledged loss in electrical transmission.

Mr. Harrison was quite correct regarding the excellent manœuvring qualities of Diesel electric, but the manœuvring qualities of Diesel hydraulic were equally good and, in fact, left nothing to be desired.

Mr. Thorn also referred to the fuel consumption figures; as already mentioned, the figures apply to the consumption of the whole installation taken over a long period. In a tug which had a great deal of manœuvring to do, this was the significant figure, not that for main engines alone. Nor should this figure be confused with figures taken on standing pull or towing trials.

In a reverse reduction vessel in the author's charge, the loss of power through the reduction gear was 7 per cent; in another vessel it was also 7 per cent. Usually the propeller speeds were considerably more than those obtained with either Diesel electric or Diesel hydraulic. The real criterion was the comparative towrope pull per 100 b.h.p. of the engines. This also was on the assumption that in each case the propeller was the most efficient for its purpose.

Mr. Thorn agreed upon the advantage of clean hydraulic oil. In the *Tom Jay* it was realized that it was just as important to keep the hydraulic oil clean as it was to keep the fuel and lubricating oil clean. The Sharples clarifier was installed on the principle that prevention was better than cure.

In reply to Mr. Green, there was only one pressure maintaining valve working at 25lb. per sq. in., the function of which was to actuate the direction valve. There was no separate retaining valve on each pump. In practice it was found advisable to fit to each main pump a small radial pump which supplied a small volume of oil at high pressure to operate the relay valve.

The engines were governed, and the speed of the engines was controlled by the captain by means of the "Powerotor" master unit and slave units. As the speed of the engines varied so did the volume of oil delivered to the propulsion motor and also the speed of the motor and the vessel.

With reference to the trials, the figures quoted were those recorded on the trials. Whatever the explanation, there was no reason to doubt the recorded figures. Recordings on the towing trial were made precisely as on the standing pull the previous day. The temperature of the oil within the limits worked to would not materially affect the results.

With regard to the calibration of engine horsepower by fuel consumption, the figure of ·365 was the engine builder's figure and was not the optimum, but one considered to be correct under the conditions obtaining at the time of the trials. The temperature of the hydraulic oil was allowed to reach 90 deg. F. before any tests were made.

With regard to fuel consumption tests, in conjunction with the engine builders, a special set-up was made of two interconnected copper reservoirs with a long small-diameter gauge glass connected so that each gallon of fuel consumed could be carefully noted and the time taken to consume exactly five gallons recorded. During the trials, particulars were taken of the atmospheric temperature in the engine room, barometric pressure, temperature of lubricating oil and specific gravity of fuel. The engines certainly were not loaded to full power and were never more than 73 per cent of their rated load.

A closed circulating water system was used because of the extremely muddy overboard water in which the tug had to work, but it was not overlooked that corrosion might accompany the use of distilled water, and special precautions were taken to combat this.

Mr. Welsh's suggestion of using higher speed engines was a point, as already mentioned in the paper, which had been considered. It was quite a feasible, and indeed an attractive, proposition if a reliable and satisfactory reduction gear could be found suitable for the pumps. Provided this could be done there was much to be said in its favour. The engines would be smaller, easily handled, easily removed, or easily replaced by a spare engine whilst the other was being overhauled in the shop. Another advantage was that it would probably give more room in the engine room but after much consideration it was decided that in the *Tom Jay* the slower speed engine moderately loaded and with direct drive to the pump might suit their requirements better.

The control valve was comprised of three valves of the piston type, two of which were actuated mechanically by track cams with the mounting shaft connected to the servo unit. The function of the first valve was to allow the output of all pumps to bypass to the reservoir when the propulsion motor was at rest; the second valve was the selector unit which determined the direction of revolution of the motor. This small selector valve admitted oil to either side of the third valve, which determined the direction of flow of the whole volume from the pumps to the propulsion motor, and it was for the operation of this valve that the presssure maintaining valve was fitted in the circuit. The third valve was operated entirely by hydraulic pressure and suitable jets could be fitted to enable the changeover cycle to be closely controlled for the time of operation.

