THE DIESEL ENGINE SECTION OF THE SHIP DEPARTMENT

SOME ASPECTS OF ITS WORK

BY

M. F. GRIFFEY, C.ENG., F.I.MAR.E., M.I.MECH.E., M.R.I.N.A., A.M.B.I.M., R.N.E.S.

This article is an edited version of a talk given by the author to the Ship Department on 13th February 1974.

Dr. Rudolph Diesel is said to have invented the internal-combustion, compression-ignition, piston engine in about 1892; probably it initially had some very long German name. Luckily Dr. Rudolph's surname was shorter and was adopted; indeed, as his British rival's surname was Ackroyd-Stuart, it is perhaps a good thing that the Germans won the race.

The Admiralty's diesel section was formed some time later*. The exact date has been lost, no doubt, during an over-zealous waste-paper fortnight. However, it was probably during the 1914–18 War, because in 1917 the Admiralty Engineering Laboratory was established in South Kensington to accelerate the development of diesel engines for submarines. Before this most submarines had spark-ignition engines.

Nearly sixty years on, the diesel section of the ship department is still alive and kicking. Although some new staff on receiving their appointments to the section consider that diesels hold little or no career future (in their eyes, gas turbines, controls, reliability, quality assurance, etc. are the new technologies, diesels being 'old hat'), they soon appreciate that diesel engine technology is both stimulating and challenging and that diesel engines will in all probability play a vital part in the Royal Navy well into the twenty-first century.

FIG. 1 shows the organization which has been adopted for the section to make the best use of the staff available. Its personnel are sometimes labelled with such epithets as 'experts', 'specialists', 'designers'; however, because of their limited numbers, varied background and rapid turnover, they are really managers in the specialized field of diesel engines. The labour force—the real experts—working for us are many and various; they include: the universities, Ricardos, and the GEC Diesel Research Centre—for research and development; the Admiralty Engineering Laboratory—for the evaluation of engines and associated systems; Y-ARD—for surveys and assessments; and, of course, all the expertise of the manufacturers many of whom have been in the business since the beginning. There are also strong contacts with the overhaul lines at Blackbrook Farm, Portsmouth, and Goschen Yard, Devonport, as well as with the drawing office in Chatham Dockyard.

---

* Editor's note:

Although not proof of the existence of a diesel section at that time in the Engineer-in-Chief's Department, the following dates are of interest.

At the end of 1904, for various reasons, it was decided to invite tenders for reversible oil engines to replace the steam machinery in Torpedo Board 047. Although this never came to fruition an order was placed in 1905 with Vickers, who were the pioneers in submarine development, for a 500 h.p. oil engine with air injection; this was fitted in 1907 in submarine A.13.

Also in 1905 when the designs for the Dreadnought were being prepared, it was decided that this ship should be provided with two diesel dynamos each of 100 kW capacity and that she should carry two 50-ft. pinnaces fitted with diesel engines of 120 b.h.p.

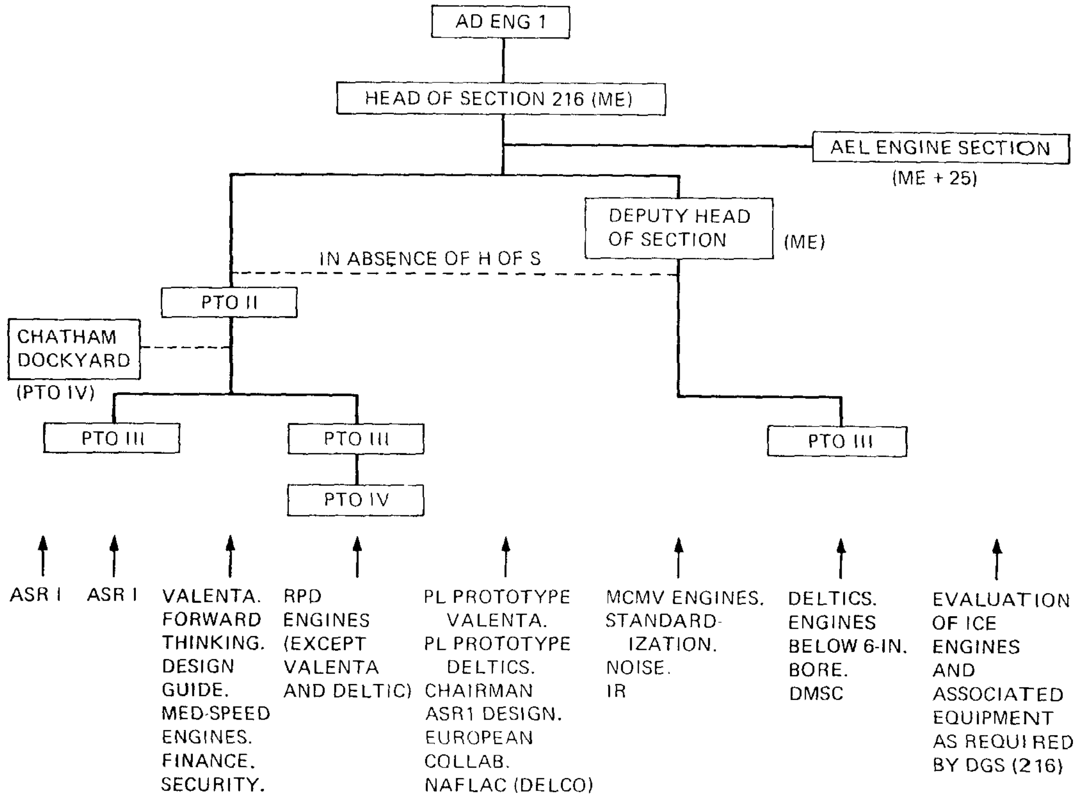

FIG. 1—ORGANIZATION OF THE DIESEL SECTION

There are well over 3000 marine diesel engines, the majority of which are in daily use, in service in the Royal Navy, PAS craft, and the R.A.F. and Army for which the Diesel Section of the Ship Department is the accredited design authority.

