EXPERIENCE WITH A.S.R.I. ENGINES

BY

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An article on the origin and development of the A.S.R.I. engine appeared in the *Journal* in January, 1956 (Vol. 9, No. 1). It is now possible to give further details of the performance of the prototype and to give some information about the production engines. Since 1949 when the prototype was completed, the engine has been built in various forms ranging from the 16-cylinder ' V ' turbo supercharged model of 2,200 b.h.p. to the 6-cylinder in-line turbo supercharged version of 540 b.h.p. nominal output. Over 220 engines have been ordered by the Admiralty and 95 of these have been completed. By June, 1956, the running hours of production engines on trials and in service have totalled 17,000 for ' V ' engines and 19,000 for in-line engines.

PROTOTYPE ENGINE

This 16-cylinder engine was built at Chatham Dockyard and, during its construction, suitable manufacturing techniques were developed which were used as a basis for the preparation of the working drawings for the production engines. It was completed in 1949 in the unsupercharged form and ran for about 400 hours at varying ratings up to 90 lb/sq in b.m.e.p. Converted to turbo supercharge, it ran for 1,200 hours at varying ratings up to 137 lb/sq in b.m.e.p. at 920 r.p.m. (2,000 b.h.p.).

After some hundreds of hours running, the whitemetal large-end bearings failed. These bearings were medium thickness steel shells, whitemetal lined. A new design incorporating a marine type large-end fork rod block with 0·040 in. whitemetal was tried but this failed after 157 hours. The design was reconsidered and, after consultations with other engine builders and the bearing manufacturers, it was decided to fit copper-lead loose shell fork rod bearings with a more closely toleranced large-end block, which permitted a more controlled nip. Phosphor bronze shells with approximately 0·001 in. of lead flash were fitted to the blade rod bearings. The engine then carried out a non-stop endurance run, on a daily cycle, at powers ranging from 190 to 2,000 b.h.p. and speeds up to 920 r.p.m. The run was terminated after 750 hours by the failure of a liner flange. The bearings, however, were found to be in an excellent condition and the En. 12 crankshaft (B.H.N. 200) showed no measurable wear. The whitemetal main bearings, originally fitted when the engine was first built, were still in good condition at the end of this trial.

It was decided to adopt the new design large-end bearings and also, from a maintenance point of view and not because of failure, to change to copper-lead main bearings. It was realized that to obtain the maximum benefit from the change to a harder bearing, a better crankshaft material was necessary. After consultations with the Federated Forgemasters, a normalized 0·5–0·55 per cent carbon-chrome-molybdenum steel with a minimum B.H.N. of 250 was adopted for all production engines after the first thirty-two. Except for the first crankshaft (En. 12) for the prototype, all A.S.R.I. crankshafts have been supplied in the normalized form. This was at the request of the forgemasters after difficulty had been experienced during the hardening and tempering of the first shaft. The shaft was bent during heat treatment and subsequently cold straightened with the result that it was unstable during the finish machining and eventually had to have a stabilizing treatment.

The bearing trials did show that it was beneficial to use whitemetal bearings for the initial running in of a new engine and it was decided to adopt this procedure on all the production engines. Experience has shown the wisdom of this as some trouble has been experienced with dirt in oil systems and the whitemetal bearings have saved scoring the crankpins and journals.

The engine was stripped and a complete dimensional check carried out. Liner wear after 1,650 hours of varied running was less than 0·001 in. on the diameter. In view of the flange failure a new type of cylinder head joint was adopted which reduced the bending stress on the flange. The backs of a number of liners showed appreciable corrosion and this problem is still under investigation at the A.E.L. Various metallic coatings applied by electro-deposition and metal spraying are under trial and nickel followed by chromium plating with a corrosion inhibitor in the cooling water has given the best results so far.

The prototype engine was rebuilt and fitted with engine-driven Roots type supercharger. A new En. 29 normalized steel crankshaft (purchased as a spare in the event of failure of the original shaft) slave whitemetal fork rod large-end bearings and the old whitemetal main bearings were fitted and the engine was then transferred to the A.E.L. for further development. This has mainly been concentrated on submarine applications but, lately, further turbo supercharge running has been done.

SOME A.E.L. EXPERIENCE

Hours Run	
Mechanically supercharged ..	1,340
Normally aspirated	344
Turbo supercharged	250
Total Hours Run ..	1,934

Mechanically supercharged and normally aspirated ratings of the engine for the submarine application are :—

Mechanically supercharged	750 *r.p.m.*	920 *r.p.m.*
Surface b.h.p.	1,500	1,840
Snort b.h.p.	1,225	1,500
Normally aspirated; surface b.h.p.	1,150	1,400

At the A.E.L., the engine ran daily on experimental work, usually on loop curve tests at selected speeds within the range 500 to 920 r.p.m., most of the running being at 750 and 920 r.p.m.