With regard to the towrope pull (standing pull), the following records of some standing pull tests showed that in this respect Diesel hydraulic propulsion was not inferior:—

| | Brake horse-power | Standing pull, ton | Pull per 100 b.h.p., cwt. |
|---|---|---|---|
| Diesel electric ... ... | 530 | 7·1 | 26·8 |
| Diesel hydraulic ... ... | 219·8 | 3·4 | 30·9 |
| Diesel reverse reduction ... | 500 | 7·5 | 30·2 |
| Diesel direct drive... ... | 695 | 10·3 | 29·6 |

It should be noted that the above figures were related to *brake* horsepower and standing pull. It was considered that this gave a more reliable comparison than that given by a towing trial with all the variables that had to be eliminated before a true comparison could be made. In any case, towrope pull was affected by the propeller design. It was assumed that the propeller in each case was at maximum efficiency.

No provision was made in the *Tom Jay* as at present designed for adjustment of valves in the motor. Provision was made for correct lift of valves, both inlet and outlet, and in proper sequence by a ring on an eccentric on the crankshaft. Should it become necessary through wear to correct this, it could be done by altering the length of the tappets in one of several ways, but it was not likely to be necessary to do this in the *Tom Jay* for a very long time. The positioning of the two eccentrics concerned took care of the timing of valve opening. The valves were spring loaded, which took care of the closing.

Towrope standing pull per 100 b.h.p. was quoted because it was a least common denominator that gave some comparison of overall efficiency. The only variable was the propeller (assumed to be in each case the most suitable and efficient for the particular job), and it showed that multi-engined Diesel hydraulic propulsion was not inferior in this respect to other methods of propulsion, or in maintenance, or in reliability, whilst in regard to the most important item of availability it was unequalled.

Mr. Petty stressed some details that had not been mentioned in the paper. This was perfectly true: the paper was intended to give a broad description of the *Tom Jay* installation and its record of two years' work. It would have been possible to have included a description of many other details, making the paper unduly long and unwieldy without adding much to the essential description of the installation.

At the time of the trials Mr. Petty was in the North of England but he could be assured that the two trials were made with care and that records taken were correct. Why there should be such a difference in efficiency on the towing trial was not readily apparent and indicated the need for further investigation and trials at different loads and different speeds. It was extremely improbable that it was due to any loss of hydraulic pressure by leakage, and unlikely that it was affected by the temperature of the hydraulic oil. This problem could be resolved beyond all theory by further very exhaustive towing tests which, however, would occupy a considerable time.

Mr. Warne very rightly said that there was safety in numbers. One of the fundamental ideas in the design of *Tom Jay* was to obviate as far as possible total stoppage of the vessel, due to breakdown or overhaul of prime movers.

The well-known examples of Diesel electric propulsion in the *Acklam Cross, Lectro, Framfield, Robertsbridge* and *Talisman* would not have been so successful and would not have put up such good records had they been single engined jobs.

In the *Tom Jay* the same principle had been carried a stage further; not only had the total power been split among three units but a reserve was also provided which could at any time be put into service in a few minutes as required. The spare engine which, it must be remembered, was a small unit, was a premium for insurance against any failure of the prime movers besides giving the facilities for maintaining the other three engines whilst the vessel continued in service at full power.

It should be remembered that the *Tom Jay* was a prototype vessel, and it was quite possible that with the present propeller, the present proportions of pumps and propulsion motor, equal results might have been obtained with engines of lesser horse-power.

With maximum load on the towhook, the engines were at 73 per cent of their rated power and if a mistake had been made, it would be agreed that it was in the right direction. The reserve of power still permitted, if required in the future, an increase in the propeller load. The merit of the *Tom Jay* installation should be judged by the overall results attained.

Commander Nicholson agreed the advantage of keeping the hydraulic oil clean but chided the author for keeping it too clean! The magnetic filter was an excellent suggestion; in the *Tom Jay*, however, in pumps and propulsion motor, manifolds and sundry valves, there was a great deal of non-ferrous material, which also had to be dealt with. The initial runs of the clarifier extracted some solid matter, but on subsequent runs it grew perceptibly less. No trace of moisture had been found. Its initial job was to arrest any solid matter left in the system. Its subsequent function was to take care of any products of wear.