As shown in FIG. 1, the work of the section is allocated on an engine-maker basis, although some individuals have additional responsibilities for general characteristics which are peculiar to naval applications, for example noise attenuation, IR attenuation, etc.

A.S.R.1 Engines

This engine was designed just after World War II and was based on a pre-war AEL-designed prototype called the Muscovic. The detailed design work was done by Chatham Dockyard and the engine was selected for naval use in February 1951 as the result of a competition with commercial designs. Its history is fully described in Refs. (1) and (2). As it is now obsolescent, a detailed description is not given here. TABLE I does, however, illustrate its widespread use and various builds and builders. Considering how specialized the technology of diesel engine design had become even in 1949, one must admire the courage of its sponsors. It still results, however, in a big post-design load on the diesel section which is the accredited design authority; a load made bearable only because of the close co-operation of the A.E.L., Chatham Dockyard, and various Ship Department Sections.

Forward Thinking

The next division of work within the diesel section relates to most of the forward thinking concerned with warships. Three projects which illustrate this work are the Valenta, medium-speed diesel engines, and a diesel propulsion system design guide.

TABLE I(a)—*A.S.R.1 engine applications*

Ship	*No. of Ships*	*No. of Eng./Ship*	*Total No. of Engs*	*Type*					
				16 VMS	16 VTS	12 VTS	12 VUS	8 LTS	6 LTS
'P' &'O' Class submarines	21	2	42	42	0	0	0	0	0
41/61 Frigates	8	12	96	0	64	0	0	20	12
H.M.S. *Vidal*	1	8	8	0	0	0	4	0	4
H.M.S. *Hermes*	1	4	4	0	0	0	0	0	4
H.M. Tug *Typhoon*	1	2	2	0	0	2	0	0	0
H.M.S. *Forth*	1	2	2	2	0	0	0	0	0
A.E.L.	1	3	3	1	0	0	0	0	2
H.M.S. *Sultan*	1	3	3	0	1	0	0	0	2
H.M.S. *Thunderer*	1	1	1	0	0	0	0	0	1
A.M.D.	1	—	8	2	2	1	0	2	1
R.C.N.	3	2	6	6	0	0	0	0	0
R.A.N.	4	2	8	8	0	0	0	0	0
Indian Navy	3	12	36	0	24	0	0	0	12
Shivaji	1	1	1	0	0	0	0	0	1
H.M.S. *Mermaid*	1	12	12	0	8	0	0	4	0
	—	—	232	61	99	3	4	26	39

TABLE I(b)—*A.S.R.1 engine builders*

Engine Builder	*Total No. of Engs*	*Type*					
		16 VMS	16 VTS	12 VTS	12 VUS	8 LTS	6 LTS
Chatham Dockyard	41	23	5	1	4	0	8
British Polar Engines Ltd.	50	6	44	0	0	0	0
Vickers Ltd.	69	12	16	2	0	12	27
Peter Brotherhood	26	0	8	0	0	14	4
Cammell Laird	28	20	8	0	0	0	0
Crossley Brothers	20	0	20	0	0	0	0
	234	61	101	3	4	26	39

TABLE I(c)—*A.S.R.1 engines building*

Engine Builder	16 VMS	16 VTS	*Remarks*
British Polar Engines Ltd.	9	2	4 in No. 16 VMS for Chile 4 „ „ „ „ „ Australia 2 „ „ 16 VTS „ India spares 1 „ „ 16 VMS Prototype one-piece-frame and bedplate
Vickers Ltd.	4	0	4 in No. for Brazil

Valenta

The Valenta is fully described in Ref. (3). Briefly, it is the latest engine in Ruston Paxman's range of high-speed diesels; it is specified by the Royal Netherlands Navy for their 1·2 MW diesel generators in their Guided Weapon Frigates, by British Rail for their high-speed train, and by the Royal Navy for the diesel generators in the new cruiser.

Medium-speed Diesel Engines

Since the end of the 1939–45 War, there has been a boom in medium-speed diesel engines for merchant ship propulsion. These are broadly defined as geared engines running at about 500 r.p.m. and which are too heavy or large for overhaul by replacement. They have eaten steadily into both the slow-speed diesel and the steam turbine markets and are continuing to do this as higher powers per cylinder are being achieved.

Many diesel engine manufacturers have produced designs for medium-speed engines, some achieving notable success and others miserable failure. The latter include the firms who put their money on the two-stroke cycle and came up against the problems of high rates of wear of cylinder liners and piston rings, and of high rates of consumption of lubricating oil. Unfortunately one of these designs at an early stage of development was specified for the submarine depot ship (luckily cancelled), was fitted in the first three *Rover* Class tankers (now to be re-engined with Pielsticks), and was nominated for the SYMES range (now deleted).

TABLE II—*S.E.M.T. Pielstick PC engines: Basic data*

Engine type			*PC2 Mk 2*	*PC2 Mk 3*	*PC2 Mk 5*	*PC3*
Cylinder	bore	mm	400	400	400	480
	stroke	mm	460	460	460	520
Maximum continuous output per cylinder		kW	368	393	478	699
		r.p.m.	520	520	520	470
Recommended service output per cylinder		kW	331	354	430	629
		r.p.m.	504	504	504	455
Cylinder arrangements available		In Line	6, 8, 9	6, 8, 9	6, 8, 9	6, 7, 8
		VEE	8, 10, 12, 14, 16, 18	8, 10, 12, 14, 16, 18	12, 14, 16, 18	12, 14, 16, 18
Power range		kW	2208 to 6622	2358 to 7085	2870 to 8609	4194 to 12582

Because of the need to substitute a proven medium-speed diesel engine in the SYMES range, an assessment of all Western European medium-speed engines has recently been carried out; the best buy for military use would seem to be the Pielstick PC series, Ref. (4). Over 1000 of these engines have been sold world wide, including more than 50 for naval applications. It has a high inherent shock resistance because of its fabricated construction and it is made in this country under licence by Crossley-Premier of Manchester (a member of the Amalgamated Power Engineering group). D.F.M.T. is already using this engine in his follow-on *Rover* Class tankers and also for re-engining the first three. It is possible that it may be used in the R.N. for such vessels as Fleet Maintenance Ships and Commando Carriers, and it is being nominated for the SYMES range. TABLE II gives its principal characteristics and FIG. 2 shows its general arrangement.

