DIESEL ENGINES IN NAVAL SERVICE

By

COMMANDER K. B. CLARKE, R.N., A.M.I.MECH.E.

The new construction programme of naval vessels during the past five years has been, as far as numbers of vessels and money spent are concerned, principally devoted to Diesel powered units. This fact is not widely appreciated and TABLE I shows the principal naval applications for Diesel engines since World War II. The total cost of the bare engines in the programme is of the order of £20 million, to which must be added £4 million for development. The total cost of the ships where Diesel engines are the prime movers must approach the current total naval estimates for a year.

TABLE I—DIESEL ENGINES AND PRINCIPAL SHIP APPLICATIONS IN NEW CONSTRUCTION

Ship	*Propulsion*	*Generators*
AD/AD Frigate	A.S.R.1 8 × 16 V.T.S.	A.S.R.1 4 × 8 or 6 L.T.S.
Porpoise Class Submarine		A.S.R.1 2 × 16 V.M.S.
Coastal Minesweepers	Mirrlees 2 × J.V.S.S. 12 Deltic 2 × 18–7A	1 × J.V. 8 3 × Foden F.D. 6 1 × 9–5A 3 × Foden F.D. 6
Inshore Minesweepers	Paxman 2 × 12 YHAX	Paxman 1 × 12 YHA 2 × Foden F.D. 6
Seaward Defence Boats	2 × 12 YHAX	2 × Foden F.D. 6
Dark Class F.P.B.	Deltic 2 × 18–11 B	1 × Foden F.D. 4
Ocean Tug	A.S.R.1 2 × 12 V.T.S.	Paxman 2 × 6 YHAXZ
Twin Screw D.Y. Tugs	Paxman 2 × 12 YHAX	Paxman 1 × 6 YHAXZ
Paddle Tug	Paxman 2 × 12 YHAX	Foden 4 × F.D. 6
Whitby Frigates		Paxman 2 × 12 YHAZ
Blackwood		Paxman 2 × 6 YHAZ

TABLE II—PROPULSION ENGINES

Engine and Model	*Admiralty Ratings for Propulsion h.p.* Continuous	*Admiralty Ratings for Propulsion h.p.* 2 Hrs Overload	*Net Weight (lb)*	*Overall Dimensions*	*Application*	*Future Development*
A.S.R.1 16 V.T.S.	2200 at 1000 at 139 b.m.e.p.	2420 at 1000 at 153 b.m.e.p.	40,050	16 ft 10 in × 5 ft 4 in × 8 ft 8½ in	AA/AD Frigates *Lynx*, *Leopard* Class	Nil
A.S.R.1 12 V.T.S.	1650 at 1000 at 139 b.m.e.p.	1815 at 1000 at 153 b.m.e.p.	30,000	14 ft 0 in × 5 ft 4 in × 8 ft 6 in	Ocean Tug *Typhoon* Class	Nil
A.S.R.1 12 V.U.S.	1050 at 1000 at 90 b.m.e.p.		28,000	12 ft 10 in × 5 ft 4 in × 8 ft	Survey Ship *Vidal*	Nil
Napier Deltic 18–11B	1875 at 1700	2500 at 2000 (¼ hour)	12,400		F.P.B.s *Dark, Bold* Class	Turbo- Blown Version 3300 h.p. at 2000 Compound Deltic 5500 h.p. at 2000
Napier Deltic 18–7A	1250 at 1313	1500 at 1400	12,400		Coastal Minesweepers *Highburton* Class	Turbo- Blown Version 1100 h.p. at 1500
A.S.R.2 Paxman 12 YHAX	550 at 1000 at 121·8 b.m.e.p.	605 at 1000 at 134 b.m.e.p.	7,647	9 ft × 5 ft 8 in × 5 ft 4½ in	I.M.S. S.D.B.s *Confiance* Class Tugs	Mk. II Engine (750 h.p. at 1200)
A.S.R.3 Foden F.D. 12	210 at 2000	240 at 2000	2,610	7 ft 9½ in × 4 ft 3¾ in × 3 ft 6 in	I.M.S. Type II	
A.S.R.3 Foden F.D. 6	105 at 1800 at 100 b.m.e.p.	115 at 1800 at 110 b.m.e.p.	1,500	55 in × 32½ in × 46¾ in	45-ft M.F.V. 40-ft L.C.A. 45-ft M.S.M.B.	Mk. II Cylinder Head Mk. III Turbo Charged 150 h.p.
Foden F.D. 4	70 at 1800 at 100 b.m.e.p.	77 at 1800 at 110 b.m.e.p.	1,300	48 in × 32½ in × 44¾ in	35-ft M.S.M.B.	
Perkins P. 6	45 at 2000 at 89 b.m.e.p.	51 at 2000 at 98 b.m.e.p.	850	37 in × 24 in × 34 in	25-ft M.S.M.B. 30-ft M.S.M.B. 45-ft Motor Launch	
Perkins P. 4	43 at 2000 at 89 b.m.e.p.	47 at 2000 at 98 b.m.e.p.	540	28 in × 26 in × 36 in	32-ft Motor Cutter 28-ft Motor Launch 36-ft Motor Pinnace	
A.S.R.4 Enfield H.O. 2	11 at 1500 at 82·5 b.m.e.p.	12 at 1500 at 90·75 b.m.e.p.	350	29½ in × 35½ in × 35 in	25-ft Motor Cutter 27-ft Whaler	
Enfield V.S. 1	5·5 at 1500 at 82·5 b.m.e.p.	6 at 1500 at 90·7 b.m.e.p.	220	25 in × 21 in × 28 in	13½-ft 16-ft Motor Boats	

GENERAL

Present Policy of Diesel Development

This new construction programme is largely nearing completion and in ships of the future Diesels will play a small part. Comparable propulsion units will be succeeded by nuclear, steam and gas boost, and gas turbines will, in general, replace the Diesel for generator prime movers and the smaller type of Diesel. As a consequence it is now E.-in-C.'s policy not to develop the Diesel engine further, except where this development is directed towards improving reliability and reducing maintenance of existing types in service.