Mr. Hobkirk showed that water supply companies long ago had to consider and cope with the all important question of constant service and described the methods adopted to supply it. The principle in the *Tom Jay* installation was somewhat akin but a long way behind. In the confined space of a tug, they could only follow in a very modest way. Nevertheless, the one reserve engine and pump did increase the reliability of the tug as a whole and enabled it to show a high availability factor. Twin screws, whose efficiency was beyond question, were generally speaking unsuitable for tugs or similar vessels in confined work because of their vulnerability to damage. It was true that there was no reserve for the one propulsion motor and it was for that reason that he had accented the wisdom of keeping the hydraulic oil as clean as possible.

The point regarding ballraces was important and was one that must not be lost sight of. The author knew of instances where, owing to the peculiar nature of the load, ball bearings had been replaced by plain bearings; up till now, however, no trouble had been experienced.

General Davidson instanced an interesting Scandinavian vessel constructed about seventeen or eighteen years ago. General Davidson could speak from personal experience of the excellent handling qualities of this vessel; it would be most interesting to know its subsequent history, and why it had not been repeated. General Davidson assured them that hydraulic transmission was not new, that it had been used for naval and military auxiliary purposes for many years. It was the application to marine propulsion that was new and in the case of the *Tom Jay* on duties which, although arduous, were not so difficult as those in connexion with road traffic in 1904. There was still much to be learned concerning hydraulic propulsion which could only become known after a considerable number of very carefully conducted trials, but sufficient was known already to indicate that it did possess outstanding advantages for some purposes.

# *Author's Reply*

Mr. Evans, whom the author had known since the early days of the cold starting engine on the Thames, was half right and half wrong. All the author had done was to reveal the weak points in engines put, at that time, to a new and unusually difficult job. In some cases he was able to overcome the trouble by redesigning details to suit the specially heavy work and in other cases emphasized the troubles so that the manufacturer could find a suitable remedy. The Diesel tug engine of today was a long way ahead of the tug engine of twenty-four years ago in regard to design and suitability for its work.

Mr. Trickey's advocacy of the reverse reduction gear was well founded. There was an increasing number of this type of tug on the Thames, all putting up good performances. The *Irande*, mentioned in the paper, was one of them. These tugs had developed from the direct Diesel and had the favourable feature of a "one way" engine, a great advantage where there was a great deal of manœuvring. The advantage was especially manifest when measuring liner wear. The decision to use low speed engines in the *Tom Jay* was mainly to enable us to dispense with gears for driving the hydraulic pumps. The question of availability, of course, could only be proved by time and experience but the fact remained that in a reverse reduction job, or in any single engined job, any repair to the main engine or gear did entail the complete stoppage of the tug.

Mr. Barnaby, having been connected with the design and construction of the last four tugs for the author's company, two cycle and four cycle direct Diesel and the later two Diesel electric, was well acquainted with the requirements and problems connected with Thames tugs. In the late 'twenties and early 'thirties, reverse reduction gears had not reached the high efficiency achieved today. At that time there was no option but to accept propeller speeds of 275 or 300. The advent of Diesel electric propulsion enabled them to use once more the well-tried, efficient, large slow moving propeller; Diesel hydraulic propulsion as in the *Tom Jay* still allowed the use of the large slow speed propeller.

Mr. Bruce summarized the essential features and principles underlying the design of the *Tom Jay*, the foremost being the high availability and the reliability to which it was intimately related. That is the point round which the whole design was centred. The record of two years' work showed that this aim, in the prototype example, had been substantially realized. As Mr. Bruce said, there was nothing very new in hydraulic transmission; the *Tom Jay* merely showed a new application of an old principle. The fact that the power was split between several prime movers was important, as also was the fact that the hydraulic medium was perfectly clean lubricating oil.

Mr. Green mentioned an installation of four engines with fluid couplings connected to a mechanical reduction gear. He had not considered an installation on those lines mainly because he did not feel too happy about fluid couplings for this work but it is a point that might be worth further consideration.

Mr. Hornbuckle had quickly grasped the salient features in the *Tom Jay* and the need for reliability and continuity of service in any installation connected with transport. Mr. Hornbuckle, with his long experience in rail traction, knew the importance of making provision against interruption of service because of breakdowns, repairs or overhauls, and in arranging that when repairs became inevitable they should be effected in the most economical manner.