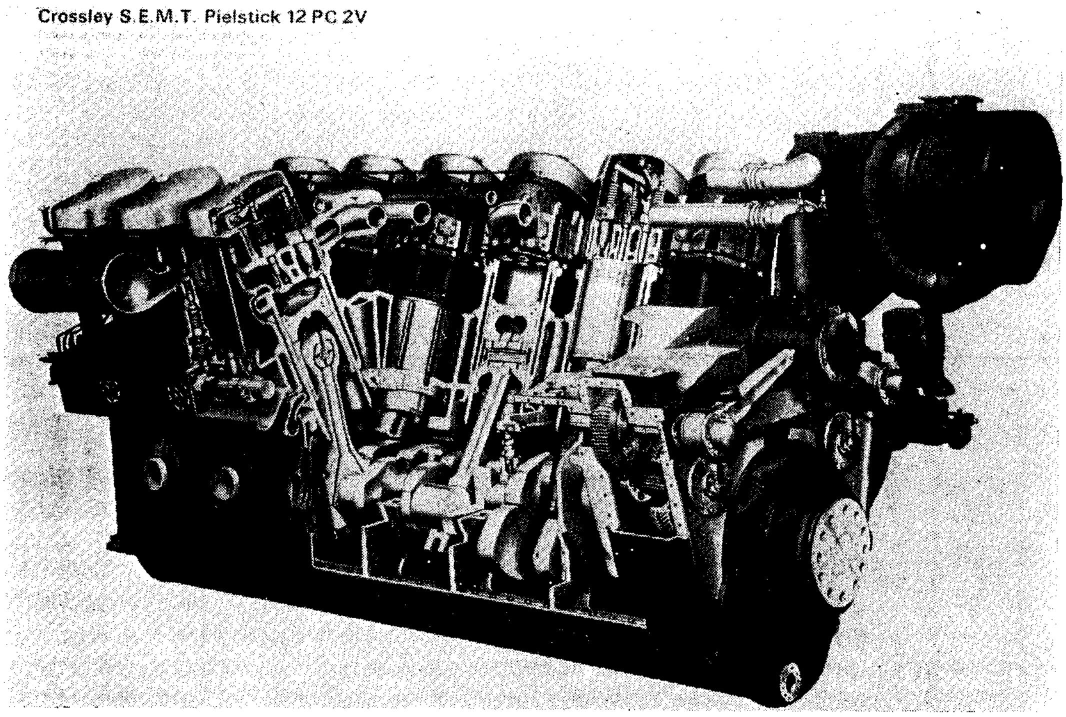

FIG. 2—CROSSLEY S.E.M.T. PIELSTICK 12 PC 2V ENGINE

Diesel Engine Propulsion System Design Guide

A diesel engine propulsion system design guide is being prepared on behalf of the diesel section by Y-ARD, Ref. (5), and the draft is about 30 per cent. complete. It is aimed at PTO III level and is an attempt to lay down a basic system design philosophy so that the optimum system is always specified and obtained. The intention is to publish the approved guide early in 1975.

Ventura

Although the main preoccupation of this group is the Ventura diesel engine, it is also responsible for the earlier Paxman designs which are still in naval use, i.e. the YHA, and RPH models. Altogether it looks after over 700 engines; of these more than 150 are Venturas now replacing the YHAs which have a smaller bore and stroke.

The introduction of the Ventura into naval service was perhaps somewhat precipitate; now, however, after more than 200 modifications it is a fairly well-proven and reliable engine. FIG. 3 shows the number of modifications

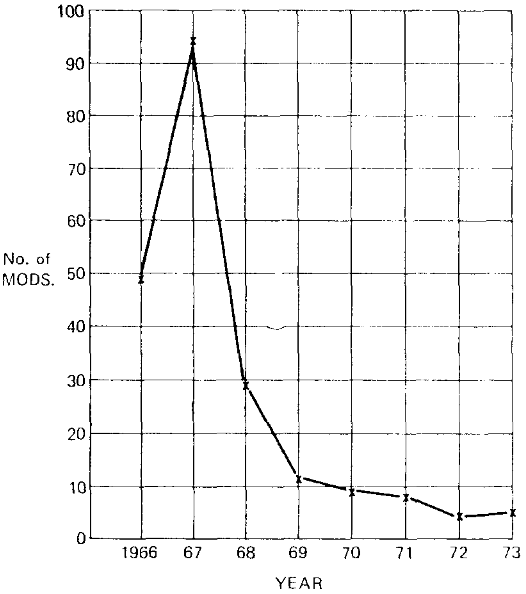

FIG. 3—VENTURA YJ. MODIFICATIONS 1966–73

introduced up to the end of 1973. It is the basis of the SYMES generator range providing the prime mover for the 500 kW, 750 kW and the 1000 kW sets. It is also used for propulsion in the survey ships, the *Seal* and *Bird* Class patrol boats, H.M.S. *Tenacity*, and H.M.S. *Abdiel*.

The more recent ship diesel generator installations, i.e. the Types 21, 42 and 22, have been designed for engine major overhaul by replacement at 12,000 hours (the equivalent of about ½ million miles in a car). Top overhauls, i.e. the refurbishing of turbo-blowers, cylinder heads, fuel pumps, etc., will be carried out *in situ* using replacement kits, the intervals being between 4000 and 6000 hours depending on the operating cycle. Line overhaul of these engines has been established by C.E.D. at Goschen Yard, Devonport, whence top overhaul kits are also supplied. In order to provide C.E.D. with data for their forward planning, the diesel section prepared a forecast of the expected Ventura population; this is shown in FIG. 4. What cannot be shown quantitatively, but nevertheless is just as significant, is the sudden increase in the *importance* of the diesel engine in surface ships. To date, all R.N. surface warships except the Type 41 and 61 frigates have relied predominantly upon their steam turbo-generators for electrical power, the diesel generators being provided mainly as salvage, emergency, or harbour duty sets; in the Types 21, 22 and 42 and in the CAH, the diesel sets will provide the *only* means of generating electricity.