Standardization and Provision of Diesel Engines

There would have been considerable difficulty in providing Diesel engines for the new construction programme had not the Admiralty adopted a rigid standardization policy and the selected prototype designs proved successful in full scale production. The thorough type-testing and development work on engines at the A.E.L., West Drayton, was also an important factor.

Standardization of Admiralty Diesels was considered in 1947 and was linked to the Ministry of Supply's requirements. It was agreed that the Admiralty should sponsor engines in the 2,000 to 500 h.p. range and the Ministry of Supply would cover the lower horse-power ranges. Both would meet the requirement by selecting suitable commercial engines for service use, persuading the manufacturers to expand the types into a range embodying a maximum number of common parts. It is interesting to note that since 1947 the Admiralty have gone much further than this ; the A.S.R.1 has been designed and developed by the Admiralty and the Deltic and Paxman engines have been designed specifically to meet our requirements. The Ministry of Supply, on the other hand, included in their list a selection of engines in current use and type tested new engines to ensure that they met requirements.

The principal engines, with their details and applications, in the Admiralty Standard Range are shown in TABLES II and III. Not included in this list are the Mirrlees J series which were ordered as an interim measure for the earlier coastal minesweepers, the Coventry 4 K.F. fitted in the skimmer, the Rolls Royce C 6 series fitted in M/S M/L conversions and the Rover Meteorite fitted in the L.C.(V). The list is now virtually complete and selection of Diesel engines for future applications and re-engining programmes will be made from this list. Currently being considered are more suitable light-weight small h.p. engines for such duties as portable pumps and emergency generators. For these the new Petter P.C. series, Lister L.D.1 and Enfield 350 are being evaluated.

SERVICE PROBLEMS

General

It was to be expected that, with the introduction of such a bold programme in a relatively short time, a number of problems would arise when the new ships entered service. These difficulties, which are few in number, have arisen from a number of causes and the following points broadly summarize the lessons learnt :—

(*a*) The prototype engine range has to be cleared for general service use and time and money do not permit, nor indeed is it always possible, to test the engine under the conditions it might have to operate in a particular ship application. To illustrate this point, the exhaust and circulating water systems of a Diesel engined ship have a considerable effect on the engine's performance. These systems differ from the engine test bed and from ship to ship. The need for a prototype ship, however, is clearly illustrated by recent experiences and by the generally adverse performance of Diesel engines in naval ships compared with those in commercial use.

(*b*) Although the Diesel engine industry has made rapid strides since the war and is most active and fiercely competitive, there does not exist, in general, the design talent which is now attracted to the gas turbine and nuclear fields.

TABLE III—GENERATOR ENGINES

Engine and Model	*Admiralty Ratings Generator*		*Net Weight (lb)*	*Overall Dimensions L × B × H*	*Application*	*Future Development*
	Continuous	*Overload*				
A.S.R.1 16 V.M.S.	1840 at 920 at 125 b.m.e.p. (1280 kW)	2024 at 920 at 139 b.m.e.p. (1408 kW)	42,500	16 ft 10 in × 5 ft 4 in × 8 ft 8 in	*Porpoise* Class	
8 L.T.S.	730 at 720 at 128 b.m.e..p (500 kW)	813 at 720 at 140 b.m.e.p. (550 kW)	24,500	16 ft 6 in × 4 ft 3 in × 8 ft 7 in	AA/AD Frigates	
6 L.T.S.	525 at 720 at 123 b.m.e.p. (360 kW)	577 at 720 at 135 b.m.e.p. (396 kW)	22,000	14 ft 0 in × 4 ft 3 in × 8 ft 6 in	AA/AD Frigates	
A.S.R.2 Paxman 16 YHX	810 at 1200 (500 kW)	890 at 1200 (550 kW)	13,440	10 ft 5 in × 5 ft 2 in × 5 ft 2 in	*Eagle*	
12 YHAXZ	508 at 900 at 125 b.m.e.p. (341 kW)	560 at 900 at 137 b.m.e.p. (375 kW)	7,645	9 ft × 5 ft 8 in × 5 ft 4½ in	*Whitby* (Repeat) D.E. Tugs	Mk. II 500 kW at 1200 r.p.m.
12 YHAZ	298 at 900 at 73 b.m.e.p. (200 kW)	338 at 900 at 81 b.m.e.p. (230 kW)	6,156	7 ft 7¾ in × 4 ft 6 in × 5 ft 5¾ in	*Blackwood Whitby*	
6 YHAXZ Mk. II	350 at 1200 (225 kW)	370 at 1200 (250 kW)	6,300	9 ft × 5 ft 3 in × 5 ft 6 in	G.P. Frigate	
A.S.R.3 Foden F.D. 6	90 at 1500 (60 kW)	99 at 1500 (66 kW)	1,925	62 in × 32 in × 46 in	C.M.S. I.M.S.	
A.S.R.4 Enfield H.O. 2	9 at 1500 (5 kW)	9·6 at 1500 (5·7 kW)	350	29½ in × 35½ in × 23 in	Emergency Gen. Sets	
Enfield V.S. 1	4·5 at 1500 (2·6 kW)	4·8 at 1500 (2·9 kW)	220	25 in × 21 in × 28 in	Emergency Gen. Sets	

(*c*) Most Diesel engines do not like running for prolonged periods at low powers. In certain circumstances in the service this is unavoidable and the standardization policy does prevent at times the fitting of the appropriate size of the engine for the particular duty required of it.

