THE ADMIRALTY ENGINEERING LABORATORY

BY

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INTRODUCTION

I had never visited the Admiralty Engineering Laboratory until I drove up to take over as Superintendent. When I got inside I was astonished to find what a wide field was covered by the work done there. I am sure that my ignorance was by no means unique among engineer officers, and it is in an effort to bring a knowledge of the work done to a wider circle that this article is written.

Because the scope of the work done here is not appreciated, I am quite certain that the brains and experience of the men in the laboratory are not used by the officers in the Engineer-in-Chief's Department nearly as much as they should be, in answering the day-to-day questions on which a decision has to be made. It is for that reason that I have always welcomed visitors to the laboratory so that these visitors can get to know the men on the various jobs and whom to contact here to assist with their problems.

Engines are noisy and there have been many complaints from the neighbours. There has been a deputation headed by the local M.P., and there have been questions in the House. In fact, an atmosphere in which proposals were likely to receive favourable consideration was created by ' outside authority ', a grace seldom bestowed upon a naval officer. Such an opportunity was not ignored. Work on the buildings will start this year.

The laboratory is like Topsy—it has just growed. Circulating pumps are scattered all over the yard, having been put in to suit some special engine or experiment and then connected up in the best way possible to the general system ; there has never been enough money for any overall plan to develop the place on a long-term policy. This is one of the inherent weaknesses of the system of administering the Navy as a whole by annual votes. The new layout will provide separate cells for each individual engine, with sound-proof control cabinets, proper inlet and exhaust silencers and a centralized pumping system. Apart from greater efficiency, working conditions will be improved and this may assist in recruitment of mechanics.

HISTORY

There are really two laboratories within the four walls—E.-in-C.'s and D.E.E's. This paper will, however, deal only with that part which is the concern of E.-in-C., though it might be mentioned that the Superintendent is responsible for the administration, though not the work, of the electrical laboratory.

The history of Engineer-in-Chief's laboratory starts in 1917 when, as a result of a recommendation of the Board of Invention and Research, the A.E.L. was set up at the City and Guilds Engineering College, South Kensington. The main object of the laboratory was to design and develop Diesel engines for submarines which, at that time, was a monopoly of Vickers Armstrong. After the First World War, there was no longer room for the laboratory at South Kensington and it was moved to temporary premises, which were available at West Drayton, until suitable permanent premises could be found. All the technical officers and laboratory mechanics are members of the R.N.S.S., the total number being about 180. Continuity is also fairly well looked after as five of the present staff served at South Kensington, and many officers have been here twenty years or more. Needless to say the laboratory is under-staffed but, as Superintendent, one gets used to running up against ceiling figures. One of the chief difficulties is the recruitment of laboratory mechanics, a reason for which is low pay in a highly industrialized area. The only technical people who are not on C.R.N.S.S.'s staff, are the fifteen draughtsmen who are borne on E.-in-C.'s books.

The laboratory started with a small mechanical engineering design and testing section employed solely on I.C. engines, but as the years went by normal expansion took place. A small metallurgical section was set up in 1919 to investigate problems connected with new materials, those arising in the Service and in the course of the development work in the laboratory. In 1937, work was started on electronic indicating equipment for measuring pressures, temperatures, vibrations, strains, etc., and this resulted in the establishment of a physics section in 1938, to expand and expedite work on this subject. In 1942, the gas turbine section was started to investigate the possibility of developing gas turbines for naval service. This in no way competes with the N.G.T.E. for, though it has never been laid down, work is confined roughly to engines of less than 500 h.p.

Noise and vibration reduction has always been one of the more important objectives and, at the end of 1950, it was decided to set up another section to deal with this problem. This section is now the Engineer-in-Chief's main centre for all work on noise and vibration in I.C. engines and gas turbines. The facilities of this section will be greatly improved when the new ' noise building ' is brought into operation this year.

From 1944–54 there was a gunmounting section run by a lieutenant-commander O/E, responsible direct to D.N.O. and, although it was manned by men for whom the Superintendent was responsible and all the facilities of the laboratory were used by it, he did not know what work was going on. This did not seem a very sensible arrangement so, with the concurrence of D.N.O., it has now become another of E.-in-C.'s sections with a bias towards work for D.N.O. Its primary function is testing small hydraulic pumps, flexible hoses, seals and packings of all kinds.