MCMV Non-magnetic Diesel Engines

These were fully described in the most recent issue of the *Journal of Naval Engineering* (Ref. 6). The following, however, is a brief résumé of the work which the diesel section has undertaken. The basic task was to meet stringent equipment magnetic signature targets laid down by the Admiralty Underwater

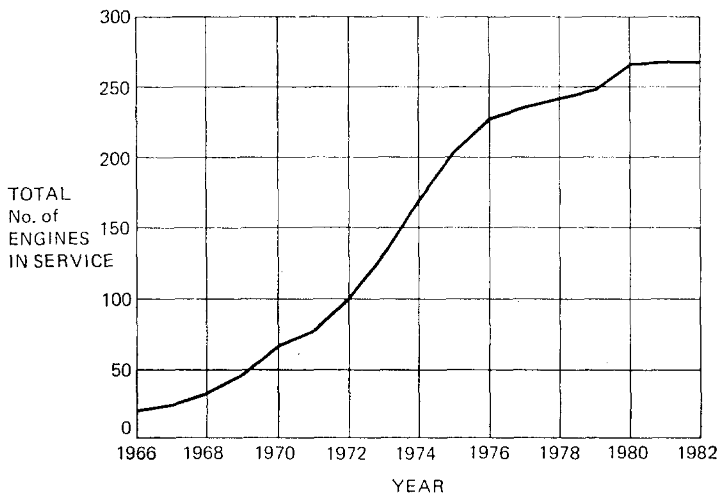

FIG. 4—POPULATION OF VENTURA YJ ENGINES

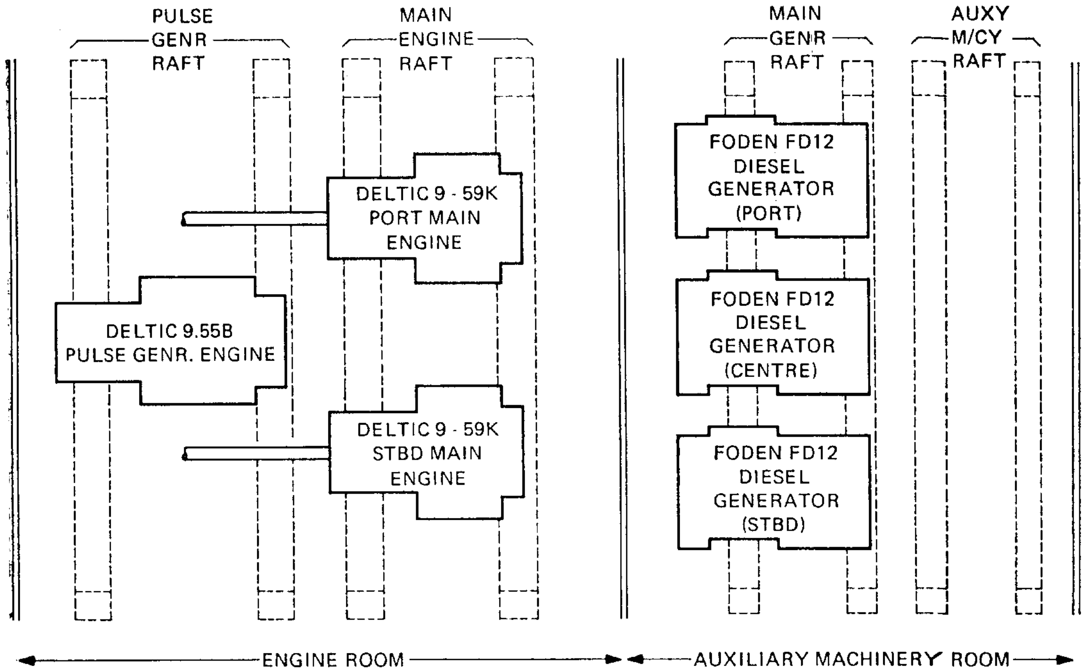

FIG. 5—GENERAL ARRANGEMENT OF DIESEL ENGINES IN THE M.C.M.V.

