DIESEL DESIGN AND MAINTENANCE

BY

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The following article is part of a lecture on the work of the Diesel Design and Maintenance Section of the Ship Department given in December, 1963, *by the Author who, at that time, was the Inspector of that Section.*

Introduction

Admiralty policy for the selection of Diesel engines is to meet all requirements for Diesel engines (except those in vehicles) from a standard range of engines. The minimum number of different types of engine are included, and the power range covered by each type is extended as far as possible by using various cylinder combinations. It should be possible to provide engines with 6, 8, 12 or 16 cylinders in ranges, 0, 1 and 2 for example.

This sound policy was approved in 1950, in view of the major logistic and training advantages it offers, and it is difficult to imagine any radical improvement on it. The other Services still use, and are still introducing, large numbers of different engine types.

By 1958, the 1950 rearmament programme had passed its peak, so far as the purchase of Diesel engines was concerned, and with the completion of minesweeper and Diesel frigate construction a year or two later, Diesels were only required for *Oberon* Class submarines, ships' generators and for various minor vessels and craft.

Diesel engines were, in 1958, distinctly unpopular. We had large numbers of them and were beset by teething troubles in many classes of ship. The Diesel Design Section had prepared sound, generally conservative, maintenance schedules for each range of engine. Comparisons were made which showed that both steam plants and gas turbines might offer much less maintenance, and it was decided that Diesel engines had only a small part to play in ships of the future. Diesel propulsion units would be succeeded by nuclear or Cosag, and gas turbines would be used to power generators. It became E. in C.'s policy not to develop the Diesel engine further, except with aim of improving reliability and reducing maintenance of existing types.

The Diesel industry, however, had advanced a great deal during the late 1950s. British firms enjoyed a sellers market for some years after the war, but by 1955 they were facing competition from foreign firms with large and competent design teams backed by well equipped development departments. Consequently they were obliged to provide similar facilities and develop new engines at their own expense and by 1961, engines substantially more attractive than those on which we standardized in 1950 were being offered to us for type test, generally at no expense to the Crown.

Policy

While the possibility of our introducing new standard range engines has been dealt with above, it is also necessary to show that it is desirable to do so.

In practice periodic change is inevitable where commercial engines are used because the original standard engine either goes out of production or is only kept in production at much increased cost per horse power. In the latter case

