The Development of the Diesel Engine for Rail Traction

J. F. HARRISON, O.B.E., M.I.Mech.E., M.I.Loco.E.*

There are now in service on British Railways some 9,000 Diesel engines of various sizes and types, most of which have been introduced during the last decade.

The paper describes the general features of service and requirements for railway motive power, and how Diesel traction has progressed to its present important position in covering different types of duties. After a summary of the three main forms of transmission, the application and selection of the Diesel engine are reviewed.

In describing the development of engines for main line locomotives, experience to date with the alternative applications of medium and high-speed engines is compared, accompanied by comments on maintenance aspects. Reference is made to fuel and lubricating oils, to cooling systems and water treatment, and to engine protective devices.

The present preference is for medium-speed engines driving through electric transmissions for all but the smaller main line locomotives. A range of standard locomotive designs has now been established, and developments in the near future will be mainly concentrated on improving reliability, reducing maintenance and extending overhaul periods.

INTRODUCTION

The modernization of motive power on British Railways has now reached an advanced stage, and there are already in traction service over 9,000 Diesel engines of various types, makes and size, representing the largest individual fleet of Diesel units outside North America. By virtue of the scale of this application and the relatively short period during which the majority of it has been introduced, much interesting experience has inevitably been obtained in meeting and overcoming a variety of problems associated not only with the engines themselves, but also with this form of traction as a whole.

This paper in describing the development of Diesel traction, with particular regard to British Railways, also aims to review some of the more interesting aspects of the Diesel engine applications, and give some comparative, though somewhat provisional, conclusions on certain alternatives.

FEATURES OF RAILWAY SERVICE

Firstly, before examining Diesel traction itself, it would be useful to review the principal characteristics required of railway motive power units.

Power Performance

Tractive performance must be adequate for starting and hauling the required train loads to the appropriate schedules, with a suitable margin of reserve to meet adverse conditions. Due regard must also be given to adhesion for starting and to satisfactory braking performance.

By reason of the individual nature of each service and the characteristics of the route, considerable fluctuations in power output, random both in degree and frequency, are normally the rule.

Reliability

Utmost reliability is very essential for the effective and economic operation of services, especially as failures in traffic can, by the very nature of the track system, affect far more than the one train directly concerned. It assumes even greater importance with Diesel and electric traction than for steam, since depots are fewer in number and further apart, and, moreover, there is a smaller number of units in reserve to call upon in an emergency.

Minimum Overall Cost

The overall economic result is, of course, the major criterion in the ultimate choice of power, and embraces several component factors comprising the following, which need to be treated together and not in isolation:

a) Capital cost, and its relation to service life.
b) Servicing and maintenance costs.
c) Operating costs, covering the provision of crews, together with fuel or electric energy and other consumable supplies.

High Availability and Utilization

Availability is the proportion of total time the unit is available for service, and is adversely affected by time involved in servicing, all maintenance, and also failures in service. Utilization is the measure of the use made of the unit during the time it is available for service, and is therefore largely influenced by operating schedules.

Pursuit of the highest level of utilization is important to enable traffic requirements to be met by the use of the least number of units, thereby keeping capital investment and standing charges to a minimum. For the same reason the unit should have an adequate life span, without necessitating early replacement or excessive repairs.

A particular feature of railway service, resulting from the dynamic effects of steel wheels rolling on steel rails and from the sundry horizontal forces due to buffing impacts, is that all the equipment and components of rolling stock are inevitably subjected to a degree of vibration and shocks, which is generally far more severe and punishing than in most other applications. Time and again this has led to premature failures or difficulties with equipment, which in many cases had hitherto given entirely satisfactory and long service in other spheres.

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* Chief Mechanical Engineer, British Railways Board.

Another point not to be overlooked is that in order to obtain intensive utilization it is often necessary that rolling stock should range over a wide area of the system. This therefore means that it is handled successively by various personnel in respect of operation, servicing and maintenance.

The foregoing two pertinent considerations emphasize the overriding need for adequate robustness, reliability and simplicity of both the unit as a whole and its constituent components. Furthermore, spoon feeding of special or temperamental units is obviously not practicable on a wide scale, and explains why it is unfavourable and expensive to operate odd units, unless these are the subject of a worthwhile trial of one or more special features. Moreover, the foregoing considerations account for the tendency for some new designs, which as initial prototypes give particularly promising results whilst they are undoubtedly subject to close observation and attention, then to provide a far less satisfactory and perhaps even disappointing performance after being introduced in quantity into general service.

HISTORICAL BACKGROUND

Whilst for well over a hundred years steam locomotives hauled the lion's share of the traffic on most of the world's railways, in the last two decades the situation has altered drastically and with increasing rapidity. Steam, reasonably effective and economic in its time, when suitable fuel and labour were readily available at relatively low cost, is unable under the conditions of the present day to compete economically with the other more refined types of traction. The reason for this is twofold; in part because fuel and labour prices have distinctly changed to the detriment of steam, and secondly and not least because of the great strides made in the technical development of Diesel and electric traction in recent years. Yet another factor, somewhat less decisive but nevertheless significant, is the general demand for cleaner conditions for the users, employees and neighbours of the railways.