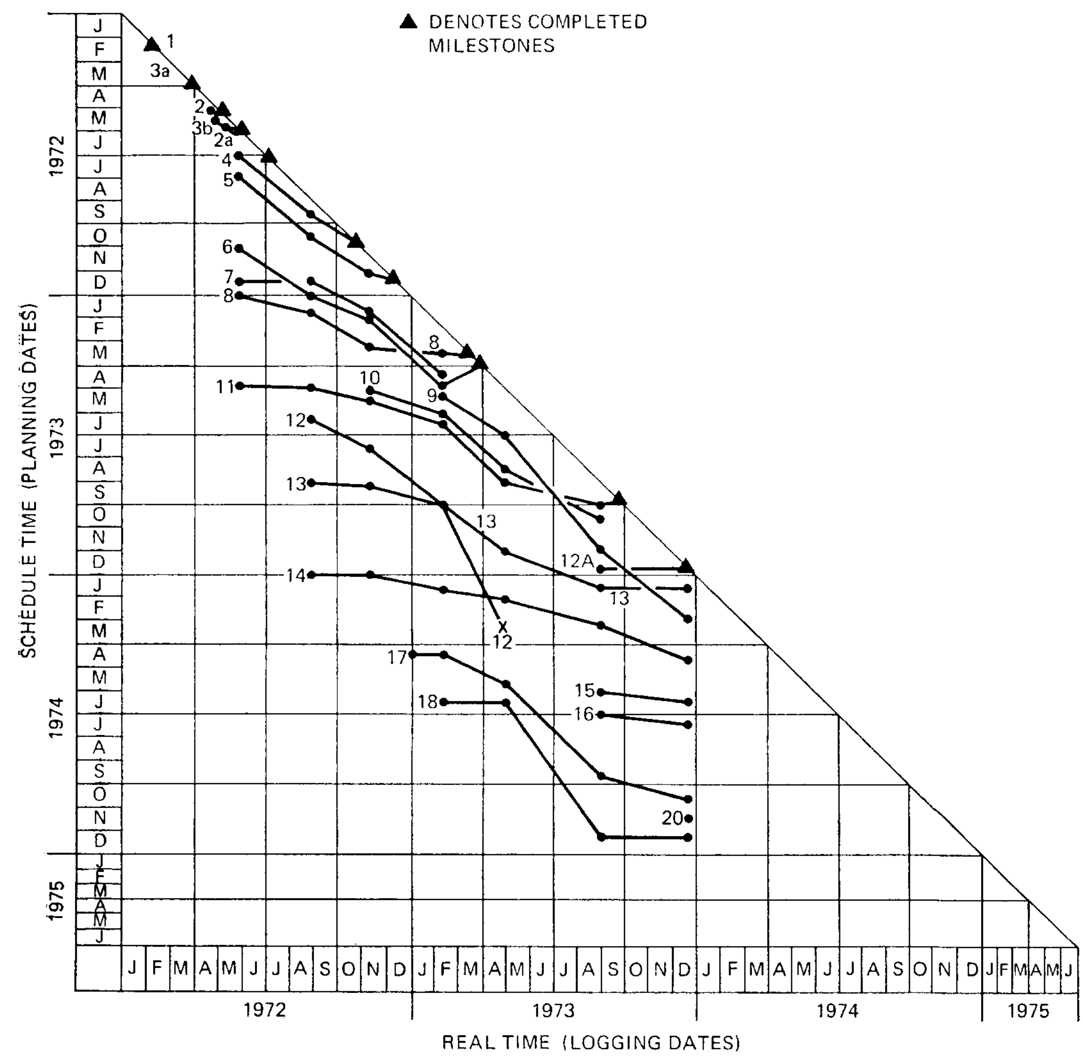

FIG. 6—LOW MAGNETIC SIGNATURE PROTOTYPE DELTIC 9–59K ENGINE

With reference to FIG. 6:

Code

1. Engine delivered to the AEL.
2. Run in, obtain performance loops.
2a. Commence 500 hrs propulsion cycle (6 weeks).
3a. Deliver and range dropped output gearbox.
3b. Non-magnetic gears fitted/gearbox re-ranged.
4. Fit governor and non-magnetic gearbox.
5. Commence testing of new components/evaluate latest build of exhaust system (Ph. II with scrubber).
6. Evaluate engine when simulating low power role of 9-55B prime mover (1400 crpm).
7. Fit 9-55B exhaust manifolds and evaluate latest build of exhaust system (Ph III).
8. Complete 1000 hrs (total) engine testing. Complete draft specification for production engine.
9. Prototype actuator to be fitted (211).
10. Commence unit tests of preferred production standard piston.
11. Complete 1500 hrs (total) engine testing.
12. Evaluate MCMV exhaust system (Ph IV non-magnetic).
12a. Evaluate modified exhaust gas scrubber system.
13. Complete 2000 hrs (total) engine testing. Partial strip to examine pistons and liners.
14. Fit engine No. 9-55B pump/generator set. Evaluate in pulsing role 500 hrs.
15. On completion of 500 hrs, statically range engine/gearbox and pulse generator.
16. Deliver engine to GEC Diesels. Strip and rebuild with A286 oblique ported liners, production pistons. Fit two additional non-magnetic gears to output gearbox.
17. Complete 3000 hrs testing.
18. Fit production standard connecting rods.
19. Maintenance evaluation as convenient.
20. Commence cold start trials.

Reasons for delay in milestone dates:

Aug. 1972

4 and 5. On completion of 500 hrs propulsion cycle, engine returned to RPD Ltd. for partial strip and modifications to con-rods. Programme delayed 3 months.

Nov. 1972

5. Delivery of engine to the AEL delayed due to difficulties with con-rod modifications. Delivery achieved 31 October 1972.

May 1973

9. Delay due to design and manufacturing difficulties.

11. Programme delayed 10 weeks due to detailed examination of non-magnetic components (Con-rods, crankshafts and gears) on completion of 1000 hrs running.

16 and 17. Delays due to revised 9-55B programmes (electrical control equipment modifications).

Sept. 1973

12. Evaluation of MCMV exhaust system in non-magnetic materials (Ph IV) deferred to STF.

9, 10, 17 and 18. Delayed due to inability of manufacturers to meet the required hardware delivery dates.

Dec. 1973

Minor delays to development programme caused by delays in 9-55B hydraulic pump testing.
17. Continued manufacturing delays.

TABLE III—*Deltic special components: Running hours achieved by end of 1973*

Components	*Material/Design*	*Test Engines* Unit engine		No. 360		No. 354		9-59K	
		Hours	No. off	Hours	No. off	Hours	No. off	Hours	No. off
Crankshafts	ARMCO 17-10P	—	—	1070	2	3280	2	2010	3
Connecting Rods	A286	—	—	—	—	640	2	500 2010	5 4
	ARMCO 17-10P	—	—	—	—	640	6	1510	5
Cylinder Liners	Std. Oblique port	3000	1	—	—	1550	9	—	—
	A286 Square port	—	—	—	—	—	—	2010	9
	A286 Oblique port	—	—	—	—	—	—	—	—
Exhaust Piston	Fire ring Mk IVa	4220	1	—	—	2920	12	30	3
	Std. ring Mk IIIc	—	—	—	—	—	—	2010	9
	Std. ring Mk IVa	1360	1	—	—	—	—	—	—
90° Exhaust Manifold (Centre Outlet)	Aluminium Alloy	—	—	—	—	—	—	1200	3
9-59K Gears (Output train)	Phase I ARMCO	—	—	—	—	—	—	1510	3
	Phase II ARMCO	—	—	—	—	—	—	0	2
9-59K Clutch	Bronze	—	—	—	—	—	—	1510*	1
Others:									
Camshafts	A286	—	—	—	—	—	—	2010	3
Flex. Drive Shafts	Monel K	—	—	—	—	—	—	2010	3
Quill Shafts	Monel K	—	—	—	—	—	—	2010	3
Oil Pump Gears	A286	—	—	—	—	—	—	2010	4
Phasing Gear Hubs	A286	—	—	—	—	—	—	2010	3

* In Ahead Drive.