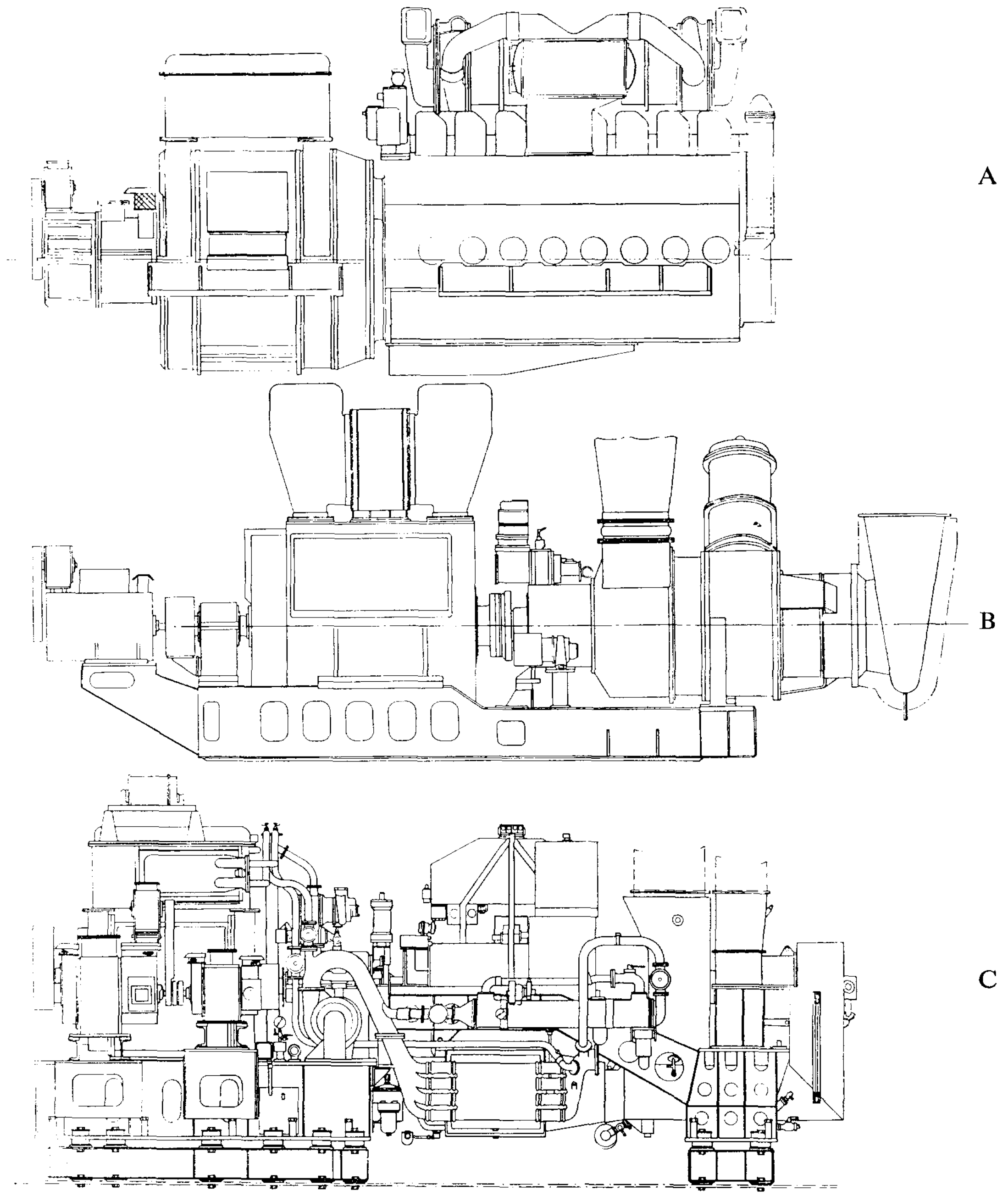

Fig. 1—(A) Ventura Diesel—1,000 kW (actual), weight 27,100 lb

(B) Ruston T.F.G. turbine—600 kW (actual), 850 kW (potential), weight 22,750 lb

(C) W. H. Allen G.T.A. Type B—500 kW, weight 19,040 lb

Note: All sets drawn to same scale

experience is that standardization is soon questioned inside the Admiralty organization, despite any arguments we base on the cost of introducing improved engines with all the spare gear, overhaul and training problems entailed. On the whole this is a good thing. It puts the Design Section in the position of a commercial sales organization in that we have to make a good case for the use of our recommended engine. We can only do this by bringing our standard engine ranges right up to date every few years.

Proof of the advantages of having modern Diesels thoroughly proved and

Range	*Existing Engine*			*New Engine*			*Remarks*
	Type	*Power Range*	*Wt/Power*	*Type*	*Power Range*	*Wt/Power*	
0	None	—	—	Ruston AO	3,750 to 10,000 b.h.p.	12·5 lb/b.h.p. (approx.)	Being developed commercially by Rustons (to a lower rating using F.F.O.) Noise reducing measures incorporated
1	A.S.R.1 Mk. 1	750 to 2,000 b.h.p.	20·25 lb/b.h.p.	A.S.R.1 Mk. 1A	1,875 to 2,500 b.h.p.	16·25 lb/b.h.p.	Two suitable Range 1 engines now under commercial development. (Powers approaching 4,000 h.p.
2	Paxman YHA Mk. 2	330 to 925 b.h.p.	18 lb/b.h.p.	Paxman Ventura	560 to 1,500 b.h.p.	9·25 lb/b.h.p.	Type tested and being introduced
3	Foden Mk. 1	61 to *210 b.h.p. *Less with tropical derating.	16·5 lb/b.h.p. (approx)	Foden Mk. VI	82 to 246 b.h.p.	14·5 lb/b.h.p.	Type tested and being introduced
				Foden Mk. VII	110 to 340 b.h.p.	11 lb/b.h.p.	This engine is a turbo-charged Mk. VI. Part 3 of type test under way
4	Perkins P Range	32 to 65 b.h.p.	17 lb/b.h.p. (approx)	Perkins 6/354 4/236	54 to 85 b.h.p.	13·5 lb/b.h.p. (approx.)	Type tested and being introduced
				4/107	36 b.h.p.	12·5 lb/b.h.p.	Type tested and being introduced
5	Enfield V.S.1 and HO2	5 to 11 b.h.p.	25 lb/b.h.p.	No Change	—	—	No new engine has been found which has substantial advantages over existing Enfield
Special	Deltic 18–11B 18–7A	550 to *2,500 b.h.p. *15 minute rating	6 lb/b.h.p. including gearbox	Deltic T18–42K	925 to *3,700 b.h.p. *15 minute rating.	4·2 lb/b.h.p. including gearbox at maximum (15 minute) rating	Production engines available 1965, with continuous rating of 2,500 b.h.p. No proposals made for Type Testing

Powers quoted are continuous tropical and power/wt ratio does not include gearbox, except where otherwise indicated.

FIG. 2—COMPARISON OF OLD AND NEW ADMIRALTY STANDARD RANGE DIESELS

ready to order is that the 1958 decision to fit gas turbine alternators in all new construction ships has been reversed. We are replacing in some applications the 500 kW Allens G.T.A. by a 1000 kW Paxman Ventura Diesel set. The Ventura is our new range II engine, developed at no cost to the Admiralty.