The oil section of A.E.L. is eight miles away from the main laboratory, at Brentford. The work on fuels and lubricants formerly done by the Chemical Department at Portsmouth, the A.E.L., and the A.F.E.S., is now concentrated there. The original intention was to build a new oil laboratory at the A.E.L. but the cost of the buildings, over £200,000, and the time it would have taken to build made this impracticable. From an administrative point of view, however, it is a thousand pities that the first scheme for a new building at A.E.L. did not go through.

This, then, is how the laboratory is divided up today and, as can be seen, it deals with neither steam nor H.T.P. machinery.

WORK UNDERTAKEN

Piston Engine Section

This section has been operating since the formation of the A.E.L. and is concerned with the design and development of Diesel engines suitable for the Service. Until the middle 'thirties, the section was almost entirely employed on submarine engine development, but since then the scope has broadened to include surface ship and small craft applications. Most of the development work has been carried out on single cylinder units, many of them being designed at the A.E.L. These units covered practically all the known forms of Diesel engine and included 2- and 4-stroke, single and double acting, and sleeve valve engines. Although many of the units may be regarded as unsuccessful in that they did not lead directly to successful Service engines, much valuable experience was accumulated. The first engine to be installed, the Unit, was a single cylinder slice of a Vickers ' E ' Class submarine engine. Its bore was 14½ in and stroke 15 in, the injection system being Vickers common rail, solid injection. Tests on this unit led to improvements in combustion and advances in component design, notably of pistons. The lessons learnt were incorporated in a complete re-design of the unit, only the original bedplate and crankshaft being retained. Intensive testing proved the soundness of the design which was adopted for the ' S ' Class submarines.

A somewhat larger single cylinder engine of similar design, the Dimit (17½ in × 18 in), was installed and tested at the laboratory, this engine in its production form being the ' T ' and ' A ' Class main engines.

Experience with the Digit, a blast-injection single cylinder engine, 20 in bore × 20 in stroke, led to the design of the X1 engines and later the ' O ', ' P ' and ' R ' Class. The Digit was later converted to accommodate a supercharged

$21\frac{1}{2}$ in bore cylinder. The data for the design of the *Thames* Class engines was obtained from the results of testing this converted unit.

The latest Service engines to be designed as a result of unit development at the A.E.L. are the A.S.R.1 series. Before the last war a ' V ' twin-cylinder unit, the Scovic, and a 16-cylinder ' V ' engine, the Muscovic, were designed by the A.E.L. and installed for testing. These engines were $9\frac{3}{4}$ in bore by $10\frac{1}{2}$ in stroke and used the Ricardo Comet Mark III combustion system. The war stopped development but, later, both were converted to direct injection and eventually provided the complete data for the design of the production A.S.R.1 engines.

Among those experimental engines which did not lead directly to new designs, but which were nevertheless of great interest, were the Datic and Maric. The Datic was the laboratory's largest ' unit ' engine and was proposed as the propulsion machinery for cruisers. It was a double-acting, two-cycle blast injection engine 25 in bore by 25 in stroke. Loop scavenge was employed and the engine was supercharged through a set of valve controlled ports above the scavenge ports. Scavenge air and supercharge air were supplied by two double-acting reciprocating pumps on each side of the power cylinder. Reversing gear was incorporated in the design. At 250 r.p.m., 120 m.e.p. was obtained with clear exhaust but at the designed speed of 350 r.p.m. results were somewhat disappointing.

The Maric, $8\frac{1}{2}$ in bore by $9\frac{1}{4}$ in stroke, was a 4-cycle, sleeve valve, jerk injection 14-cylinder radial engine. A single unit and one bank (7 cylinders) of the complete engine were operated, but although the design showed considerable promise, piston ring and head ring sticking and big-end failures on the radial caused the project to be abandoned.

Some years were spent on the development of free-piston gas generators of the Pescara type but this experiment was dropped before success was achieved.

Type Testing

About 1936, the laboratory began to type test those small commercial engines which might prove suitable for naval use and the following procedure was adopted :—

(*a*) The engine was run on a test bed to check the maker's test figures

(*b*) It was then stripped for examination and measurement

(*c*) Tests were run at all loads, up to safe maximum, at several speeds throughout the speed range. The results were plotted as a series of constant speed ' loop ' curves giving fuel consumption, exhaust temperature and state against brake mean pressure

(*d*) From these characteristics and the general observations made while running, the engine was given an Admiralty Test Rating (A.T.R.)

(*e*) A short endurance trial was then run consisting of 72 hours at 95 per cent A.T.R., 12 hours at 100 per cent A.T.R. and 2 hours at 110 per cent A.T.R.