Weapons Establishment; ideally this was to be achieved by the use of materials which were inherently non-magnetic. The reliability of the equipments had at the same time to be maintained. An additional, although in no way minor, requirement was to meet the MCMV's overall noise target.

The equipments which had to be developed by the diesel section were the main propulsion engines, the pulse-generator/hydraulic-transmission engine, and the ship services generators. FIG. 5 shows the arrangement of these engines in the MCMV.

The Deltic propulsion and pulse-generator engines are fundamentally the same. The standard production 9-cylinder engine has a fairly high non-magnetic weight of about 50 per cent. due to its aluminium pistons, cylinder blocks and casings. The aim has been to increase this to 90 per cent. by changing the materials of large components but, as most of these parts are highly stressed and as no dimensions have been altered, the quest for suitable non-magnetic materials has been long and difficult. FIG. 6 illustrates the slippery slope to success and TABLE III shows the number of running hours achieved by non-magnetic components at the end of 1973; these include more than 2000 hours of prototype engine running.

Endurance testing is continuing, the aim being to achieve at least 4000 hours on the prototype engine. This running is now overlapping the production order for the first ship sets, but it is confidently felt, based on the knowledge acquired to date, that these first production engines will perform reliably in service and will meet the magnetic signature target levels.

The prime mover for the pulse generator set is the same as that for the propulsion engines and therefore most of the development effort has been expended on the electrical end, i.e. the pulse generator and its control system. Considerable attention also is now being given to the various hydraulic transmission systems associated with this multi-purpose centre engine. These comprise a slow-speed ship drive, a bow thruster drive, and a supply to miscellaneous deck and sweep services. Although none of these is its direct responsibility, the Diesel Section is concerned with the gearbox which drives these four hydraulic pumps and with the performance and life of the engine when subjected to the various loads and operating patterns imposed by the hydraulic and pulsing systems; trials to evaluate these aspects are in hand at the AEL.

The other MCMV diesel engine is the Foden FD 12 Mk. VII which drives the 200 kW generator; three of these are now to be fitted. Much of the basic non-magnetic material philosophy reads across from the Deltic to the Foden. However, although the Foden is a two-stroke engine, it does not use opposed pistons and a major problem to date has been to develop a satisfactory non-magnetic cylinder head. As this is still unresolved, it appears at present very likely that the first production engines will have cast-iron heads using dipole magnets, if and where possible, to reduce some of the permanent magnetism. When a suitable non-magnetic head is developed, it will be easy to modify any installed engines.