Mechanical Condition

During stoppages for change of equipment, change of build, etc., the opportunity was taken to inspect and gauge bearings, pistons, liners, etc. and, generally, the results gave very little cause for alarm. The lead flashing was still intact on the fork-rod large-end bearing shells after 2,350 hours running which included the 750 hours at Chatham and a change of crankshaft. The crankpins showed less than 0·001 in. average wear after 1,650 hours. The original whitemetal main bearings were still serviceable after a total of 3,500 hours.

Liner wear was less than 0·001 in. on diameter at the top after 1,700 hours running at the A.E.L., the pistons showed no measurable wear in the ring grooves and the top ring gaps had increased about 0·015 in. on the average. One gudgeon pin cracked after 3,300 hours running.

6 L.T.S. Engines

The A.E.L. has installed a 6 L.T.S. engine which was used, until a 6 L.T.S. generating set was available, on generator governor development. It has been used since for turbo supercharge development running. Experience to date is as follows:—

Total Hours run—1,000.

Ratings

With existing turbo supercharger, 160 lb/sq in b.m.e.p. at 900 r.p.m. Fitted with a 2/1 ratio turbo supercharger, the engine has run at 200 lb/sq in b.m.e.p., 920 r.p.m., which is equivalent to an output of 1,100 b.h.p.

Bearings

The centre main bearing had wiped before the engine was received at the A.E.L., where it was replaced. It was later necessary to replace this new bearing and No. 6. The trouble with these bearings was accompanied by severe fretting of the centre bearing cap face. The same trouble was experienced in some of the earlier 6 L.T.S. production engines, but increasing the tightening torque on the main bearing bolts seems to have cured the trouble.

The slave whitemetal large-end bearings fitted to the engine when received at the A.E.L. have been retained and on examination after 1,230 hours running were in a reasonable condition apart from scratches.

The engine had a general strip after 1,230 hours running and liners and pistons were all in good condition showing negligible wear. It is interesting to note that the backs of the liners showed no sign of water-side attack. Exhaust valve seats were pitted and were ground in : all valves were free in the guides.

6 L.T.S. 360 kW. Generating Set

This was a production set intended for a frigate, but it was transferred to the A.E.L. for governor development work because of the failure of the original hydraulic generator governor to govern both D.C. and A.C. sets to the specified limits. This engine has run for more than 750 hours during this development work and three different types of governor have been tested. The A.E.L. also type tested at least 30 production governors, for generating sets for H.M.S. *Vidal* and frigates, on this engine.

H.M.S. 'VIDAL'

This ship is fitted with four 12 V.U.S. propelling engines and four 6 L.T.S. 360 kW. D.C. generating sets. These engines were built at Chatham and all underwent a good deal of running on brakes in the shop to prove gearboxes and for electrical trials. *Vidal* commissioned in 1954 and after three commissions the engine running hours were :—

Engine		*Hours*
12 V.U.S.	No. 1 ..	2,960
	No. 2 ..	5,100
	No. 3 ..	3,700
	No. 4 ..	2,100
6 L.T.S.	each set ..	3,600–4,900

The following failures occurred during the first two commissions :—

(*a*) Some four or five cases of cylinder head joint leaks during the first commission. As a result, the joint external diameter was reduced to avoid the danger of joint trapping and the cylinder head tightening torque was increased. Since this modification, no further trouble has been experienced.

(*b*) Some supercharger and inlet valve fouling on the 6 L.T.S. engines. The supercharger fouling was undoubtedly due to a lot of light-load running and it is very likely that the valve trouble is due to the same cause.

(*c*) Failure of a small number of components, including two air start valves, 4 feed pump seizures, 4 fuel pump springs, 10 injectors with stuck needles and 1 blade rod bearing shell cracked. This shell was probably already cracked when fitted.

PRODUCTION ENGINES

In addition to *Vidal's* engines, the following models have been ordered :—

16 V.T.S. for propulsion of *Salisbury* and *Leopard* Class frigates.
6 L.T.S. and 8 L.T.S. for generating sets for the above frigates.
16 V.M.S. for Diesel-electric drive of *Porpoise* Class submarines.
12 V.T.S. for propulsion of an ocean tug.