(*f*) The engine was again stripped, examined and measured and a report was made out.

For the first ten years or so, this was the complete type test and it was a very satisfactory way of determining the potentiality of an engine and revealed many major weaknesses. Nowadays, the test outlined above is known as Part I of the type test and is used only to determine the possible suitability of an engine for a particular service. Selected engines are now subjected to further testing.

Part II takes care of certain special tests such as governor trials, gearbox tests, etc.

Part III consists of long-endurance running, usually 1,000 or 2,000 hours, on a load-cycle simulating Service conditions. These tests are usually run continuously, except for a weekend shut-down, the engines running unattended during the night, protected by shut-down panels which operate when safe working conditions of temperature, pressure and speed are exceeded.

The section has at the present time a full programme, but staff limitations and change of policy divert effort from the longer term development items in favour of *ad hoc* problems. This is to be regretted as the most important work of the section has always been its development programme.

A considerable part of available test bed space is devoted to A.S.R.1 engines. Three single-cylinder units are available. One of these is at present being used for an intensive investigation on the water side attack of liners, which is known to be very serious under certain conditions. On the other units investigation into combustion and supercharge problems is being pursued. Already b.m.e.p.s in excess of 200 lb/sq in have been reached. A six-cylinder turbo-blown A.S.R.1 is being used for development. A high pressure Napier turbo blower is fitted and experiments are in progress which indicate that when the matching is finalized and various minor design changes are incorporated in the engine, a b.m.e.p. of 200 lb/sq in should be achieved at full speed (920 r.p.m.).

The 16-cylinder prototype A.S.R.1 was installed after it had been type tested at Chatham in the turbo blown form. The engine, after a long programme of tests at the A.E.L. in its mechanically blown form, is now re-converted to turbo blowing and is being used for *ad hoc* testing. At the moment, flexible-plate couplings, similar to those fitted in *Vidal* and coastal minesweepers, are being endurance tested. A standard 6 LTS alternator set is being used for governor tests and development.

Type testing has rather changed in character since the number and type of commercial engine has been reduced. Generally speaking, the tests are confined to Part III under definite Service conditions. The 12-cylinder Paxman YHA recently completed 1,000 hours on an inshore minesweeper rating and will shortly be tested in a modified form at higher outputs. Other engines being subjected to endurance running are Foden FD6 and FD12, Coventry KF Mark II, Rolls Royce C60 and Perkins P6. Cold starting is being investigated on an Enfield twin-cylinder engine.

The Deltic engine, the basic design of which originated at the A.E.L., has been endurance tested at the laboratory under minesweeper conditions. Further testing on a modified engine is expected to start shortly.

Design

It is a great disappointment to the laboratory that present policy seems to rely on industry to design and develop naval Diesel engines. The laboratory has not been unsuccessful in the past and a very considerable amount of knowledge and experience has been gained. It seems most unlikely that there will ever be a commercial engine suitable for submarines because the commercial designer is not concerned with suction depression and high exhaust pressure, nor in making his engine capable of withstanding high shock figures.

There is still, however, a section known as the Design Section, which is manned partly by Admiralty draughtsmen and partly by R.N.S.S. grades, and it deals with stress calculations and general engine dynamics. Since 1950, the whole of the Admiralty investigations into torsional vibration of Diesel engine systems has been carried out by this section. These investigations include the original fundamental calculations, design of dampers, measurement and analysis of torsional vibration wave forms in all types of Diesel engine installations in Admiralty service, and the assessment of resulting stresses. This work is rather specialized and its volume is such that it entails the continuous employment of a number of specially trained staff.

Metallurgy and Materials Section

This section deals largely with the examination and testing of materials relating to naval engineering in general and to I.C. engines and gas turbines in particular, where the metallurgical aspects of failures under working conditions are investigated. Up to two years ago, when the Admiralty Oil Laboratory came into being, this section also undertook some of the examination and testing of Diesel fuel and lubricating oils.

During the war a large number and variety of failures of components in I.C. engines were investigated and reports submitted. One such investigation was concerned with the sudden epidemic of failures of valve springs which occurred during operations in the Mediterranean. The cause of the failures was traced to corrosion fatigue caused by the rusting of springs when operating in a moist marine atmosphere ; steps taken to overcome the failures were successful and are still being used for such conditions. Fatigue testing of materials, both under normal and corrosive conditions, has been carried out almost continuously during the last few years and fatigue testing of aluminium alloys up to 50,000,000 cycles of stress in a sea-water laden atmosphere are now proceeding.