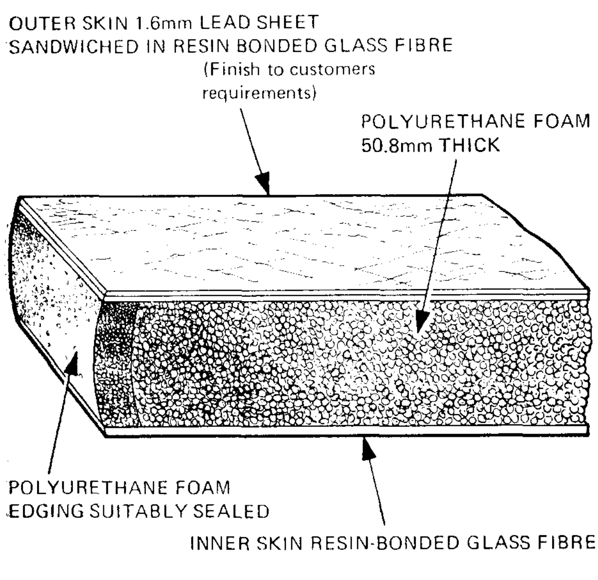

FIG. 7—CROSS-SECTION OF CLADDING MATERIAL

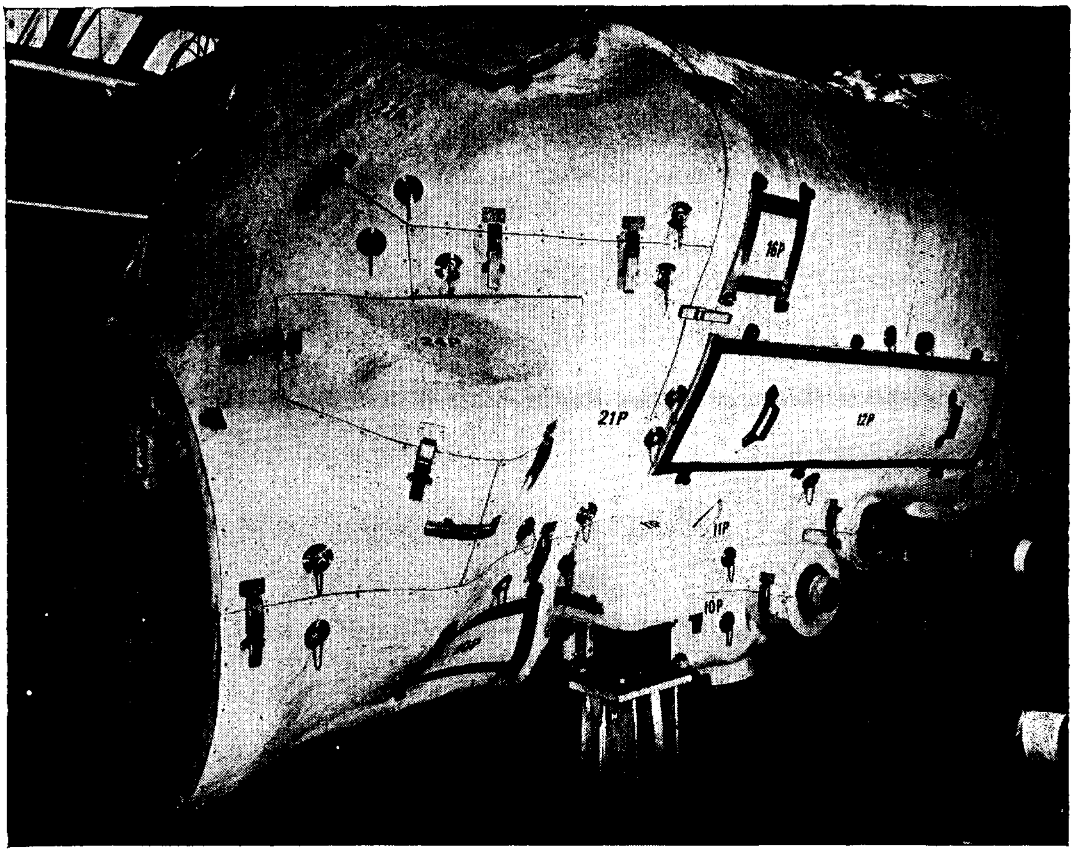

FIG. 8—CLAD DELTIC ENGINE

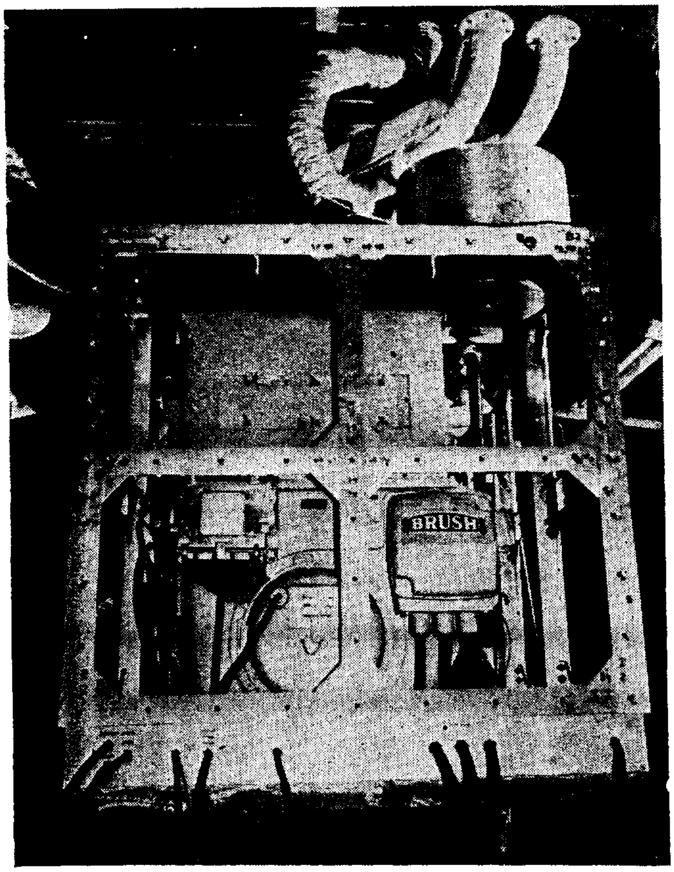

FIG. 9—ACOUSTIC HOOD FOR FODEN MODULE

Noise

Another requirement of the MCMV which has received the attention of the diesel section during the past few years has been noise attenuation. By virtue of their own shock and vibration mounts and the machinery rafts, each diesel engine has a double-mounting system which will give good attenuation of structure-borne noise; the more difficult problem is the attenuation of air-borne noise. For the Deltic engines this is being achieved using cladding. In cross-section this overcoat comprises fibreglass-lead-fibreglass/foam/fibreglass and constitutes a classical spring/mass system (FIG. 7). A clad Deltic engine is shown in FIG. 8.