(*d*) Much of Diesel design knowledge is on an *ad hoc* basis. Processes of combustion and piston ring performance are not fully understood and hence a good engine design in these respects occurs only by chance or at the expense of considerable development.

A.S.R.1 Engines

16 V.T.S. Type

The development work on the A.S.R.1 series has been mainly carried out on this model and the details of this work have been fully described by Mr. W. M. Sampson in his article in Vol. 9, No. 1, of the *Journal.*

By July, 1956, when the first production engine carried out sea trials in the first AA/AD frigate, H.M.S. *Lynx*, a large number of these engines had been built by the six manufacturers concerned. There was considerable anxiety, therefore, when, just before the sea trials of H.M.S. *Lynx*, a 16 V.T.S. engine undergoing an acceptance test at one manufacturer's works had a major failure of a line of parts. A piston and a liner disintegrated suddenly together with the fracture of a connecting rod, causing consequential damage to the associated piston and liner. There were several possibilities for the cause of failure :—

(1) The engine was the first reverse rotation engine, being prepared for H.M.S. *Jaguar* (which was to be the first ship of the Class to be fitted with a C.P. propeller). Some design point associated with the reverse rotation might have been overlooked. This was ruled out after closer investigation.

(2) The particular manufacturer obtained pistons from a source of supply which no other A.S.R.1 builder used. This particular source of supply had also been giving trouble with similar failures in a commercial engine in naval service.

(3) The suddenness of the failure and the appearance of a fatigue crack below the eye of the fractured connecting rod were evidence for the fracture of the connecting rod being the initial cause of the failure.

(4) Disintegration of the liner through distortion. Mal-operation was ruled out on the grounds of the satisfactory condition of the remainder of the engine components.

No definite cause of failure has yet been established ; a close inspection into the method of manufacture of the connecting rod revealed, with no doubt whatsoever, that a complete examination of connecting rods in the engines built and in production was necessary. This examination included crack detection and a tightening up of dimensional and quality control.

During the acceptance trials of H.M.S. *Lynx* in August, 1956, shortly after the first serious A.S.R.1 failure had occurred, a 16 V.T.S. engine in this ship suffered what at first sight was a similar serious failure. The engine had been built by the same manufacturer but there were, on further investigation, two important differences between the two failures :—

(i) A heavy piston/liner seizure had occurred before the disintegration of the piston. This had been aggravated by the engine having been driven for two minutes subsequently by the full power of the remainder of the engines coupled to the shaft. The possibility of an air-lock in the liner jacket could not be ruled out.

(ii) The fork connecting rod had not fractured initially but had battered its way intact into the liner jacket.

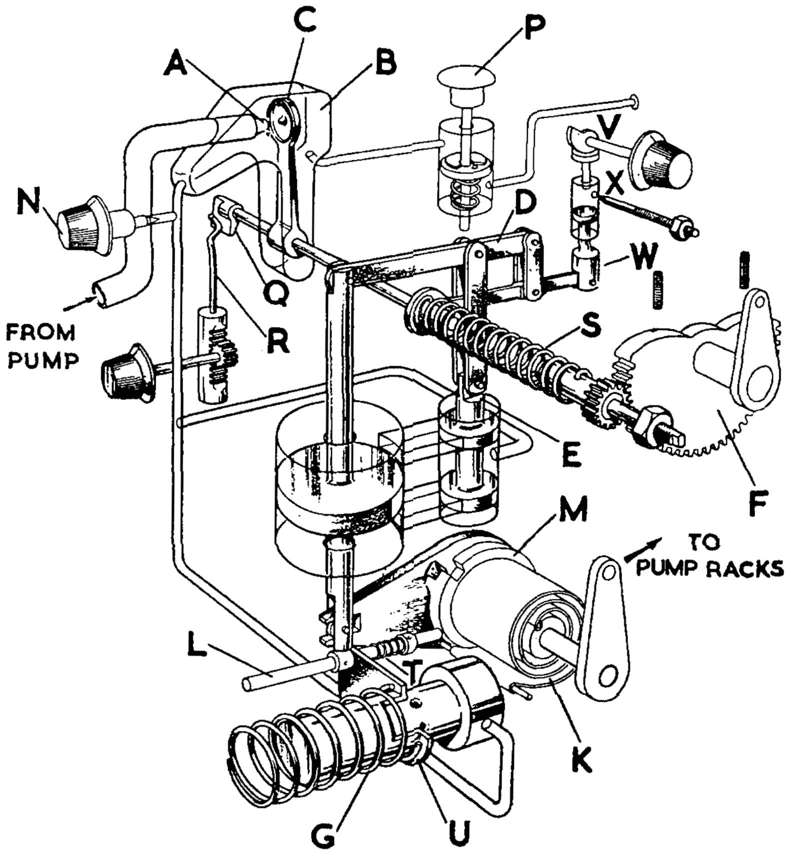
This engine was beyond repair *in situ* and had to be removed from the ship and as a consequence the following action was taken :—

(*a*) The pistons from the particular manufacturer were scrapped.