Tests on materials for underwater bearings, as possible alternatives to lignum vitae and cutless rubber, have been made and are continuing. A rig constructed to test the segments while submerged, under conditions closely resembling those in service, is used and a number of materials, including nylon, have been tested and valuable pre-service experience gained.

The metallurgical aspect of the water side attack of Diesel engine cylinder liners is being investigated under high priority. The attack, which is often very localized and frequently confined to the thrust side of the liner only, closely resembles cavitation erosion. Tests in a laboratory rig, using small specimens subjected to intense conditions to produce cavitation erosion in a short period of running, are being made to assess the performance of liner materials and protective coatings.

A considerable amount of work has been done in this section on testing lubricating oil filters and centrifugal separators. Exhaustive comparative tests to determine the actual performance of different types of centrifugal separators at, and also above the makers rating, have been carried out. Various types of filters have also been examined. An extensive programme of tests on filters for the Y.E.A.D.1 machinery is in hand and test rigs with capacities up to 3,000 galls. per hr are available. Examination of samples recently received emphasizes the need for more careful attention to the cleanliness of machinery systems.

A.S.R.1 crankshafts made of 0·4 per cent carbon steel and used in the normalized conditions have a Brinell hardness of the order of 180 which, under comparatively moderate conditions of engine performance, are satisfactory for operation with whitemetal lined bearings. Under conditions of higher bearing loads, these frequently failed by cracking and a change to copper-lead, as a stronger and harder material, was made. It is generally accepted that, particularly where dirty lubricating oil is present, copper-lead bearing material requires steel of a higher Brinell hardness than 180 against which to operate. Because of this, tests in conjunction with Messrs. G.E.C. have been made on a dummy crankpin of 0·4 per cent carbon steel in which, in a period of less than 5 minutes, a surface skin approximately 1/16 in. in depth and having a hardness of 630 V.D.H. which was subsequently tempered back to a hardness about 340, was produced. The loss in diameter of the 6½ in diameter pin by this treatment was in the order of 0·002 in. The hardening of the bearing surfaces of existing crankshafts could thus be undertaken without serious loss in dimensions. This experiment is to be carried further at Chatham Dockyard by the treatment of a finished, machined, multi-throw A.S.R.1 crankshaft which will subsequently be subjected to metallurgical examination and fatigue tests.

Physics Section

This is the most heavily overloaded section in the A.E.L. It is hardly surprising because, in addition to entire responsibility for the maintenance of all electronic equipment in the laboratory, which is in daily use, a very great number of requirements for accurate electronic measurement are undertaken. A seismic mass velocity pick-up for the measurement of torsional vibration in Diesel engines has been developed and it is a robust and most satisfactory tool. It is in constant use all over the country and it is necessary to calibrate it before and after every trial, a task which is a heavy drain on man-power.

Some years ago the aircraft carriers suffered severe axial vibration in their propeller shafts, especially when turning. A comprehensive series of trials was carried out by the laboratory using inductive type pick-ups and specially developed measuring equipment before a cure was found. This was effected by using three-bladed propellers on the outboard shafts and five-bladed on the centre, which prevented interaction exciting the natural frequency of the system. Hydraulic dampers are now also being incorporated in the Michell thrust block systems which help further to reduce these axial vibrations.

A long-term series of trials, covering five to six years, was carried out in H.M.S. *Savage* to measure steady torque and thrust, fluctuating torque and thrust and general machinery vibrations. These were combined with trials to measure propeller efficiency and sound-ranging in Loch Goil and at Portland. Simultaneous records from six different points were required and there was no suitable instrument available. A six-pen recorder, therefore, had to be developed and it has turned out to be a thoroughly satisfactory instrument.

Bold Pathfinder was another ship to give a lot of trouble and it was found that the natural frequencies of the hull and the thrust blocks were very close and when turning at above 7,000 r.p.m. gas generator speed, these were excited and it appeared that the hull, rather than the thrust block, started off extremely severe vibrations.

At present, a priority job is to find out why the quill shafts driving the Godfrey blowers in A.S.R.1 are breaking. These have had strain gauge torquemeters fitted, which has not been at all simple, but it is hoped that they will give the information required without too much difficulty. Strain gauges are used in many applications, and we now think that we have developed a very satisfactory method of overcoming their previous weakness, which was deterioration of the insulation resistance after a very short time in use. The practice has been to have the surface to which they are to be applied chemically cleaned and then, for the strain gauges to be stuck on with cold-setting araldite. If the part to be gauged is small enough it is always put in an oven and baked at a temperature of 60 degrees C. for three or four hours.