Mr. Jeves rightly mentioned the propulsion motor and pumps in *Tom Jay* as vital links. This was perfectly true, more particularly with regard to the propulsion motor, for which there was no reserve. It was for that reason that precautionary measures had been adopted to keep the oil clean. It presented no difficulties, it was inexpensive, and paid a good dividend in reliability of working and reduction of wear to the absolute minimum.

With regard to the query about the life of these units, it was early as yet to hazard a statement. As, however, the moving parts were made of high grade material, machined to very close limits, working in perfectly clean high grade lubricating oil, it was reasonable to expect a very long life. In any case, pistons, liners and valves could be renewed if necessary, at any time. On balance he would say that upkeep on a tug would be less than with electric transmission. It would be rash to attempt to forecast the future development of multi-engined Diesel hydraulic propulsion, so much depended on the development and improvement of details; let it suffice that the two years' record of the *Tom Jay* showed it to be a system of propulsion that warranted consideration.

Mr. Shoosmith was correct in saying that the greatest care and skill were put into the design and construction of the *Tom Jay*, but it would be safe to say that Mr. Shoosmith would be equally thorough in launching any new project. The tug was watched very closely during the early months of its career but as time went on it settled down to work without any special supervision. He agreed that the engine room had the appearance of complexity when compared with an ordinary direct drive Diesel of the same power but one could put up with apparent complexity when the net result was freedom from trouble and continuous service. It was recognized that it was not practically possible to measure the amount of work done but it had been assumed that what might be best described as the "power factor" of the five tugs mentioned in the table was approximately the same, especially over a long period. In another fleet, dependent on the character of the work, it might be even higher. Due allowance should be made for tugs whose normal work was of long tows at full speed or, on the contrary, tugs whose normal work involved short tows and considerable manœuvring.

With regard to availability, generally it had been engine overhauls that had taken the major time. As a rule, hull repairs could be completed within that time. In the *Tom Jay*, hull repairs had been speeded up by concentration of labour and it was hoped that all necessary repairs to the machinery would be done within the time required for hull repairs.

He was glad that Mr. Shoosmith was able to affirm the remarkably good handling qualities of the *Tom Jay*.

He thought the suggestion that a spare engine unit should be kept ashore was an excellent plan, provided there were no malalignment snags in changing; in the *Tom Jay* it was one unit out of four that was in reserve and it was always in place and could be put into action in a few minutes.

# INSTITUTE ACTIVITIES

**Minutes of Proceedings of the Ordinary Meeting held at the Institute on Tuesday, 8th January 1952**

An ordinary meeting was held at the Institute on Tuesday, 8th January 1952 at 5.30 p.m. Mr. J. Turnbull, O.B.E. (Chairman of Council) was in the Chair. A paper by Mr. F. J. Mayor, A.M.I.Mech.E. (Member), entitled "Diesel Hydraulic Propulsion", was read and discussed. Ninety-seven members and visitors were present and eleven speakers took part in the discussion.

A vote of thanks to the author was proposed by Mr. R. Cook, M.Sc. (Member) and received with enthusiasm. The meeting ended at 7.45 p.m.

**Local Sections**

*Hull*

The first meeting of the Hull Local Section was held at the Station Hotel on Thursday, 21st February 1952, at 7.30 p.m., when Mr. B. Taylor, B.Sc.(Eng.), A.M.I.Mech.E. (Member) repeated the lecture* he had given in London in November entitled, "Automatic Combustion Controls for Marine Boilers".

Forty-seven members and visitors were present and Mr. G. H. M. Hutchinson (Chairman of the Section) was in the Chair.

An interesting discussion followed the presentation of the paper and a vote of thanks to the author was proposed by Mr. F. C. M. Heath (Vice-President) and seconded by Mr. F. T. Green (Member).

*Swansea*

A meeting of the Swansea Section was held at the Central Library, Alexandra Road, Swansea, on Friday, 25th January 1952, when Mr. R. S. Hogg gave a lecture on "The Elements of Ship Construction and Naval Architecture". Mr. F. C. King was in the Chair and the audience of fifty-six included members, friends and students.