(*b*) Steel liners, chromium plated in the bore, were fitted in current production and will be fitted on major overhaul in future. These liners will minimize serious damage to an engine should failures of components occur and they have the additional advantage of securing a more effective cylinder head joint.

(*c*) Temperature indicating devices were fitted to the water jacket of each liner.

The only other major trouble which has occurred with this type of engine was the failure of the soldered seal of the viscous type torsional vibration damper on the crankshaft. These have been replaced by welded sealed dampers incorporating a stiffer hub to prevent distortion of the case on tightening up the damper on the crankshaft cone. Some fifty minor modifications have also been introduced in the course of production and with the acceptance of H.M.S. *Lynx* the design of the engine has been frozen. While much more experience is required to justify this step for modifications which are practicable



A. NOZZLE
B. CHAMBER
C. IMPELLER
D. LINKS
E. SERVO VALVE
G. RELIEF VALVE
K. SAFETY SPRING
L. PAWL
M. SPRING HOUSING
N. NEEDLE VALVE
Q. LEVER
R. BEAM SPRING
S. TORSION SPRING
T. SPRING
U. ACCUMULATOR MEMBER
V. MAXIMUM LOAD STOP
W. DASHPOT
X. NEEDLE VALVE

FIG. 1—SCHEMATIC ARRANGEMENT OF THE SPEEDLOCK GOVERNOR

in the course of refit, experience on H.M.S. *Vidal*, with unsupercharged 12 V.U.S. engines, indicates considerable optimism for the future. Three of these engines which have completed 5,000 hours' running have been overhauled revealing a most satisfactory wear rate of the majority of the components compared with experiences in normal engines of a similar character.

The most serious problem outstanding is erosion attack of the water side of the liner; a disease prevalent in modern high-speed Diesel engines. Its cause is liner vibration and much research is proceeding to determine an absolute cure. This possibly will involve a major change in design and palliatives, such as coating the back of the liner with a hard substance, will have to be applied to the A.S.R.1. The standard material in common use is a Ni/Cr plating of 0·01 in. thickness ; the manufacturing techniques to ensure a uniform coating on the A.S.R.1 liner have not yet been completely overcome. A more promising coating now on trial is a ' Kanigen ' coating which involves the deposition of nickel by a dipping process.

6 and 8 L.T.S. Engines

From a mechanical point of view, these engines have given little or no trouble in service but an intractable problem of turbo-blower fouling persists during long periods of low-load running.

The most difficult problem to solve has been the development of a governor which will meet D.E.E.'s specification for minimum speed changes with load. A 4 per cent temporary and $2\frac{1}{2}$ per cent permanent change of speed is permitted with a 25 per cent load change.

The original Bryce Berger governor, now fitted to the 16 V.T.S. engine, could not meet the specification ; the engines were fitted with a Paxman governor as an interim measure with a relaxed specification. A new Bryce Berger governor, the Speedlock, illustrated in FIG. 1, is under trial in H.M.S. *Salisbury*. The future requirements of D.E.E. will, it is felt, be tighter and it is likely that the ultimate answer will be an electric sensing governor which reacts to load changes before the engine feels the effects. This type of governor is under development in the U.S.A. and in this country and more stringent engine control will be possible by this means.

16 V.M.S. Engines (Submarine Propulsion Engine)

It was decided, as certain changes were made in the production model of this engine, to give the first production engines at Messrs. Vickers-Armstrongs, Barrow, a 1,000-hour test.

The performance of this engine during the test was, to say the least, disappointing. The start of the test was delayed by the AA/AD Frigate gearbox trial and the test was scheduled to take 1,000 hours to complete before it was required to be installed in the first submarine. In fact it took eighteen months to complete, after considerable modification under pressure of circumstances and no mean effort by the Diesel Section of Vickers-Armstrongs.

The first 16 V.M.S. engine to be built in Chatham Dockyard was completed at about the same time as the first Vickers engine was due to start the 1,000-hour trial. A series of characteristic trials were planned at Chatham with the engine coupled to a brake, as opposed to the complete installation at Vickers with the flange mounted generator.

The first trouble that arose, in fact, occurred at Chatham when the quill shafts, illustrated in FIG. 2, driving the mechanical Roots type blowers, repeatedly fractured. It was apparent that the stresses induced in the quill shafts were greatly in excess of those calculated and the quill shaft was either responding to an unpredicted natural frequency in the blower system or that torsional vibrations were being transmitted from the crankshaft through the step-up gear and were not being isolated by the spring wheel located in the drive system (see FIG. 3).

Quill shafts of 100 tons/sq. in. U.T.S. steel were fitted to the Vickers engine and a series of trials were carried out at Chatham by the A.E.L. involving the fitting of strain gauges to the quill shafts and modifications to the spring wheel to determine the root cause of the high stresses. These trials involved new techniques and were a technical achievement of a high order. The interpretation of the results and conclusions caused much discussion and argument ; at one point Dr. Ker Wilson of the De Havilland Company, one of the foremost torsional vibration experts in the country, was called in as a consultant. A subsequent trial with a spring wheel fitted to the crankshaft, which was completely successful, proved the point that the torsional vibrations were arising from the crankshaft and could not be isolated by the existing spring wheel in the step-up gear system.