For the Foden modules, acoustic hoods are being developed. The aluminium

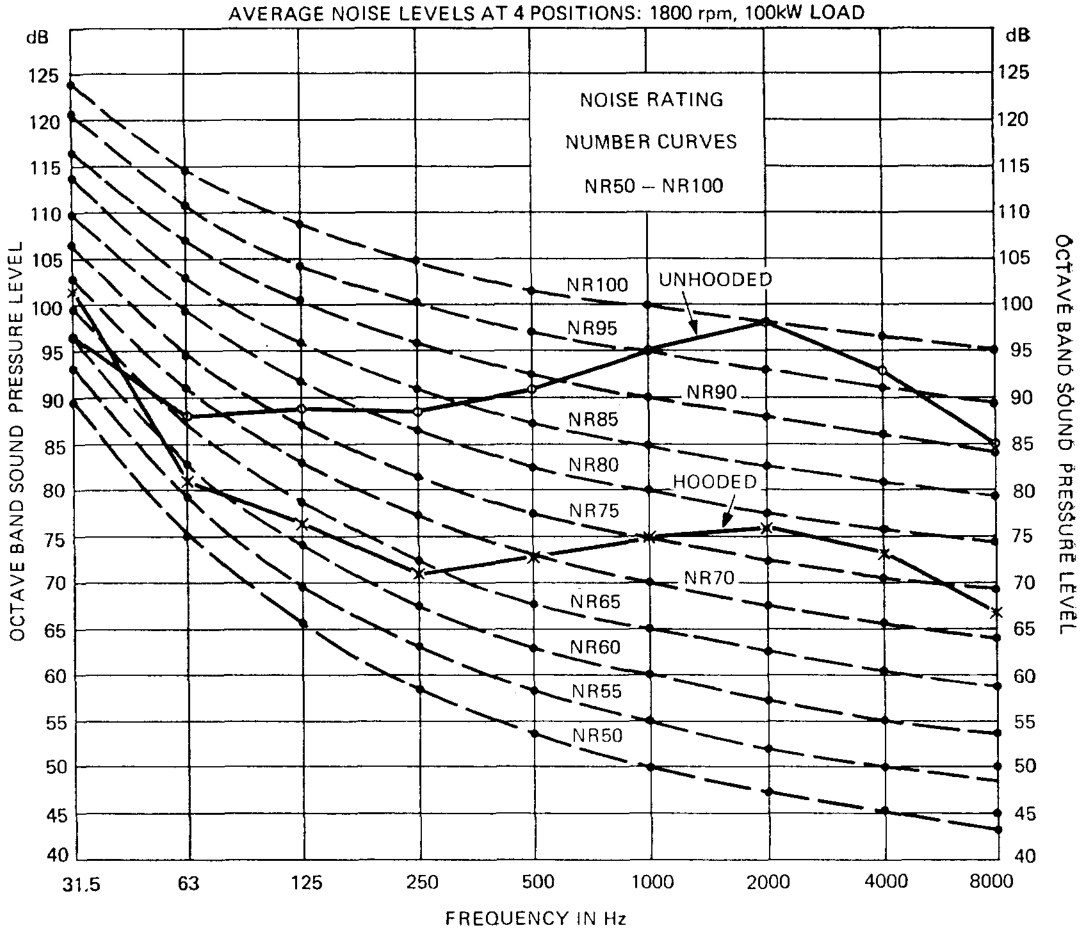

FIG. 10—FODEN 200 kW MODULE: NOISE ATTENUATION

framework for these is clearly shown in FIG 9. Fixed to this frame are panels which in cross-section comprise $\frac{1}{8}$-in. aluminium/$\frac{1}{8}$-in. epoxide resin damping compound/$\frac{1}{8}$-in. aluminium/plus, on the inner surface, rock wool and perforated metal. The hood together with the $1\frac{1}{2}$-in. thick cast aluminium sub-frame entirely encloses the engine and generator. The noise attenuation obtained is shown in FIG. 10.

Other Activities

Besides the foregoing, there are over 2000 engines of ten different makes euphemistically classified as 'Deltics and engines below 6-in. bore' which give rise to the normal gamut of problems which stem from running equipments.

Other activities which have been dealt with during the last few years by the diesel section include:

(*a*) the preparation of a diesel engine policy paper;

(*b*) work on IR suppression using water curtain techniques;

(*c*) development of an ultra-sonic device for the atomization of Avcat for use with outboard motors, so that petrol can be eliminated from ships;

(*d*) investigations into the feasibility of a mechanically supercharged Valenta for possible use in new conventional submarines.

Project Leadership

As well as collaboration with European and Commonwealth navies and committee work, much time has been occupied with project leadership in the planning, finance and carrying through of new projects. For both the MCMV non-magnetic engine projects and the prototype Valenta project, large sums of development money have been involved together with a variety of contracts and contractors, and as well as the normal technical problems there have been other issues arising from industrial re-organization.

The imposition of rigorous disciplines on both the section and others has resulted in the majority of milestones being achieved to both price and (relative to the first of class) to programme. Firm and informed project leadership, controlling both finance and technology, is a vital adjunct to the timely achievement of a technical goal.

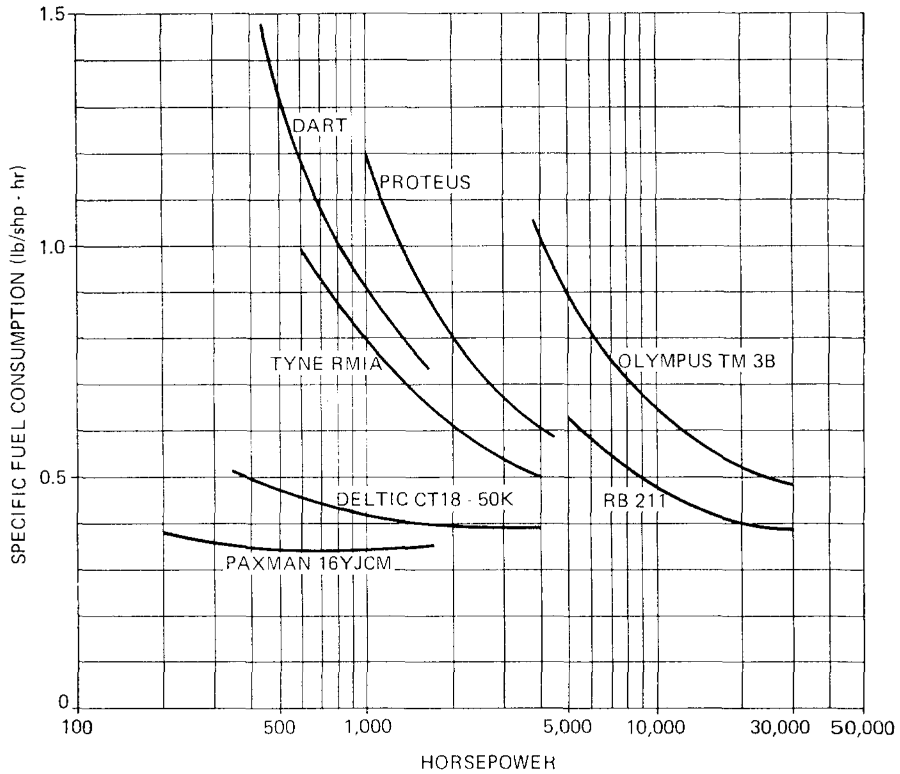

FIG. 11—COMPARISON OF SPECIFIC FUEL CONSUMPTION OF VARIOUS PROPULSION POWER PLANTS

The Energy Crisis

Although the diesel engine has been with us for more than eighty years it is still probably the most efficient means in current production of converting fossil fuel into usable power. Its specific fuel consumption is about 0·35 pounds per brake horsepower-hour and this is surprisingly constant over the power range. FIG. 11 compares various propulsion engines. Thus, until alternative energy sources are available, there may well be a partial return to diesel engines for the main propulsion of small warships and the cruise propulsion of larger ones, and so a need to place an even greater reliance on diesel engines in the future.

References:

1. Sampson, W. H., 'History of the A.S.R.1', *Journal of Naval Engineering*, Vol. 9, No. 1. p. 56.
2. Sampson, W. H., 'Experiences with A.S.R.1. Engines', *Journal of Naval Engineering*, Vol. 10, No. 2, p. 211.
3. Griffey, M. F., 'The Ruston Paxman RP 200 Valenta', *Journal of Naval Engineering*, Vol. 21, No. 1, p. 77.
4. Y.335., 'Assessment of Medium-speed Diesel Engines for Naval Ship Propulsion'.
5. Y.355., 'Propulsion Machinery: Diesel Engine System Design Guide'.
6. Blackman, Lt.-Cdr. R. S., 'Development of Non-magnetic Diesel Engines', *Journal of Naval Engineering*, Vol. 21, No. 2, p. 210.