Governors for I.C. engines occupy a lot of time, and the section is developing an instrument to measure very small changes in engine speed. It is also hoped to develop a governor test rig which will simulate engine conditions and avoid running a 6-cylinder A.S.R.1 just to test a small piece of machinery such as a governor.

At considerably lower priority, attempts to develop a governor for Diesel alternators, which will detect load changes before the engine speed alters, are being made. It is hoped that this governor will also balance the load between different sets.

Two very useful tools have been developed, one, a dynamic balancing rig for small gas turbine rotors which can easily be operated by a laboratory mechanic, and which will balance to an accuracy of 0·004 oz ins. Although it operates to such fine limits, the mechanic can complete the work in about two hours. The other is a miniature measuring amplifier suitable for noise and vibration work generally, and this, it is hoped, will be suitable for issue to dockyards and other refitting authorities to check that, on completion of the refit of any piece of machinery, it is acceptable from a noise angle as well as a mechanical one. A new general purpose torsional vibration pick-up is being developed to detect the failure of engine dampers, mainly those fitted in the A.S.R.1. It is likely to consist of a pick-up on the free end of the shaft and a permanently connected box containing an indicating instrument will help to ensure that no crankshaft is broken by the failure of the damper.

Gas Turbine Section

As part of the general work of the laboratory a study of cycles and, in particular of the free-piston gas generator with power turbine, started about 1940 and culminated in the manufacture and testing of Fratric. It was not, however, until 1943 that the section emerged as a separate entity. From then until 1948, its efforts were devoted mainly to paper studies of the many possible cycles of varying degrees of complexity which could be used in a marine gas turbine, and to checking the performance estimates made for the Metropolitan-Vickers Gatric, the English-Electric E.L. 60 and the Rolls Royce R.M.60 engines.

In 1948, installation of one of the three Gatric engines at the A.E.L. was completed and when test running began the work of the section entered a more practical phase which has continued up to the present time. Operation of Gatric included performance and endurance tests, extensively instrumented acceleration tests designed to provide information for Messrs. W. H. Allen in designing the governing arrangements for the 100-kW alternator set, and operation on the reference residual fuels Nightlight and Mothball.

Concurrently with the operation of Gatric, two Merlin engines, driving Griffon superchargers, were installed and a number of runs were made with a kerosine-burning B.37 combustion chamber to provide basic data concerning the ash-free oxidation rate of Nimonic 80a. This work, carried out in conjunction with N.G.T.E., was followed by the installation and operation of an N.G.T.E. cyclone combustion chamber and associated rig, for determining the rates of fouling and metal loss experienced by static blade specimens at a range of temperatures, when exposed to the combustion products of a number of residual fuels in combination with various additives. During the interval between the operation of these combustion rigs the equipment was used for testing an inward-flow radial turbine. The results of these tests were made available to Messrs. W. H. Allen, who were at that time designing a 200 h.p. engine of that type under an Admiralty development contract.

At about this time, the Naval Marine Wing at the N.G.T.E. came into existence and it was decided that the A.E.L. section should undertake work on small gas turbine engines up to about 500 or 1,000 h.p., the N.G.T.E. taking from that size to 10,000 h.p. and Pametrada any above the limit of N.G.T.E.'s brakes. In further defining the duties of the section, E.-in-C. instructed that first priority should be given to the testing and development of small gas turbines for naval use. This section is, however, encouraged to continue rig work on residual fuels to maximum extent, without prejudicing engine testing.

Engines recently or at present being tested are the Rover T.8, a free power turbine engine with a marine rating of 150 h.p., the Turbomeca ' Artouste I ', a 250 h.p. single-shaft engine, the Rover 1S/60 single-shaft engine and the Budworth 30 to 60 h.p. engine. The Solar ' Mars ' gas turbine driven fire pump has also been tested. Work on the Artouste has been divided between endurance and performance testing of the engine and development of components such as silencers, clutch and control gear for the forthcoming marine installation of four engines in two L.C.R.s. One engine is at present engaged upon an endurance test with Nimonic turbine parts of English manufacture in order to establish the maintenance and overhaul requirements for the craft. The Rover 1S/60 will be used as the prime-mover in portable fire pumps, fire and salvage pumps for tugs and in the main electric generators for the Proteus engined M.F.P.B.s. Up to the present it has been tested as a portable fire pump in parallel with the firm's own development running and combined experience has been fed back in modifications which are steadily improving its performance and reliability. Work at the A.E.L. includes building-up a light-weight generator set using one of these engines and a B.T.H. aircraft generator in which D.E.E. is interested.