During the course of these extended trials, Vickers managed to run 500 hours with the strengthened quills without failure. The trials at Chatham were prejudiced by the differences between the torsional system compared to the submarine system involving the flange mounted generator. On the other hand, three quill shafts have fractured on the Vickers engine during the 1,200 hours' running at Vickers and at the A.E.L. where it is now completing its endurance running. These failures can, however, be directly attributed to torsional damper failures on the crankshaft and failures of the blower bearings

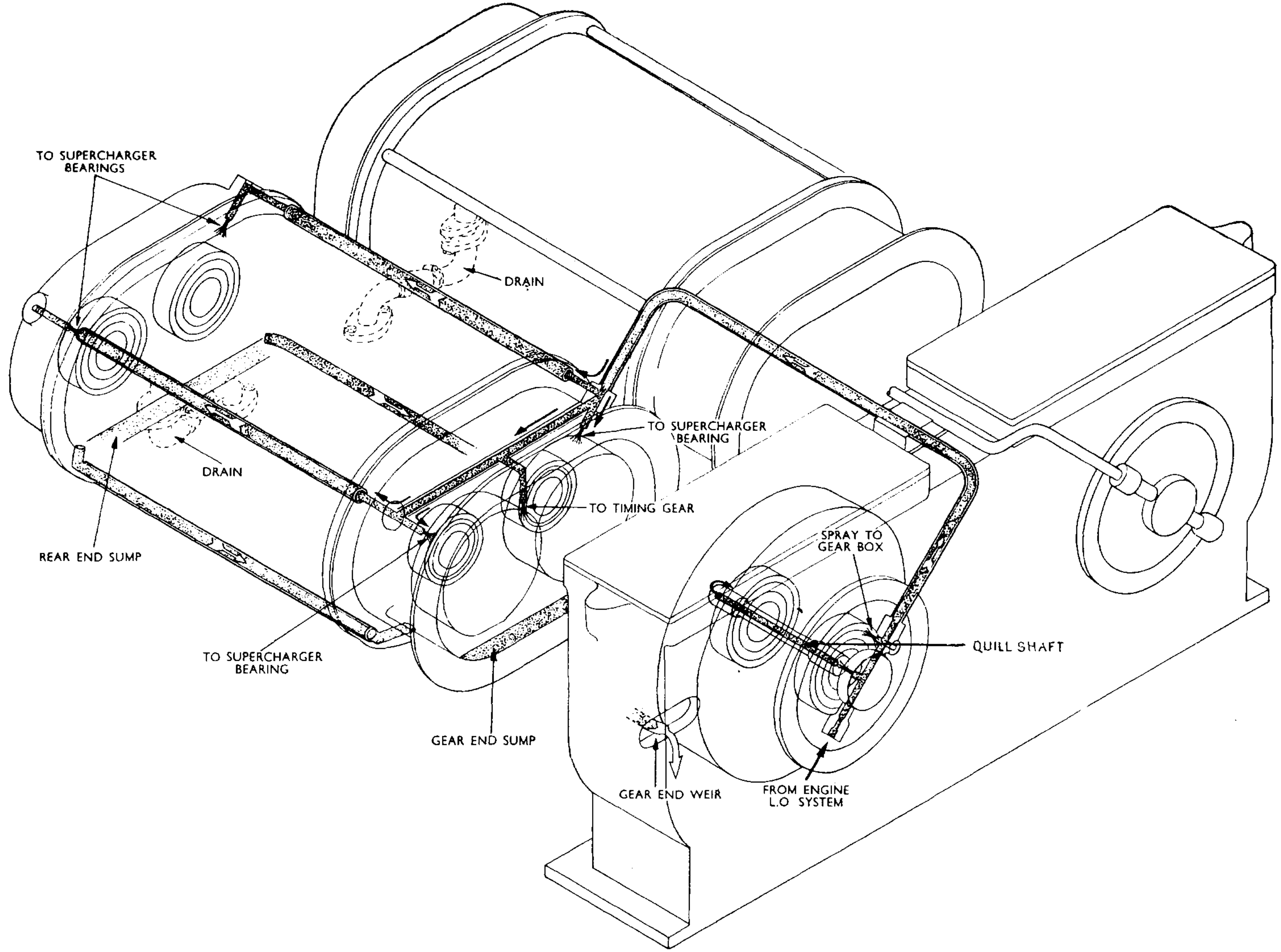


FIG. 2—16 V.M.S. ROOTS BLOWERS

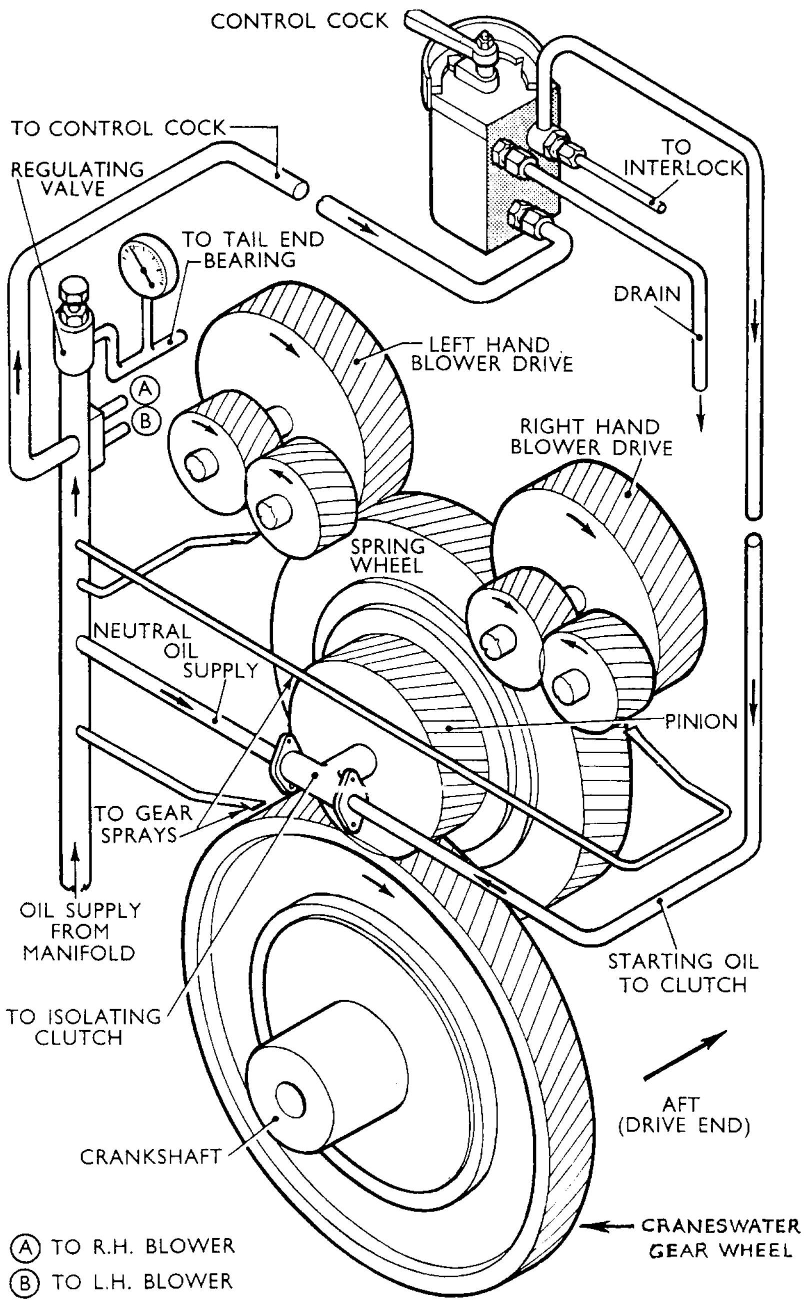


FIG. 3—16 V.M.S. BLOWER DRIVE

which have now been enlarged. A further seven production engines have also successfully passed their acceptance tests. At Vickers the crankshaft gearwheel and pinion (FIG. 3) suffered heavy pitting after a short period of running ; torsionals were the cause and hardened and ground gears have now been fitted to all production engines.

The major issue during the 1,000-hour trial at Vickers was that of oil leakage from the engine into the flange mounted generator. The sealing arrangements on the shaft and the design of the bulkhead were not under the jurisdiction of E.-in-C. The Department, however, undertook to build up a further sealing arrangement in the engine side as crankcase conditions appeared to be unusual. This eventually proved to be unsuccessful and the engine and generators were finally separated by six inches so as to incorporate two bulkheads each with its own sealing arrangements on the crankshaft. This will guarantee freedom from expensive failure of the generator, not readily removable, particularly under conditions of extended running hours when crankcase pressures are likely to build up. This problem has also been recently met in railway traction engines in this country and the policy is now to separate the two units as has been done with the A.S.R.1.

The 16 V.M.S. engine does appear to generate more crankcase fumes than the 16 V.T.S. engine ; this is thought to be due to the higher boost pressure in the inlet manifold which allows air to pass the piston rings on the induction stroke. The crankcase breathing varies in engines of different manufacture and the root cause has yet to be established.