Design

The 1000 kW Ventura Diesel set goes into the same space required for the 500 kW Allens gas turbine set, its specific fuel consumption is twice as good and its initial cost only half that of the less powerful gas turbine. This should not of course be taken as expressing any final comment on the relative merits of Diesel and G.T. prime movers. Reference to FIG. 1 will show that the compactness of the Diesel set is due to its requiring no gearing and no bedplate. The Diesel engine itself is heavier and larger than the gas turbine. The reason for the attractive price of the Ventura is that Paxmans rely for their continued existence very largely on selling it in the open market. Since the engine must give good service to continue to attract commercial sales, and since our rating for it is conservative, we hope that the maintenance load per kW will be much less than we experienced with Y.H.A. Mk. I generators.

FIG. 2 gives a comparison of the old and new Standard Ranges.

Small Engines

Although there are several closely comparable engines on the market, we have not yet found anything decisively better than the Enfield to fulfil requirements for very small engines. The 4/107, of which basic design Perkins manufacturers some 700 a day, has been introduced as a motor boat engine. It is likely to last about as long between overhauls as the present P series, despite its better power/weight ratio. The Perkins 6/354 and 4/236 replace the P.6 and P.4. engines, the former of which we have used for 25 years. The power/weight ratio is not much improved, but the overhaul life of the new engines should be double that of the old ones. All Perkins engines are extremely inexpensive. Foden engines are not cheap, though the purchase price of the Mk. 6 is the same as that of the very satisfactory Mk. 1 and we therefore gain about 25 per cent in cost per h.p. and in power weight ratio by adopting it. Trials of a turbo-supercharged version of this engine are proceeding at A.E.L., with the object of closing the gap in the range between the largest Foden and the smallest Paxman. The turbo-supercharged Foden produces very high powers per square inch of piston area, and in the heavy lorry market is competing well with much bigger and heavier 4-stroke engines.

Range 2

The attractive power/weight ratio of the Ventura is obtained in quite a different way. The cylinders are pitched very close together and the firing loads transferred to the frame from the cylinder heads with the minimum of bending stresses (see FIG. 3). It will be seen that all cylinder head studs are screwed directly into the main frame plates.

Range 0

In late 1960 consideration of the Foden and Paxman Ventura designs, together with knowledge we had of foreign navies' Diesel frigates, led us to consider whether a modern Diesel frigate engine might prove attractive. By this time the *Whitby* class had seen sufficient service for a less rosy view to be taken of their maintenance than in 1958, but the more reliable Diesel frigates were still costing about twice as much to refit. It was obvious that a modern Diesel frigate must have far fewer working parts than a Type 41, greatly simplified transmission, and full access for repair by replacement of machinery. Engines of three different types were designed by us sufficiently for weights to be estimated, and it did appear that for long range frigates Diesel engines could be developed to give very