Mr. Hogg gave an outline survey from the building of wooden ships to the construction of the modern steel vessel and by blackboard illustrations conveyed to his audience the outstanding principles generally applied in modern design. He illustrated on the blackboard the Isherwood system and later developments based on that system. Mr. Hogg concluded his talk by touching upon the controversial subject of the merits and demerits of welding as applied to shipbuilding. At question time this subject of welding proved a source of lively discussion, on which many opinions were expressed.

A vote of thanks to Mr. Hogg was proposed by Mr. C. E. Cloudsdale, B.Sc. (Member) and seconded by Mr. H. F. H. Dolling (Member), who expressed the wish that Mr. Hogg would return to Swansea at a not too distant date to give his lecture on "The Launching of Ships". This suggestion was warmly received by all present and the vote of thanks was carried unanimously. The meeting terminated at 9.15 p.m.

* Trans.I.Mar.E., Vol. LXIV, p. 1.

**Junior Section**

*Belfast College of Technology*

A meeting was held at the College of Technology, Belfast, on Thursday, 14th February 1952, at 7.30 p.m., when a lecture on "The Electric Propulsion of Ships" was given by Mr. M. W. T. Rees, B.Sc. (Member) and G. J. Tuke, B.Sc. There was an audience of 130, mostly young men, and the Institute was represented by Mr. W. E. McConnell (Member).

The lecture was well received and was followed by a good discussion; the vote of thanks to the authors was carried with acclamation and the authors were pleased with the lively interest which had been shown in the subject discussed.

*Wandsworth Technical College*

On Thursday, 28th February 1952, at 7 p.m., a meeting was held at Wandsworth Technical College for the reading of Mr. C. C. Pounder's paper entitled "Marine Diesel Engines". In the unavoidable absence of the author, Mr. A. G. Arnold (Member) deputized most ably for Mr. Pounder in presenting the paper. Dr. S. E. Robinson was in the Chair and the meeting was attended by about 300 students.

Mr. F. D. Clark (Associate Member of Council), who represented the Institute, proposed a vote of thanks to the author and to Mr. Arnold, which was heartily accorded.

*Woolwich Polytechnic*

On Wednesday, 6th February 1952, at 7 p.m., the Junior Section held a meeting in conjunction with the Woolwich Polytechnic Engineering Society. Between eighty and ninety people attended the lecture given by Mr. C. J. Hasler, B.Sc., on "Boiler Water Treatment". Mr. C. W. Tonkin, B.Sc. (Associate Member of Council) represented the Institute.

The lecture covered the whole field of water treatment and the audience were confirmed in the engineer's opinion that it is much easier to make water fit to drink than to make it fit for a high pressure boiler. Several specimens of tubes were shown, illustrating the effects of unsatisfactory water treatment. Afterwards, many questions from the audience were answered by Mr. Hasler, to whom a hearty vote of thanks was accorded for his interesting and informative talk.

**Membership Elections**

*Elected 10th March 1952*

MEMBERS

Alexander Barr
William Henry Booth
John William Corney
Mohammed Ibrahim Kidwai
Andrew Thomas Lawrie Lindsay
Alexander Macdonald
Donald McIntyre
Kenneth Carmichael Magee
William Miller, O.B.E.
James Forman Morrison
David Blair Paterson
John Roland Patterson, Com'r(E), O.B.E., D.S.C., R.N.

Stamatioo Ventouris
Giuseppe Vigo

ASSOCIATE MEMBERS
Robert Russell Gillies
James Percy Heslop

ASSOCIATES
George Barlow
Alfred George Boyden
Hylton Burdon
Robert Cyril Charles Crews
William Henry Edwards
Harold John Holman
Frederick Edward Lawrence
William Dawson Martin
Edward Francis Lucas Pimlott
Leslie Thomas Reed

GRADUATE
John Edward Philip Cresswell

STUDENTS
Jorgen Peter Jespersen
John William Thwaites

TRANSFER FROM ASSOCIATE TO MEMBER
Douglas George Paterson
Samuel Abraham Samson
Thomas Thomson
Leonard Henry Waller Wright