For the later *Porpoise* Class submarines, a centrifugal blower will be fitted in conjunction with a fluid coupling instead of the spring wheel clutch. This should prove to be quieter, more efficient, and free from torsional effects as far as the blowers are concerned. It will fit on the engine in the same place as the Roots type ; the two blower systems are in fact interchangeable. Conversions can be effected, including the self-contained oil system of the centrifugal supercharger.

Deltic Engines

A full report of the prototype 18-11B 2,500 h.p. Deltic engines fitted in an ' E ' boat is contained in Lieutenant-Commander Venton's article in Vol. 7, No. 3 of the *Journal.* Since this, nine *Dark* Class and two *Bold* Class F.P.B.s have been brought into service and considerable running experience has been obtained.

Initial experiences included two simultaneous seizures in a boat which indicated overloading of the engines by a combination of circumstances. Since more suitably matched propellers have been fitted, satisfactory operation has been achieved. Overloading still occurs on turns and an exhaust temperature limitation has to be applied. A greater exhaust back pressure than was previously anticipated and high ambient temperatures in the engine rooms are contributory factors. Trials to increase the engine speed to 2,200 r.p.m. are in progress ; the production of 2,500 h.p. at these engine revolutions more suitably matches the propeller characteristics and a higher maximum boat speed is attainable.

Apart from one or two defects, attributable to manufacturing difficulties, the engines have performed most satisfactorily with the establishment of the 1,000-hour overhaul life. The current pistons in production, made from a more durable material, will permit a higher exhaust temperature which will overcome the limitations set by the installation.

The down-rated version of the Deltic (18–7A) is being fitted in later Coastal Minesweepers. The prototype, H.M.S. *Highburton*, has been in service for two years and, apart from incidence of funnel fires, the engines have performed most satisfactorily with a minimum of day-to-day maintenance. Examination of the engines after a total of 3,000 hours running was most encouraging. Piston ring wear, attributable to long periods of low-load running, is noticeable but minor modification to the positioning of the rings should permit a 4,000-hour overhaul life.