The Budworth engine is of special interest because of its inward radial turbine and its deliberate simplicity and consequent low price. Here again development is proceeding in conjunction with the firm.

Other engines which are expected for testing are the Blackburn development from the Turbomeca range, the Turmo 600, and the Rover ' Aurora '. These are both free power turbine engines, the former will be available either as a single unit of 350 to 400 h.p. or as a twinned unit of two engines geared together through roller free wheels which will have attractive possibilities as a means of providing high power without impairing cruising economy. The Aurora is expected to have a peak power of about 150 h.p. and a marine rating of about 100. In its present form, it has an integral reverse gear and a heat exchanger, the latter should permit it to compete on more than usually favourable terms with piston engine fuel consumptions.

Other aspects of the section's work, includes activity on residual fuel, centred on the operation of a self-supporting rig comprising a Napier turbo-blower, a heat exchanger and a Shell louvred combustion chamber. The rig has operated for 1,000 hours on Mothball with magnesium napthanate additive and a turbine inlet temperature of 700 degrees C. The turbine is now being re-bladed with a selection of high temperature materials for a run at 750 degrees C. The heat exchanger, fitted primarily to preheat the air for combustion, has also been used to test tube materials provided by B.N.F. and I.C.I.

Noise and Vibration Section

This section was formed in November, 1950, and its function is the measurement and suppression of noise and vibration produced by all types of main propulsion machinery (other than electric and steam) and certain classes of auxiliary machinery.

Past Problems

The investigation of noise, even today, is as much an art as it is a science. The problems of instrumentation are not yet fully solved, and it was necessary to learn techniques and develop equipment during the early stages, so the section built up slowly. However, early in 1951, it was possible to undertake a number of trials such as the assessment of the efficiency of an acoustic hood and to determine whether or not to remove the gears from H.M.S. *Eagle* for shaving and the effectiveness of the axial vibration dampers in reducing the noise in the gear rooms. Recently, 30,000 vibration readings and a lot of thought showed that a different or modified mounting for the Mirrlees pulse generator set was not as good as the original. Furthermore, the very important fact emerged than an engine set must be mounted as a rigid mass and not as a number of separate masses connected by a flexible bed-plate.

Scope of Present Work

At present, the section is engaged on an assessment of 'L' type production mountings in collaboration with the A.M.L., the development of a new 600 lb strip mounting to replace the present 'S' mounting, and an assessment of the fitting limitations of the 1,000 lb strip mountings which were reported to have failed in a number of French minesweepers. The failure of the compressor impellers of two small gas turbines is being investigated, and new inlet splitter designs have been proposed by the laboratory, in conjunction with D.N.C., to reduce the very high airborne noise from H.M.S. *Highburton*.

A limited series of model tests for the design of acoustic hoods, using light-weight but stiff panels, is being progressed as man-power permits. This work is based on research by Messrs. Metropolitan Vickers, and some full-scale tests made on a Rolls Royce engine in *Maytime*. Technical aid is also given to H.M.S. *Hornet* in their experimental work on water injection silencing for the Deltic engine exhausts in the *Dark* Class fast patrol boats.

Trials outside the laboratory take up quite a large amount of time, for it is not only the period away from the laboratory that counts, but also the preparation and calibration of instruments before the trial and calibration and reporting (including analysis) after the trial, that must be considered. Shortly there will be trials at Chatham on the 16 VMS engine to assess the efficiency of the blower hood and inlet silencers. A trial is also to be carried out on a similar engine at Messrs. Vickers Armstrong for vibration and engine movement.

Future Facilities

During the development of the section, it became clear that to undertake the major problems of reducing engine noise at source, a building designed especially for noise work would be necessary. This building has two acoustic test cells with spring mounted test beds. One of these will accommodate such engines as the 16 VMS A.S.R.1 type, while the smaller cell can take such engines as the Foden FD6 and perhaps, for vibrations tests, a Paxman YHA. Attached to these cells are offices and laboratory accommodation for carrying through all aspects of noise work.