# OBITUARY

HUGH MACDONALD ARTHUR (Member 9618), who died suddenly on 28th January 1952, was born in 1902. He served an apprenticeship with Clarke, Chapman and Co., Ltd., of Gateshead, from 1919-24, and then went to sea; from 1927-38 he served as fifth to second engineer with the Clan Line and obtained a First Class B.o.T. Certificate. He came ashore in 1938 and worked until 1942 as mechanic examiner for the chief inspector of armaments; from 1942 until 1946 he was an inspecting officer with the Ministry of Supply at the Royal Ordnance Factory, Ellesmere Port. Mr. Arthur went back to sea in 1946, as chief engineer with E. R. Management Co., Ltd.; in 1948 he transferred to the Palm Line, with whom he remained as chief engineer until his death. He was elected a Member in 1943.

ALEXANDER CAMPBELL (Member 3068) was born in 1878. He served an apprenticeship with R. and W. Hawthorn, Leslie and Co., Ltd., of Newcastle-on-Tyne, and then spent twelve years at sea, six of them as chief engineer; he obtained his First Class B.o.T. Certificate. In 1916, Mr. Campbell went to the Argentine as chief engineer to Frigorifico Nuero; he remained in South America after his retirement and died in Buenos Aires as the result of an accident on 22nd July 1951. Mr. Campbell was elected a Member in 1916.

DAN MACPHEE DENHOLM (Member 7255) was born in 1891. He served an apprenticeship with Alley and McLellan, Ltd., of Glasgow, completing it with Scott's Shipbuilding and Engineering Co., Ltd., of Greenock, with whom he stayed until 1917. From 1917-19 he was a naval architect with Cammell, Laird and Co., Ltd.; throughout the greater part of the 1914-18 war he was engaged on Naval construction with special reference to submarines. In 1919 he joined the Kitchen Reversing Rudder Company of Liverpool as naval architect and director and stayed with them until 1926, negotiating the sale of their patents in various parts of the world, including America. Then he joined the staff of Norris, Henty and Gardners, Ltd., being concerned with export sales at their London office; in 1933 he was appointed to the board of the company and in that year, and following years, toured the world on their behalf. In 1947, Mr. Denholm was appointed to the board of the parent company, L. Gardner and Sons, Ltd., when he transferred to the head office and works at Patricroft, Manchester. He died after a short illness on 15th February 1952. Mr. Denholm, who was elected a Member of the Institute in 1933, was also an Associate Member of the Institution of Naval Architects.

SAMUEL WILLIAM CALDERWOOD FLEMING (Member 8570) was born in 1891. He served his apprenticeship with Alley and McLellan, Ltd., of Glasgow, from 1907-10 and with Ross and Duncan of Govan from 1910-12 and then continued in their service as journeyman fitter for six months. From 1913-19 he served at sea in various companies and obtained a First Class B.o.T. Certificate. In 1919 he came ashore and, after a brief period with James Coombe and Son of Glasgow as a draughtsman, he settled down in the drawing office of Alexander Andersons and Sons, Motherwell, staying with the firm as chief boiler designer when it amalgamated with James Marshall and Sons.

In 1945, Mr. Fleming designed a boiler which was accepted by the Patents Office; it is known as the Fleming Patent Water Tube Vertical Boiler and is produced in various sizes. He was a member of the Association of Engineering and Shipbuilding Draughtsman and was elected a Member of the Institute in 1938.

HARRY GLENTWORTH (Member 3426) was born in 1872. He served an apprenticeship with T. Scott and Company, Goole, and Earle's Shipbuilding Co., Ltd. In 1894 he went to sea, obtained a First Class B.o.T. Certificate in 1898, and then sailed as chief engineer until he left the sea in 1904. From that time until a year before his death, Mr. Glentworth practised in Goole as a marine surveyor and consulting engineer. He was a Fellow of the Society of Consulting Marine Engineers and Ship Surveyors, a Member of the Institution of Naval Architects, and had been a Member of the Institute since 1918.

MALCOLM JAMES HENDERSON (Associate 8771), born in 1904, was apprenticed from 1920-26 with Craig and Rose, Ltd. From 1930-34 he was branch manager with the Clydevale Oil and Colour Company, from 1934-38 he was manager of Craig and Rose, Ltd., and from 1935 until his death on 18th February 1952 Mr. Henderson was Director of the Greyhound Paint and Composition Company. He was elected an Associate of the Institute in 1938.