Initial difficulties were experienced while undergoing certain manœuvres from ahead to astern in that the engine speed was reduced below its normal idling speed and the engine was locked in a critical speed, which resulted in the fracture of a quill shaft driving the blower system. Minor modifications to the fuel injection equipment, increase in idling speed, and increase in blower torque prevented this fall into resonance.

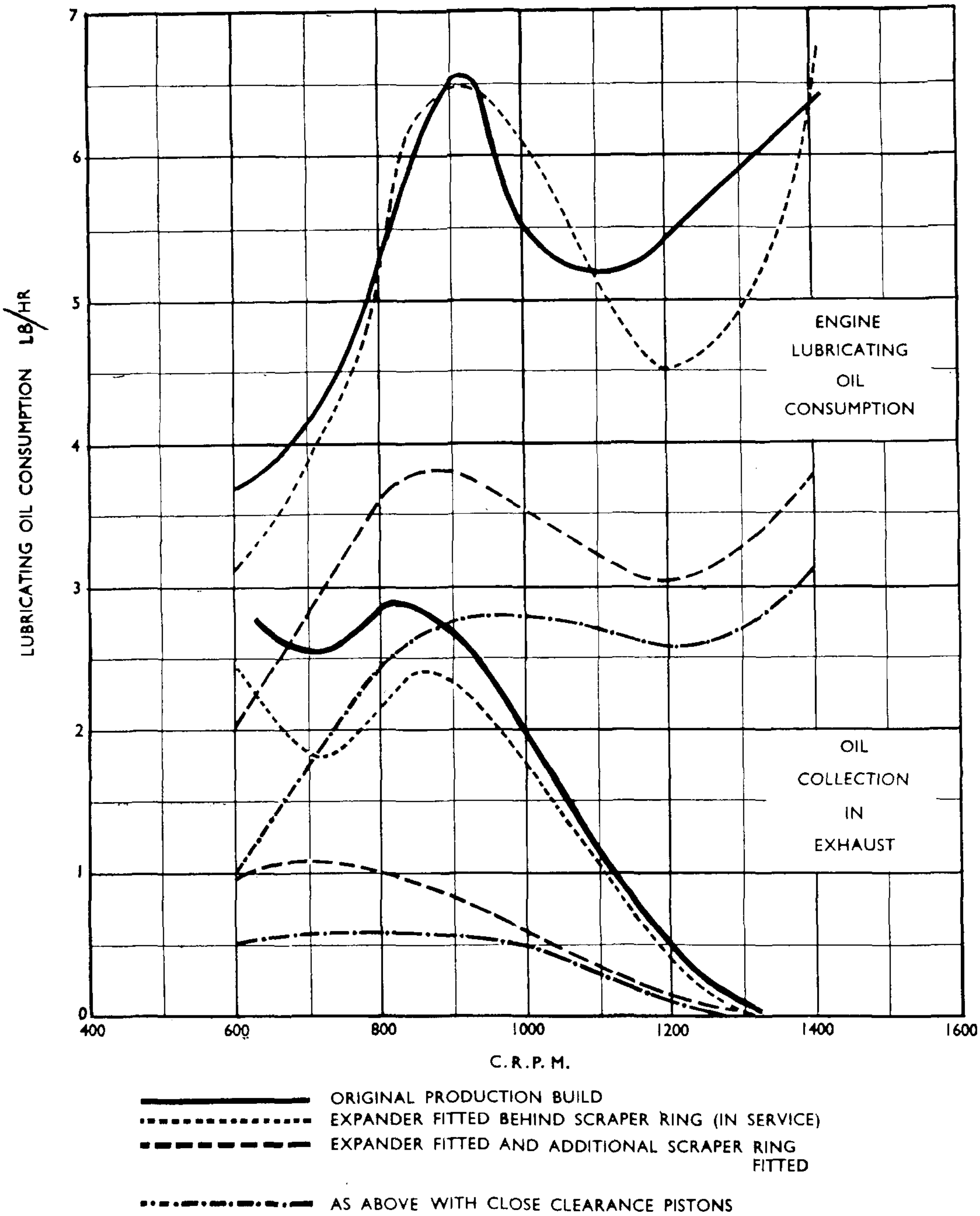


FIG. 4—DELTIC 18-7A LUBRICATING OIL CONSUMPTION TRIALS

The characteristic of this engine of discharging lubricating oil from the exhaust ports and causing exhaust fires in the complicated silencing system has caused much concern. The throw-out of oil occurs at low speeds which corresponds, of course, to the maximum usage of the engine during minesweeping. The basic reason for this characteristic, prevalent in most exhaust ported two-stroke engines, is that to maintain high torques at low speed excessive scavenge air is supplied. Considerable progress, as indicated in FIG. 4, has been made by the fitting of an additional scraper ring half-way up the piston skirt and by fitting pistons with reduced clearances. Further progress to a complete cure lies in throttling and heating the intake air so that the exhaust temperature at the critical speeds ensures that the lubricating oil which is discharged is burnt. The Minesweepers are, however, being fitted with a water scrubber in the exhaust system to collect oil and minimize the fire hazard.