Although electrification has a very high potential for excellent performance, reliability, cleanliness and freedom from noise and smell, as the source of the electric power is concentrated at the generating stations, it can only be justified on strictly economic grounds where the traffic density is sufficiently high to offset the heavy investment in the extensive fixed installations for electric current supply. Considerable scope therefore exists and will continue to do so, although perhaps to a diminishing extent as the railway system is rationalized, for Diesel traction, which has many of the advantages of direct electrification, if not to quite the same degree.

The first attempts to use internal combustion engines for railway traction took place in the last century, but progress thereafter was slow and intermittent, and had a negligible effect on train operation for many years. It was not until the 'thirties that Diesel power began to play any effective part, when Diesel railcars and shunting locomotives began to appear in noticeable numbers, though generally still in a minor role in this country, on the Continent and in America. It was in fact in the latter country where Diesel traction first superseded steam at such a spectacular rate in the period following the last war. Since that time steam locomotives have been replaced steadily by Diesel or electric traction in most other countries, and during the last few years the construction of steam locomotives anywhere has virtually ceased.

At the close of 1954, when the modernization plan was announced, British Railways operated the following Diesel units: 7 main line locomotives, 309 shunting locomotives and 62 railcars and motor cars. At the present time the respective figures are in the order of 2,100, 2,000 and 2,500. When the first large batch of 174 main line locomotives was ordered in 1955 it was arranged as deliberate policy that these would comprise a range of locomotive designs prepared by different manufacturers and British Railways, and powered, furthermore, by a variety of Diesel engines which, incidentally,included four-stroke and two-stroke, heavy medium-speed and lightweight high-speed types. The purpose of this procedure was twofold; firstly to enable the railways to obtain experience with the various prototypes for making an assessment of merit to guide future ordering, and secondly to provide a large segment of the British traction industry with direct experience on the home railway system.

The former intention was somewhat overtaken by events, because the pressure to extend, as early as possible, the use and obvious benefits of Diesel traction made it necessary to order further locomotives before the prototype trial was in full operation and able to be assessed. Consequently ordering policy in the meantime had to be partly based on judgement, augmented by direct experience as this accumulated, but there was nevertheless a very deliberate move towards limitation of variety in order to simplify the problems of spares, operation and maintenance. At the present time new orders are being confined to five basic designs of main line Diesel locomotives, each one of these covering a different power range. The programmes for shunting locomotives and Diesel multiple unit trains have already been virtually concluded.

FORMS OF DIESEL MOTIVE POWER

Diesel railway motive power takes three main forms, all widely used on British Railways:

i) Main line locomotives, whose installed engine power lies in a range from about 600 h.p. to over 3,000 h.p. and can reach 4,000 h.p. In view of the wide versatility of the Diesel locomotive, the same design is often suitable for hauling both freight traffic and high-speed passenger trains. It is current world wide practice for these locomotives to be carried on two swivelling bogies, which provide good riding and curving properties.

ii) Shunting locomotives primarily operate in yards and around terminals for shunting and marshalling either freight or passenger trains. In this country and Europe the installed engine horsepower is usually appreciably below 700 h.p. since these locomotives only operate at relatively low speeds and adequate tractive effort can therefore be obtained by the use of a high reduction gear ratio. For the sake of simplicity and adhesion most of these locomotives are carried on two, three or four axles mounted in the rigid underframe of the locomotive itself.

iii) Railcars and multiple-unit trains represent an important alternative to locomotive-hauled passenger trains, especially on branch line and local services where the advantages of reduced overall train weight and quicker turn-round time can be exploited.

FORMS OF POWER TRANSMISSION

Reference should be made to the transmission which is a very essential part of the equipment, needed to provide a variable speed ratio between the engine crankshaft, rotating within a fairly limited speed range, and the driving axles which must be accelerated from rest to the top speed of the train. There are three main forms of transmission, all widely used in rail traction, and these are summarized in the following paragraphs as each one has an influence on the way the Diesel engine itself has to operate.

Mechanical Transmission

This in general is the simplest and cheapest form, consisting essentially of a gearbox, often of the epicyclic type, in association with appropriate types of clutch and resilient or fluid couplings. This form of transmission has only been widely used for transmitting powers generally below 300 h.p. but in this range it is economic and effective for the smaller shunting locomotives and for railcars and multiple unit trains.

The overall efficiency of mechanical transmission exceeding 90 per cent is higher than the other types since only friction loss is involved, but on the other hand the orthodox gearbox arrangement suffers from the disadvantage of the power interruptions that occur when the gear ratio is altered, and also from the feature that the crankshaft revolutions and therefore the power output of the Diesel engine are, in each gear ratio, directly related to train speed. For this reason, where such a transmission is incorporated, the Diesel engine is subjected to far more fluctuations in output and revolutions, and furthermore it is obviously not able to maintain maximum engine output over the whole range of train speed, therefore the utilization of installed engine power is somewhat restricted.