JOHN CARRICK KENNAUGH (Member 12650) was born in 1888. He served an apprenticeship with Clover, Clayton and Co., Ltd., Birkenhead, and attended Liverpool Technical College. He went to sea in vessels owned by the Liverpool companies of Lowden Connell and Co., Ltd., Welshford and Co., Ltd., and Yeoward Brothers, and obtained a First Class B.o.T. Steam Certificate. For a year after this he was employed with the Dundee Shipbuilding Co., Ltd., and then, in 1913, he went into partnership as a consulting engineer with the late Mr. T. T. Kennaugh; on the death of Mr. Kennaugh in 1938, the firm was renamed J. C. Kennaugh and Partners.

Mr. Kennaugh was president of the Society of Consulting Marine Engineers and Ship Surveyors from 1946-48 and, as a founder member, had been associated with the society for thirty-two years. He was a member of the Institution of Naval Architects, the North East Coast Institution of Engineers and Shipbuilders and the Liverpool Engineering Society, and was elected a Member of the Institute in 1949.

FREDERICK GEORGE NEILL (Member 5539) was born in 1879. He served an apprenticeship with James Morrison and Sons, Leith, and then spent twenty-three years at sea, obtaining a First Class B.o.T. Certificate. In 1923, the vessel in which Mr. Neill was serving as chief engineer was bought by J. and C. Harrison, Ltd; he stayed with the ship under the new owners until 1925 when he came ashore on his appointment as the company's chief superintendent engineer. He was responsible for the building of the company's ships under the 1930-35 fleet expansion programme, when twenty-six cargo ships were built in British yards under his supervision. Mr. Neill was at work, as he would have wished, until a week before his death on 13th February 1952. He was elected a Member of the Institute in 1926.

WILLIAM HENRY PILMOUR (Companion 8348) was born in 1876. In 1898 he joined the Parsons Marine Steam Turbine Company and two years later he was appointed secretary. In 1930 he was made a director and in 1936 he became managing director. Until his sudden death, while seated at his desk, on 7th March 1952, Mr. Pilmour's entire professional life was spent in the service of the company; he had been closely associated with the late Sir Charles Parsons until his death in 1931. He was a former treasurer of the North East Coast Institution of Engineers and Shipbuilders, an Associate of the Institution of Naval Architects, a Fellow of the Chartered Institute of Secretaries, and had been a Companion of the Institute since 1937.

WILLIAM THOMAS PINNOCK (Member 4603) was born in 1886. For five years he was apprenticed to the Great Western Railway Company; after two years, in which he saw some sea service during trial trips, and a further two when he was engaged as a charge hand on marine repair work at Southampton, Mr. Pinnock was appointed to an L.C.C. technical institute as a lecturer in engineering. In 1922, at the time of his election to membership of the Institute, he had been for five years a lecturer in engineering at Swindon Technical Institute. He died at Newcastle-on-Tyne on 29th July 1951.

ALEXANDER SPENCE (Member 12831) was born in 1888. After an apprenticeship served with Richardsons, Westgarth and Co., Ltd., from 1904-09, he spent the next four years at sea, sailing fourth to second engineer, and obtained a First Class B.o.T. Steam Certificate. From 1914-18 he was assistant foreman with Richardsons, Westgarth and Co., Ltd., at Middlesbrough and Sunderland but returned to sea in 1919 and sailed as chief engineer from 1920-27. From 1927-38 he was maintenance foreman with I.C.I., Ltd., at Billingham, but in 1939 he returned to sea once more to gain experience in motorships. In 1940 he obtained a motor endorsement to his certificate and sailed as chief engineer until September 1942, when his ship was lost through enemy action. From 1943-47 Mr. Spence was an engineer inspector for the Ministry of Aircraft Production at the Power Gas Corporation, Ltd., Stockton-on-Tees, and in 1949 he was appointed progress engineer inspector at the Furness Shipbuilding Co., Ltd., Billingham. He died on 17th February 1952. Mr. Spence was elected a Member of the Institute in 1950.