A few words on noise and vibration measurement would not be out of place here. Noise is a train of three-dimensional pressure waves and the level at any one point measures the mean energy at that point, in a complex system. Such a reading does not describe the system. Further, there are physical or objective measurements quoted in decibels and subjective measurements quoted in phons, or sones, which relate to what the average person hears. Similarly with vibration, one figure will not give a clear picture of how a machine is vibrating ; a general survey is necessary. The measurement of medium frequency vibration is comparatively easy but with the presence of high and low frequency components in more than one plane, the problem becomes more difficult. Holding a pick-up

' on ' by hand between 100 to 2,000 c/s is possible but fatigue and degree of skill of the operator may cause answers to vary considerably. Above and below these frequencies the pick-up must be bolted on, preferably on ground and well greased surfaces or contact resonances will become predominant. Accelerometers have to be used for the higher frequencies since the amplitude is small, and this brings along its own troubles because of the impedence circuits which must be used. In these circuits, broken leads and sometimes noisy leads give greater signals than the true reading ; experience and understanding of what is being done is the only guide to warn the operator that the readings are spurious.

Hydraulics Section

History

This section started in 1945 as an out-station of the A.G.E., Teddington, directly under D.N.O. for gunmounting problems. In 1954, it became the hydraulics section of the A.E.L. under the E.-in-C. with the same relationship to the Superintendent as the other mechanical sections, a much better arrangement.

Until 1954, the test work undertaken for D.N.O. comprised performance tests on small pumps, pipe joint rings, gland seals, H.P. and L.P. hoses, gears, and heat exchangers. Since 1954, tests have also been put in hand on items for E.-in-C., and this work at present occupies about half the available effort.

Soft Packing Tests for E.-in-C.

Tests are being carried out to evalute the performance of the various soft packings supplied as *Rate Book* articles by D. of S. These are divided into reciprocating pump shaft glands, rotary pump shaft glands and steam valve glands. Tests of reciprocating pump shaft gland packings for oil have been running for several months. A long time is required for these tests—1,000 hours for each packing. Rotary pump shaft gland tests will start shortly, and tests of steam packings later. All these tests, and those on improved materials and designs which can be expected to follow them, are likely to last for several years, Reciprocating pump packings for F.F.O. and distilled water, rotary pump packings for F.F.O., sea water, distilled water and Avgas, and steam packings for superheated and saturated steam will be tested.

' V ' Packing Tests for D.N.O.

Tests continue on ' V ' shaped packing rings, such as James Walker & Co.'s chevron packing, for use on gunnery equipment. A considerable amount of testing has been done, and continues, present tests being at lower speeds, with a view to widening the sources of supply when possible. It is hoped shortly to compare the performance of a soft packing with that of a ' V ' packing (when the latter is endless and when it is cut), for sealing F.F.O., and if successful distilled water.

Rotary Lip Seals for D.N.O.

A series of tests for selecting suitable makes of synthetic rubber garter spring loaded rotary lip seals is in progress. The longest part, 500 hours running of 6 seals of a type to determine leakage and friction, is nearing completion. Tests will later be done with shafts running eccentrically to the seal, and also tests at temperatures down to -40 degrees F. Shaft sizes used are 1 in and 4 in diameter.

Underwater Bearing Materials for E.-in-C.

Tests are being made, in conjunction with the Materials Section, on a number of synthetic materials as substitutes for cutless rubber and lignum vitae in ' A ' bracket and stern tube bearings. Friction, both running and static, and wear are being measured. Materials include Ferrobestos, Capasto, Tufnol, Mintex, Nylon.

Pipe Joints for D.N.O. and E.-in-C.

Tests are being made on diamond-shaped nylon joint rings as a substitute for the A.E.L. joint rings, which themselves were developed in the Hydraulic Section a few years ago to replace copper diamond joint rings. The A.E.L. joint ring, which is as effective a joint ring as is likely to be found for the existing flanges, has proved difficult and expensive to make. For the new flanges, a variety of joint rings is possible. The shrouded ' O ' ring has been in use on prototype mountings, and spiral-wound gaskets have been tested and found suitable in principle and one, the Metaflex, containing rubber tape between the steel tape windings, and also an asbestos tape-wound gasket, have been satisfactorily tested. Other types are being developed. For E.-in-C., tests will shortly be made on C.A.F. jointings, reputed to be equally suitable for steam, oil and petrol. Three firms have supplied these materials. The oil and petrol tests only will be made at the A.E.L.