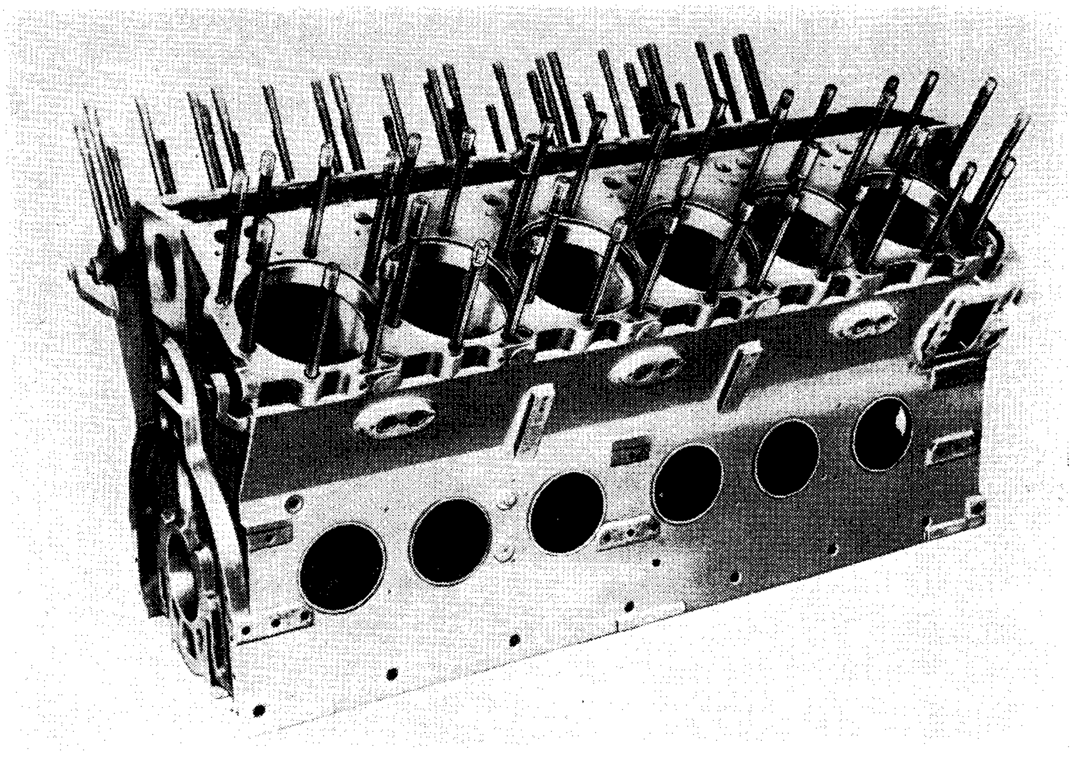

FIG. 3

substantial advantages compared with any other prime mover. It was discovered that both Messrs. Ruston and Hornsby and Messrs. Mirrlees National had already determined to develop engines in this class for commercial reasons. Both firms were shown details of the Admiralty work and Rustons found our ideas were closely similar to their own. Despite there being no certainty that we would use the engines, Rustons proceeded with design and manufacture of the AO engine at their own expense, and it has been approved that if the engine is successfully developed, it will be type tested for inclusion in the Standard Range. The design combines the high power per square inch of piston area of the Foden with the compact cylinder arrangement of the Ventura, so far as this is possible.

Work has proceeded on the basis of commercial development with Admiralty support only to enable certain drawings to be produced more rapidly than would have been the case if we had waited for the firm's commercial programme. The design work has been entirely Ruston's responsibility, and no parts of the original Admiralty study have survived unchanged; though the cylinder centres, bore, stroke, r.p.m., b.m.e.p. and crankshaft scantlings are little altered. Rustons have introduced a lattice frame, unique in Diesel practice, with the objects of being able to calculate all frame stresses and to find a less expensive alternative to fabricated steel plate construction. FIG. 4 shows a model of part of the frame. The outer skin of the engine is entirely unstressed, and it should be much quieter in operation than similar engines of conventional construction, as much noise is radiated from stressed frame panels in most engines.

The valve gear, the fuel system and the piston cooling system are run continuously on rigs, a single cylinder engine has been run intermittently since June, 1963, and a 4-cylinder development engine since Christmas. Another 4-cylinder engine should join it a few months later. If this range 0 engine fulfils expectations, it should be an ideal long range frigate engine, as the necessary power for small and medium sized frigates can be produced from not more than four engines. As the engines are to be reversible, a very simple and compact transmission system becomes possible. A good deal of development has already been done.