Further development of the Deltic engine is in progress, although no supported by the Admiralty for financial reasons. The 9-cylinder engine has been fitted with a turbo-blower to increase its power and will be supplied to the British Railways for traction purposes in their modernization scheme. A similar conversion is in progress with the 18-cylinder engine and the summit of Diesel development—the Compound Deltic—has now run. The 18-cylinder engine, fitted with a gas turbine driving a compressor in the centre of the triangle, provides power both for the Diesel and gas turbine. 5,500 h.p. at 2,000 r.p.m. giving a weight/s.h.p. ratio of 2 lb is an impressive target. This unit could be run as a gas generator supplying a free turbine. In this way four units feeding a common turbine would be a most compact and economical arrangement for small ship propulsion. The Deltic unit could be mounted on its end, so that if the need arose all pistons could be accessible *in situ.*

Paxman YHA Engines

Large numbers of the Paxman YHA series engines have been ordered and are in service. This series was specifically designed to meet Admiralty requirements incorporating cast aluminium blocks and a compact form for low magnetic weight.

Relatively little operational experience has been gained with this engine owing to low usage rate of the Inshore Minesweepers. More experience will be gained in the tug applications which are now in service and in the unsupercharged engines in the *Blackwood* and *Whitby* Class.

They have generally performed satisfactorily and have proved to be a worthy successor to the R.P.H. series whose virtues are acclaimed regularly in ' Notes from Sea ' in the *Journal.* Two major defects have come to light. The design of the exhaust manifold joint to withstand the varied expansions of the aluminium engines and the gas leakage so caused, produced unpleasant conditions in the engine rooms of the I.M.S. and brought in their train acute turbo-blower fouling. A re-designed joint has passed satisfactory trials. Over the past year there has been an incidence of piston failures and excessive ring wear in propulsion units. This has been attributed to low load and low temperature running. The thermostat controlling the coolant temperature has been re-designed and trials are in progress with modified scraper rings allowing increased lubricating oil consumption at the lower powers.

A Mark II 12 YHAX engine has been on test at the A.E.L. and a rating corresponding to 500 kW at 1,200 r.p.m. is foreseen for future applications. The Mark II 6 YHAX engine is being fitted to the G.P. frigate as an emergency generator and for the *Eagle* the 16-cylinder YHX engine incorporating a steel frame has been ordered for the replacement of the non-standard D.C. Diesel generators.

Foden Engines

The Foden engine, now familiar to many more users in a great variety of applications, is available in 4, 6 and 12-cylinder units. It is basically a commercial engine adapted for naval requirements and is, by virtue of its compactness and light weight, most suitable. It has given a good account of itself, particularly from the standpoint of mechanical design and durability of its working parts. It has suffered from three major complaints.

Firstly, it does not appreciate low-load running for prolonged periods which inevitably occurs in some applications ; the F.D.6 generator, although rated at 60-kW has had to endure prolonged periods of 5-kW operation in the I.M.S.s. This low-load running causes in service a build up of carbon on the exhaust valve thus eventually seizing the valve with consequential damage to a line of parts. When the situation permits, running at 1,500 r.p.m. instead of 1,800 r.p.m. has been authorized to reduce lubricating oil consumption. It is curious, however, that with Rotella T.30 lubricating oil in the sump, a series of trials at the A.E.L. have failed to reproduce these failures. The use of OMD.111 and OMD.110 from unreliable sources have aggravated this defect which should not exist when OMD112 is eventually available.

In certain craft an epidemic of fuel pump plunger spring failures has occurred. This is due to contamination of fuel oil by salt water. Re-designs of spring with suitable coatings are under trial but the original spring acts as a fuse to prevent more expensive failures of the associated governor. Improved filtration and elimination of the sea water at the source are the only practical cures to this problem.

Megator sea water pumps, in spite of much modification, have proved unequal to the task of pumping sea water loaded with sand. The Jabsco pump, embodying a rubber impeller, is now becoming available as a replacement. Exhaustive trials have proved its reliability and its replacement a more economical proposition.

Examination of engines undergoing overhaul at Blackbrook Farm after 3,000 hours' running has shown that this overhaul period can be extended to at least 5,000 hours.

A Mark II engine is now available incorporating separate cylinder heads. This modification, to prevent gasket failures under certain conditions, and to allow for uprating with turbo blowing, has not been accepted by Admiralty as this defect has not been observed in naval service and the spare gear position would be complicated to control.

Enfield Engines

The low end of the power range has been filled by the Enfield H.O.2 and V.S.1. The performance of this engine, so far as wear and general reliability are concerned, appears to have been most satisfactory. No other engine maker in this country has produced an engine in the same class from the standpoint of weight and space. Owing to a defective design of the original crankcase and difficulties in supply of certain items, four marks of engine have been introduced.

Varied criticisms of the startability of this engine have been actively considered. There is undoubtedly a knack in hand starting any air cooled Diesel, particularly in the use of the decompression lever. The Start Pilot device assists in cold weather. Resiting of the decompression lever and an inertia starter are under trial to improve the situation.

CONCLUSION

Diesel engines have had, in the past, a bad reputation for reliability. There is no doubt, however, that the reliability has improved since the War in spite of impressive improvements in power/weight ratios, etc. Their reliability can be further improved by strict adherence to maintenance schedules and modification. Diesels, unlike many other items of equipment, are amenable to modification. Reports on Forms S.2022 are starting to flow in and prompt action is thereby readily possible by E.-in-C. The introduction of a modification procedure similar to that adopted by aero-engines is in the course of preparation.

Although the future may not see Diesels introduced in such vast numbers as has occurred during the past five years, they are very much a part of the active fleet. Their compactness, economy and power/weight ratio are unequalled in any other form of prime mover, when all these factors are considered together. Suffice it to say, however, that even with the advent of nuclear propulsion, an auxiliary Diesel is required to support it in certain applications.