Future Work

The present test programme of work will last in part for 9 months, and in other parts for 4 years. Other investigations will be made with substitute bearing materials for oil-impregnated porous metal—such as P.T.F.E., resin-bonded fabrics and nylon. Further tests are expected on small pumps and oil motors, and an investigation of the tilt-arm efforts of a V.S.G. pump.

The Admiralty Oil Laboratory

This laboratory, the youngest section of the A.E.L., started work in January, 1954, in premises formerly owned by the Motor Industry Research Association in the Great West Road. It was set up as a result of a resolution passed, in 1950, by the Admiralty Oil Quality Committee which said—' The Admiralty should establish a central naval petroleum organization with high scientific status, including within it a central laboratory for investigational work and with adequate facilities for the physical, chemical, mechanical and engine testing of naval fuels and lubricants.' Other recommendations dealing with specific problems such as the pumpability of fuel oil, the provision of a lubricant for steam turbines having high gear-tooth loading and the level of heavy duty Diesel engine lubricating oils which the Fleet would require, form the blue print for a very substantial research and development effort. The importance of regular investigations of stocks of oils and greases to ensure that the Fleet always receives material of adequate quality was strongly emphasized.

At the time the laboratory was established, Mr. Stansfield, a man of international repute in oil matters, had just retired from the Anglo Iranium Oil Company and he agreed to become the Admiralty Consultant. The successful start made by the A.O.L. has been very largely due to his help and advice. Most unfortunately he is now sick and unlikely to return to duty, but we shall always owe him a very great debt for the excellent work he did.

The work of this section, which is even more under-staffed than any other, is divided into two parts : the inspection of all new purchases, whether furnace fuel, Diesel fuel, lubricants or greases, to ensure that they are up to standard, and the longer term research and development. The laboratory is divided into two sections : chemical and physical, and engine testing.

Chemical and Physical Side

This sub-section is able to control a very large number of inspections of new purchases or of samples taken from stocks, ashore or afloat, during service. The facilities include a laboratory devoted to those tests peculiar to lubricants, one devoted to fuels and one capable of chemical analysis of deposits, greases, detergent additives, the estimation of trace metals in used oils, vanadium in fuels, or any other purely chemical work that is likely to be required. The laboratory is exceptionally well provided with modern and comprehensive equipment, including such things as a Hilger medium spectrograph, a flame photometer, a Grubb Parsons infra-red spectrometer, an electron microscope and an X-ray diffraction camera. It caters for many of the day-to-day service problems on which the staff is required to advise, since these can frequently be solved by a planned programme using standard equipment permanently installed in the inspection laboratories. This equipment also plays its part in long-term research and development.

Engine Test Laboratories

Despite all this gear, Diesel engine lubricating oils cannot be assessed for performance by purely chemical or physical means, they have to be run in special test engines and their performance judged by a de-merit system. The de-merit marking is made according to the amount of carbon build-up behind the top ring, choking of scraper ring slots, the condition of the valves and the lacquer coverage. These readings are remarkably reproducible in the Caterpillar and, with experience, the assessment of de-merit by two independent judges will always be within 5 per cent. The amount of sulphur in Diesel fuel has a marked effect on the suitability of lubricants. Our rating of oils has also got to be acceptable to the Americans, to all N.A.T.O. countries and to the oil companies. The standard oil-test engines we have chosen, therefore, are the Caterpillar 1A, the General Motors 2–71, the Petter A.V.1 and the Shell Ricardo. The Caterpillar, which is the best-known engine, has to be run continuously for 480 hours and any test is consequently fairly protracted. As each test is done with a new piston, new liner and new bearings, it is a fairly expensive business. It will be of great advantage if, as is hoped, the Petters A.V.1 becomes generally acceptable as a test engine because it is of British manufacture and tests with it will take only 120 hours.

Other engines being installed include the Foden F.D.4, Enfield H.O.2, a single-cylinder unit of the Deltic, and a Ruston for routine cetane testing. The single-cylinder engines are mounted on concrete blocks supported off the floor by six spring-packs. This has proved a most successful design of bed and gives complete isolation from the surrounding structure. To test the load carrying capacity of lubricants for highly stressed reduction gears we have the I.A.E. rig, a Shell four-ball lubricant tester and the Timkin machine. None of these is entirely satisfactory and efforts are being made to find a test rig which more nearly simulates service conditions. Grease test rigs are also being installed, but due to pressure of other work not much has been done on them so far. A compact and well laid-out machine shop is available but any heavy machining beyond the A.O.L.'s capabilities is done at the A.E.L.