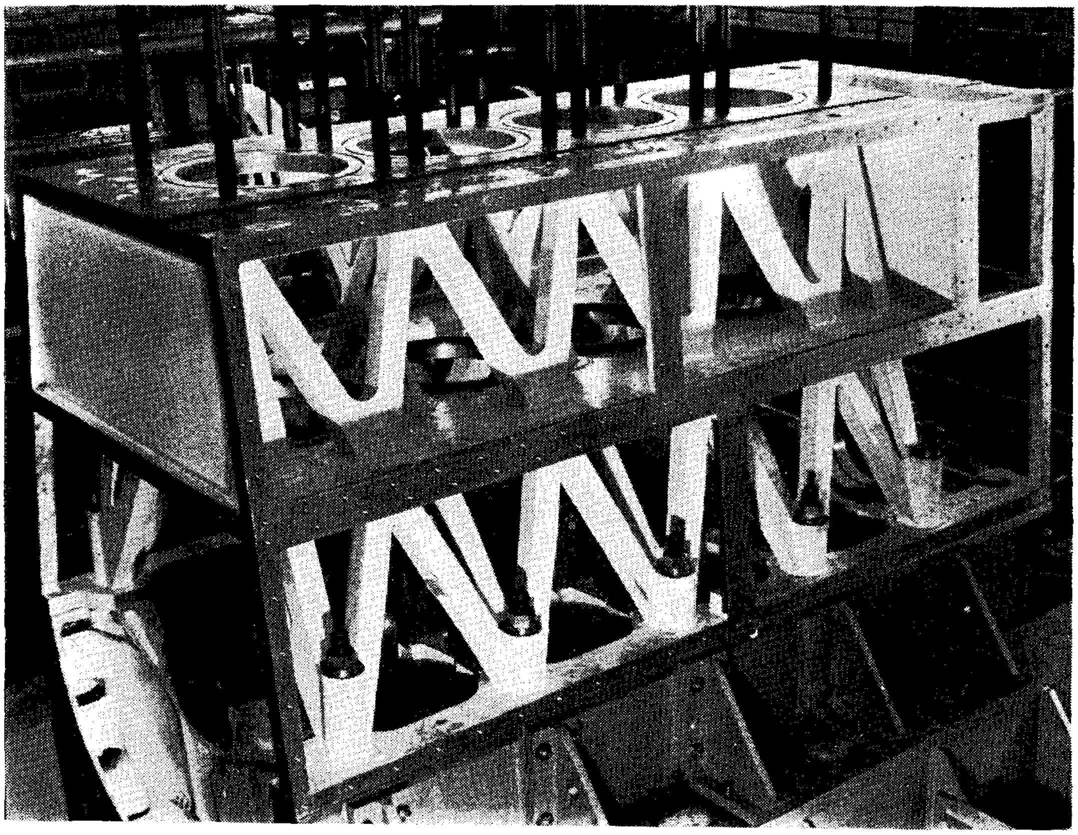

FIG. 4—MODEL OF PART OF RUSTON'S LATTICE TESTING FRAME

In the last two years, the Japanese have fitted three alternative designs of modern medium speed engines (two of them of European origin) in their frigates, and the French and Germans both developed more powerful versions of their own frigate engines.

The maximum capability of the foreign engine types concerned appears to be about 6000 to 8000 h.p., assuming 16 cylinders in all cases except that of the German engine, which has 24. The A0 is more compact and should develop more power than any of them, though no doubt the foreign firms will make every effort to compete.

Range I

In 1961 it was decided as an interim measure to bring our existing engine in this range thoroughly up to date, though the amount of redesign was limited by a desire to retain as many of the parts of the existing engine as possible, as they were thought to be well proved. Another limitation was that Chatham Dockyard M.E.D. drawing office were heavily committed on other work. As a result of the above our desire to increase the bore of the engine while keeping the same cylinder centres had to be dropped, and the Mk. 2 design was commenced on the understanding that the engine was likely to be superseded by a commercial design in 1970 or thereabouts. The Mk. 2 design incorporated a stiffer crankshaft, much better breathing, a stronger camshaft and camshaft drive and improved accessibility of fuel pumps. It should have been suitable for 200 b.m.e.p. with 2·5/1 supercharging. Our present frigate engines are rated at 126 b.m.e.p. This year the new design has been cancelled owing to the lack of possible service for it before 1970 and the advance of two comparable commercial engines which were not envisaged two years ago. Some of the parts designed for the Mk. 2 engine are being introduced as modifications to the Mk. 1.

Deltic

There has been very little interest in fast patrol boats in this country in recent years, and we have therefore undertaken no engine development. Napiers have made rapid progress both in design and internal organization and have proved capable of capturing a large part of the world market for F.P.B. engines. They also have a footing in the rail traction field and by developing engine support on aircraft engine lines, claim to have provided British Railways with the highest locomotive availability of any type in service. We have not tested Napiers' latest M.T.B. engine, but powers of about 3,300 h.p. are quoted at present, with further development in hand to reach 3,700 this year, on a 15-minute rating.

Direct Drive Engines

These are used to an increasing extent for Fleet Train vessels, and presumably most if not all new supply and support ships will be Diesel-powered in future. We have no responsibility for the machinery, and very little connection with the design except that we do maintain cordial relations with D. of S.'s Marine Engineer Superintendent and pass on information about such matters as our new range of Ventura engined generators. A more direct link with Doxfords exists through our membership of the B.S.R.A. Diesel sub-committee and through connections with D.S.I.R. if development loans are under consideration. In this field the British marine industry has been caught at a disadvantage and at present over half the motor ships built in British Yards are engined by Sulzer R.D. range engines built in this country under licence. Not only are licence fees paid but the engines are built in very small numbers by many different shipyards. This does offer an opportunity to Doxfords to regain the leading position they once held, and this Section and our R.N.S.S. colleagues have been involved to a small extent in such matters as bearing and damper design for the new J range of Doxford engines. Government support, however, is unfortunately not now an Admiralty responsibility.

Governing

Towards the end of 1960, Diesel generator governing problems became acute. These problems have existed for many years, with generating sets either just meeting or just failing to meet D.E.E.'s requirements. On Paxman's advice an attempt was made to provide a major advance in governing by introducing a load-sensing electric governor of their design. Eventually this attempt failed, but a great deal was learnt. When full instrumentation was brought to bear it was found that our well-proved and comparatively cheap and simple mechanical/hydraulic governors functioned much better if driven off some part of the engine relatively free of cyclic and torsional disturbances. They are traditionally driven from the worst possible place—the free end of the camshaft. It was also found that fuel pump elements with a more linear relation between effective stroke and delivery were both necessary and available. We therefore reverted to mechanical/hydraulic governors, with satisfactory results.