16 V.T.S. Engines

Sixteen of these were ordered at the same time as the engines for *Vidal* and they were well in hand before much experience had been gained with the turbo supercharged prototype. As a result, modifications were incorporated in them during building.

' Running in ' is done with the whitemetal bearings fitted, but the copper-lead bearings are fitted for the official trials. It is of interest, from the interchangeability point of view, that the same whitemetal slave bearings are used on as many as four engines before the mains are sent back to the suppliers for re-metalling and re-machining.

The only serious troubles have been with governors and connecting rods. Originally a Bryce Berger Mark I hydraulic governor was specified but, as for *Vidal's* 12 V.U.S. engines, these did not prove reliable and a Mark II design with an improved rubber drive has been tested and, to date, has been satisfactory. The connecting rod problem has been tied up with drop-forging tolerances, heat treatment and machining inaccuracies and has involved the removal for examination of a very large number of rods from completed engines. The problem is still under investigation.

Other 16 V.T.S. failures include valve and fuel pump springs, three large-end bearings, fuel pump seizures and a number of valve gear components. The spring failures were all due to bad springs and the design and material specifications have been tightened to obviate this. Two of the large-end bearing failures were with whitemetal slave bearings fitted and were due to drillings left in oil holes and the incorrect drilling of an oilway. The third occurred during a trial omitting the initial running-in on the slave bearings and, although the actual cause of failure could not be ascertained, it was believed to be due to cuttings left in the shaft. A more thorough inspection of crankshaft oilways and oilways generally has been instituted and no further failures have occurred.

Some of the fuel pump seizures have been due to badly made springs but the reasons for the others are obscure. They appear to be connected with running-in, as a liberal application of lubricating oil to the new plungers and provision of grooves in the plungers has apparently solved this problem, after over 18 months investigation into the geometry of the operating gear.

The valve gear component failures were similar to those on the prototype engine and engines for *Vidal* and were on items that are now obsolete.

6 L.T.S. and 8 L.T.S. Engines

These drive 360 kW. and 500 kW. A.C. generators at 720 r.p.m. and the main difficulty has been in governing. Relaxations in the electrical requirements have allowed the temporary use of a mechanical type governor. An entirely new governor is being developed and has been satisfactorily tested at the A.E.L. It will be fitted for trials in a ship shortly.

16 V.M.S. Engines

These are flange mounted 1,250 kW. generating sets for submarines. They are fitted with engine driven superchargers which on the first twelve engines will be of the Roots type, the remaining engines will have centrifugal type superchargers which, it is hoped, will be quieter and more efficient than the Roots. In view of the complexity and the need to ensure that the designs of the supercharger gear train, generator oil sealings, etc., were sound, it was specified that one of the first sets would undergo a 1,000-hour endurance trial during which the opportunity would be taken to check interchangeability by replacing a number of liners, pistons, connecting rods and bearings.

In the mechanically supercharged version of the prototype engine, the superchargers were driven off the camshaft drive which necessitated the use of hardened and ground gears. This gear train gave no trouble during over 1,300 hours of running at the A.E.L. When the production engines were ordered, it was decided to fit a separate supercharger gear drive train using wider hardened and tempered gears, which was not possible in the camshaft drive train. This was done to avoid production difficulties with the supply of hardened and ground gears. The modified arrangement has given a lot of trouble during the 1,000-hour trial owing to a vibration problem which has proved extremely difficult to solve. Trouble has also occurred with the oil sealing between the engine and generator and they have had to be separated by six inches so that more effective sealing arrangements can be fitted.

GENERAL

The prototype engine served a very useful purpose, even though its completion was delayed for over a year, and by the time it was producing useful data the first flight of production engines was well in hand. Looking back, it is a pity a number of prototype engines were not built and that the overall responsibility for the design and development was not carried out under one roof. Development of a range of engines for a variety of duties on one prototype 16-cylinder model with the staff dealing with the design working in Chatham, the A.E.L. and at Bath was not, as it turned out, a very efficient way of doing the job because it resulted in a number of serious delays.

This can be seen when progress on this engine is compared with that on its commercial competitors. On two of these, work started well after that on the A.S.R.I., yet they passed the Admiralty engine in development and went into service well ahead of it. They had the advantage that design, development and production were all carried out under one roof and, if the need arose, a major decision could be made, or an order placed, in a very short time.

However, the Admiralty method, while slower, has been more thorough and the early decision to scrap anything that showed up to be at all unreliable should, in the end, prove sound and give the Navy a Diesel engine which, from the maintenance point of view, should be the equal, if not the better, of its competitors.