ABDUL QADEER WARRAICH (Associate 13052) was born in 1924. From 1942-46 he served an apprenticeship with the Karachi Port Trust and then, until 1948, went to sea as junior engineer. For six months in 1948 he attended day classes at University College, Southampton, and then returned to sea as a junior engineer in the Royal Fleet Auxiliary. In 1950 Mr. Warraich obtained a Second Class M.o.T. Steam Certificate and returned to sea in the service of the R.F.A., but he died on 5th September 1951. He was elected an Associate of the Institute in 1950.

MR. THOMAS ALBERT CROMPTON

## MR. THOMAS ALBERT CROMPTON

By the death of Mr. T. A. Crompton, who passed away on 2nd April 1952 at the age of seventy-two, the Institute has lost one of its oldest and most enthusiastic members. I remember him as one of the links with the early days of the Institute when, at the end of the nineteenth century, we both attended classes for students and engineering apprentices at our first premises in the Romford Road, Stratford.

The son of an old member of the Institute, Mr. T. Albert Crompton—principal of the firm of consulting engineers, T. Albert Crompton and Co., Ltd.—he was born on 4th February 1880 in that part of London noted in those days for the large number of marine engineers who resided there. He was educated at Woodgrange College, Forest Gate, E., and at the East London College.

He commenced his apprenticeship in April 1896 in the drawing office of A. W. Robertson and Company at their Lea Shipyard, Canning Town, shortly after I myself started there, and later served at their ship repairing works in the Royal Albert Docks.

After completing his apprenticeship, Mr. Crompton went to sea as fifth engineer in the s.s. *Duke of Westminster,* followed by service in the s.s. *Glen Almond* (Galbraith, Pembroke and Co., Ltd.), s.s. *Narragansett* and s.s. *Housatonic* (Anglo-American Oil Co., Ltd.); in the last-named vessel he sailed as chief engineer. He then joined the s.s. *Somerset* of the Federal Line as second engineer, the chief engineer of the vessel being Mr. Robert L. Logan, the father of our present energetic Member of Council and Past Chairman, Mr. Alexander Logan. He obtained his First Class Board of Trade Certificate and joined the Institute immediately as a full Member, being elected on 27th January 1905.

He left the sea in 1909 and joined Blundell's London Copper and Brass Works, Ltd., of which his father was a director, and in April 1910, when the company was reconstructed and became known as Blundell's London Copper and Brass Works (1910), Ltd., he was appointed a director and occupied the position of works manager. On the death of his father in 1925 he became joint manager of the business (along with his brother) which, in 1931, was registered as Blundell's and T. Albert Crompton and Co., Ltd. This position he held until being appointed general manager in 1938. In December 1949 the title of the company was shortened to Blundell and Crompton, Ltd., and, in April 1950, he was appointed managing director, which position he occupied until his death.

Under his influence the company went ahead and made remarkable progress. He was personally responsible for the development of certain patents, amongst the best known being Blundell's "Atmos" Pressure and Vacuum Relieving Valves.

As an engineer he kept himself abreast of modern developments in shipbuilding and marine engineering. He was a Member of the Institution of Naval Architects and was elected a Member of the Institution of Mechanical Engineers in 1945.

Elected to the Council of the Institute in 1939, he became Vice-Chairman in 1940/41 and Chairman in 1941/42; he was a Vice-President from 1947 until his death. He was particularly keen on upholding the status of the marine engineer and undoubtedly exercised considerable influence in extending the knowledge of the Institute's activities.

He took considerable interest in City affairs, being a Member of the Court of Assistants of the Worshipful Company of Horners, a Liveryman of the Worshipful Company of Shipwrights, and President of the City Livery Club in 1947. He was also President of the Aldgate Ward Club in 1949, Chairman of the Candlewick Ward Club in 1950, and a Vice-President of the "Anchorites".

He will be long remembered for his most active and generous support of our Guild of Benevolence, rarely missing a meeting of the General or Executive Committees, always keen and ever ready to help a deserving case. His cheery smile and wise counsel will be greatly missed by his many friends, who all realize the irretrievable loss we have suffered.

ALFRED ROBERTSON,
Honorary Treasurer.