It was apparent, however, that far better governing was possible. An electric speed sensing governor has been designed by Mr. Strong of our Scientific Staff, with the collaboration of D.E.E. and A.E.L. The objects of the design were to provide a simple, very accurate and fast acting governor, made up of a number of sub-assemblies, any one of which could readily be changed by ships staff without any necessity for either detailed investigation or extensive work in situ. This object has been very largely achieved, and the governor has run 1,000 hours on a Y.H.A. generator at A.E.L. with complete success. This governor is being applied to a turbo generator and its amplifiers considered for use in A.V.R.s. The potential electrical advantages of really accurate and fast governing lie in the reduction of complexity of H.F. motor generators, and these advantages must be assessed against an increase in cost etc. incurred by more accurate governing.

Turbo-Supercharging

The improvement in power/weight and power/space 'ratios' (shown in FIG. 2) for the new standard range engines results mainly from the adoption of 2/1 turbo-supercharging. All the larger engines shown are turbo-blown to 15 lb/square inch or over and it is the association of gas turbines (in the form of turbo-superchargers) with Diesel engines which has given the Diesel its present dominating position in the Merchant Service and in rail transport. The Diesel gets more air per lb of fuel burnt than ever before, and the turbine runs at well below the temperatures met with in pure gas turbines. So both partners benefit. Higher pressure blowers, of 3/1 ratio, are already available for trial. The full exploitation of these might lead to substantial complications in engine design, and it may be that some years will pass before it can be decided whether this complication allied to higher thermal loadings and slightly worse fuel con-consumption is worth having. So far as we can see, ratings of 240 b.m.e.p. from 4-stroke and 160 b.m.e.p. from 2-stroke engines, at piston speeds of 1,750 ft/min in each case, can be obtained using 2·5/1 ratio blowers and without complication beyond the use of oil cooled pistons and attention to detail in valve seat and injector cooling. High quality detergent oil will be required and work is already in hand at A.O.L. to produce a specification. We have obtained the collaboration of most leading Diesel manufacturers in this development, and our Oils Section have brought in the major oil companies to assist A.O.L.

MAINTENANCE WORK

Far more effort is put into this than into work in connection with future thinking and new designs, as of necessity priority has to be given to mitigating the troubles met with at sea. It is also very desirable to follow up one of the original aims of the Standard Range Policy—'as a result of experience with the engines to incorporate such modifications as will increase their life between overhauls'. Reference to FIG. 5 will show that considerable progress has been made in this respect. Little modification has been required to achieve increased life on Enfield, Perkins and Foden engines, but Paxman Y.H.A. engines have required a different liner and a new design piston to achieve double their previous overhaul hours. This raises a question of general interest—the costing of modifications. We have several hundred Y.H.A. engines. The cost of modification parts for a 12-cylinder engine is about £675. Assuming that 300 engines are affected the total cost is—at first sight—£200,000. Further examination, however, is necessary. When this modification was introduced Blackbrook Farm were finding it necessary to replace all pistons and all liners on engines being line overhauled, after running 4,000 hours. There were no stocks of spares at S.P.D.C. Since the new design parts are only slightly more expensive than parts to the original design and these parts would have been required in any case, a second look at the costing indicates that this modification costs nothing at all. It is possible to go further. Experience so far indicates that the effect of this modification will actually be to double the overhaul life of the engines. It is difficult to estimate the financial consequences of this accurately, but the cost of line overhaul at present is £1,650, and over 40 engines are line overhauled a year. Assuming that transport costs and the costs of removing and replacing engines, etc. are equal to half the overhaul costs, the introduction of this modification should eventually save the R.N. more than £50,000 per annum (if all engines reach their full overhaul life) without counting the saving on engines overhauled in situ. Although this is an exceptional case, arithmetic of this kind does show

Range	*Type*	*Original*		*Present*		*Target*	
		Top	*Major*	*Top*	*Major*	*Top*	*Major*
1	A.S.R.1 VTS LTS	2,500	5,000	3,500	7,000	3,500	10,500
	A.S.R.1. VMS	2,500	5,000	2,500	5,000	3,500	7,000
2	Paxman YHA Mk. I	2,000	4,000	2,500	5,000	—	—
	Paxman Mk. IA Mk. II	—	—	4,000	8,000	4,000	12,000
	Paxman Ventura	—	—	4,000	8,000	4,000	12,000
3	Foden Mk. I Mk. II Generators	1,500	3,000	1,500	6,000	3,000	6,000
	Propulsion	1,500	3,000	3,000	6,000	—	—
	Locomotives	1,500	3,000	3,000	9,000	—	—
4	Perkins 'P' Series	500	1,000	750	1,500	—	—
5	Enfield VS.1 HO.2	1,000	2,000	1,000	2,000	—	—

FIG. 5—ADMIRALTY STANDARD RANGE DIESEL ENGINE OVERHAUL PERIODS (HOURS)

how difficult it is to evolve a modification procedure which makes sense at one and the same time to the Treasury, Admiralty Departments, and the Fleet. Since the existence of line overhaul depots for Diesel engines and the use of commercial engines puts the Diesel Design Section in a better position than other specialist sections in the respect of modifications, a brief review of our modification policy may be of interest.

Modification Procedure

Each year we attempt to put £50,000 in the Vote 7 estimates under the heading 'Modifications to I.C. Engines' without specifying what we want the money for. With line overhauled engines, it would be difficult to divide the cost between classes of ships and in any case this money is intended for modification parts which are urgently required during the course of the year for unforeseen modifications. Our Finance Section deals with the difficult job of inserting this requirement in the estimates, and in practice the money is available. With it we buy the initial stocks of parts for the more important (A and B) modifications only. Spare gear group organize purchase of parts for C modifications by D. of S., and D. of S. provides for subsequent years' requirements. Details of the modifications are then promulgated by a modification leaflet which goes into the engine handbooks for the A.S.R.1 range and into B.R. 3002 for all other Standard Range engines. The modifications themselves are designed by the engine builders in conjunction with us, and are sometimes proved by A.E.L. before introduction. A.S.R.1 modifications result from teamwork between ourselves, A.E.L. and Chatham D.O.

There are still long delays between our realizing a modification is necessary and that modification actually being incorporated in the Fleet, but the procedure itself seems sound. It must, however, be realized that time is often unnecessarily lost between the users realizing that a modification is necessary and our finding out about it. We welcome information by S.2022 or by any other means. There have been several cases where most expensive damage has been done between the time when an S.2022 has been written and its arrival in the section through the official channels, and other cases where heavy usage of spare parts has only come to light when members of the Section have visited ships or outports.

Incorporation of Modifications

Those engines which are removed from ships for line overhaul have all modifications put in automatically by personnel who specialize in the engine concerned. The line overhaul establishments do their work in clean surroundings with all facilities available, and in our experience engines are both refitted and tested more thoroughly than is possible in situ. It is agreed that in any new Diesel propelled ship provision should be made for refit by replacement of I.C. engines, partly to enable very rapid turn-round of ships requiring refit in an emergency. Experience is that this is only possible where permanent provision for it is built into the ship. Portable plates are not enough, except in small craft, and engine-room trunks seem to be the only answer. These trunks could of course be largely filled with equipment belonging to the engine room department. Engines using 2/1 and higher ratio turbo-blowers are almost as sensitive to intake depression and back pressure as are gas turbines, and the large intakes, uptakes and ventilation ducts necessary will take up most of the space. Where engines are refitted in situ incorporation of modification is much more difficult and expensive, and although modifications are frequently unavoidably incorporated because spare gear supplied is already modified, some other modifications often cannot be undertaken due to shortage of time or money.

A.S.R.1 Engines

These are all overhauled in place, and the amount of modification found necessary to submarine engines has been very heavy. Fortunately there is a tradition of very heavy expenditure on the older submarine engines, and so the work needed to keep A.S.R.1 V.M.S. engines running has excited less comment than might have been expected. Both Roots and centrifugal superchargers proved thoroughly unreliable on their first introduction at sea, despite extensive shore testing. At first it appeared that Root failures were all associated with their inability to compress nuts, bolts, etc. and even now the reasons for some of the failures remain obscure. However, the introduction of radical modifications to the bearing oil systems, together with adjustment to rotor clearances, seems to have effected a substantial improvement in the average running hours before failure. Centrifugal super-chargers suffered from impeller failures at resonant speeds which occurred at part load, not discovered during shore testing which was mostly done at full load, but eventually bowled out by co-operation between our R.N.S.S. staff and A.E.L. Other failures occurred, mostly connected either with oil supply to bearings or the bearings themselves. So many modifications have been incorporated that these superchargers are still refitted by the makers and brought up to date individually. Better service is now being obtained, and we may be in sight of achieving trouble-free running between refits. However, as a precaution, a very much simpler (though larger and heavier) blower has been designed for us by Hawker Siddeley Brush. This blower uses the major components of one of H.S.B.'s commercial turbo-superchargers.

We have also met piston and gudgeon pin troubles due to mechanical overstressing of the design, and failure of camshaft gear drive trains caused both by bad gear-cutting not being detected by inspection and by a mistake in design for welding which leaves a major part of the cradle very weakly secured.

Connecting rod failures—see FIG. 6, have been met with due to insufficient attention to maintaining radii as specified in bolt head and nut recesses during manufacture. These radii were typical of good commercial design practice when they were drawn some sixteen years ago, and are in fact just adequate if very carefully made. Modern practice is to use much larger radii and to specify a high surface finish. Further connecting rod trouble has occurred through fatigue failures of the old-fashioned blade rod large end bearings. All these and other troubles are in process of being dealt with by modification. We now hold a meeting shortly after the start of each refit in *Porpoise* and *Oberon* Class submarines, to examine the stripped and gauged parts, find out any new troubles, and see whether any action is necessary to expedite supply of parts.

These meetings are proving so useful that they will be extended to Diesel frigate long refits. In frigates the engines perform far better—providing care is taken to clean air intake filters and operate exhaust flap valves—and we have just worked out what modifications are essential before their life between majors can be extended to 10,500 hours.

Deltic Engines

Two major troubles have plagued us. One, starter failures damaging the phasing gearcase, has apparently been either mitigated or stopped altogether by a modification. The other, excessive wear of the top ring of the exhaust piston, leading to piston seizure and extensive damage, has so far proved too much for us. A.E.L., Napiers and A.O.L. have put in more work on this problem than on any other single Diesel problem tackled in the last three years. Once or twice it looked as if a cure was found, but now we are down to two further possibilities. We could drop the rings further down the piston, so that the top ring is more or less clear of the exhaust port when the timing edge of the piston clears it. Alternatively we could face the very heavy expense involved in modifying engines to incorporate Napiers' commercial practice—bowl crown pistons with far better combustion characteristics than the flat top piston taken from the German Junkers design. Unfortunately the cost is about £5,000 an engine, as liner changes are involved, and we have 200 engines. Therefore the search for some way of mitigating the trouble at reasonable cost continues. We have introduced a better oil, more accurate coolant thermostats and additional maintenance routines to keep exhaust ports clear. Engines in which Rotella oil has been used from new should reach 4,000 hours reliably, and we may have to accept this as a permanent limit with these engines, which are used under conditions far different from those for which they were designed.

The Fate of Repairable Components

This rather melodramatic sub-title has been chosen quite deliberately to draw attention to the fate of the components. These are items such as turbo-superchargers, governors, injectors, fuel pumps and cylinder heads. There is no system of accounting for them. Those replaced as defective in ships, depots and dockyards ought to be returned to S.P.D.C. In practice too many are left to rot and quite a proportion of those which are returned are never repaired due to defects, not in the parts themselves, but in organization. This problem, which is not confined to Diesel spare gear, is now receiving attention from all the depart-

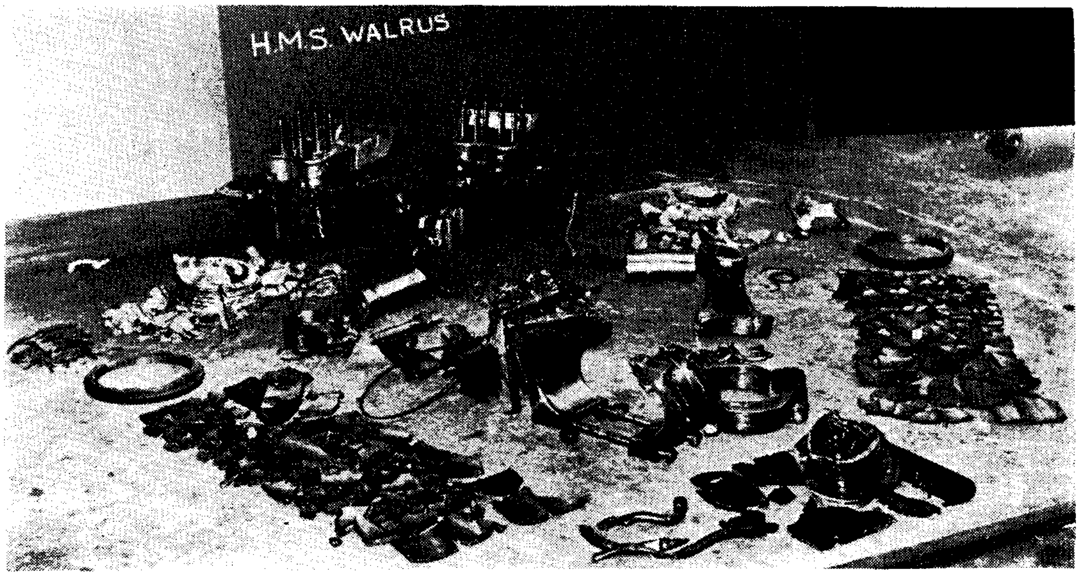

FIG. 6—CONNECTING ROD FAILURE

ments concerned. Its effect on the total cost of keeping the Navy's Diesel engines running is very large. The only further contribution we can make to this problem is to review our Parts Lists and make certain that items are correctly assessed as returnable or expendable. This is being done, and has been completed on A.S.R.1 and Foden engines.

Conclusion

It does appear that Diesel engines have a future in the service for many years to come, as up to well over 30,000 s.h.p. they offer solid advantages for frigate propulsion. This does not necessarily depend on the development of the A0 engine as several other engines could be considered if need be. As prime movers for generators, Diesels are not likely to be supplanted until a large industrial or marine market exists for some other type of engine.

Despite the increased design strength of British Diesel firms, there is still much to be done by ourselves if the optimum advantage is to be taken of Diesels in the Service.