Hydraulic Transmission

The system, as described by this term, generally consists of an arrangement of torque converters and fluid couplings, used either separately or in combination, and frequently in association with alternative gear trains. The use of the hydraulic components overcomes the drawback of the plain mechanical transmission in which the crankshaft is mechanically coupled to the axles in each gear ratio, and makes it possible to operate the Diesel engine at a more constant output regardless of train speed. Furthermore it is also practicable to select alternative gear ratios more expeditiously and whilst transmitting much higher powers than is the case with a normal mechanical transmission. On the other hand the introduction of the hydraulic units impairs the transmission efficiency somewhat, and to a variable extent depending upon the application and range of duty, but the overall efficiency is generally in the order of 80 per cent or more for an appreciable part of the range. Hydraulic transmission is suitable for a wide field, and in various countries has been fitted to a considerable number of railcars and all sizes of locomotives from shunters right up to some of the most powerful main line locomotives in the world, although the number of actual applications decrease greatly as the installed power capacity increases.

By virtue of the inherent characteristics of torque converters, at any given input speed an hydraulic transmission will impose a definite torque loading on the engine, the relation between these two quantities following what is known as the propeller curve. This feature therefore provides a useful automatic torque control for the engine, whose crankshaft speed is in general governed according to the setting of the driver's controller.

The true hydrostatic transmission, wherein an hydraulic pump supplies oil under pressure to variable speed hydraulic motors driving the axles, has not to date met with any significant application for rail traction.

Electric Transmission

This represents the most versatile type of transmission, being technically suitable for the entire range of traction applications, and is by far the most widely used and successful transmission at the present time for all but the lower powers. The engine drives directly an electric generator feeding current to the traction motors geared to the axles, providing an infinitely variable speed ratio, and maintaining an overall transmission efficiency better than 80 per cent over a wide range. Furthermore the generator provides a convenient means of starting the Diesel engine, for which function it acts as a motor drawing current from the batteries.

A more elaborate system of engine control is, however, required in order to ensure the engine is not overloaded by the demands of the generator. Engine output and crankshaft revolutions are raised progressively by the movement of the driver's controller, but for a given setting of the latter, are held at the required level over a wide range of train speed by the action of the engine governor co-ordinated with fuel rack setting and generator excitation.

THE DIESEL ENGINE

Special Conditions of Rail Application

Railway traction represents a particularly arduous application of Diesel engines for the following reasons:

i) The engine is required to operate satisfactorily through the whole range of its output, with frequent fluctuations and random periods of loading varying from idling to full load. Furthermore the engine is likely to be started and shut down several times a day.

ii) Being mounted on a railborne vehicle, it is subject to the flexing and vibration of the structure of the vehicle. In addition it is liable to receive horizontal impacts due to buffing forces, which on occasions may be severe.

iii) As space and weight generally constitute a problem, particularly in the design of main line locomotives, there is a natural tendency to press a given type and size of engine to as high a rating as possible. The engine manufacturers moreover are tempted to do this in order to improve their own competitive position.

iv) Regarding servicing and maintenance, there are several aspects which tend to be unfavourable in comparison with other applications:

  a) Because of space limitation, accessibility of the various components is not always as good as could be desired.

  b) As the unit is likely to be dealt with at different depots in the course of its intensive duties, servicing and maintenance are inevitably carried out by a wide range of personnel.

  c) For that reason accurate control of the quality of lubricants, coolant and maintenance standards is more difficult to achieve consistently.

  d) Whilst the unit is in regular service, it is in the charge of the driver, who is primarily an operator and is not mechanically trained, although he has received a course of instruction and training on Diesel traction. As no engineering personnel is normally on board, in the event of any failure or malfunctioning, little more than elementary diagnosis, isolation of equipment, or replacement of fuses can be undertaken by the crew.

  e) In some cases intake air may be unusually dirty, on account of either the character of the atmosphere in certain areas, or dust circulated into the intakes by the turbulence of the moving train.

The foregoing considerations emphasize the overriding need for an engine to be straightforward in design, robust and thoroughly reliable, and not critically dependent upon conditions being at all times near to perfection. This requirement is of prime practical importance and tends to outweigh the majority of other technical factors, including such items as minimum fuel consumption.

Noise emission is a feature which has to be given a certain amount of consideration, both in its relation to the locomotive crew and also the public at large. The output of noise varies appreciably with different types of engine and only in certain cases is the problem particularly acute. The situation can be improved by suitable sound insulation applied to the locomotive structure and by the use of engine silencers, which must be carefully designed with the lowest possible pressure drop so as not to affect the performance of the turbocharger.

Choice of Engine

The Diesel engine, being the heart of the locomotive, or vehicle which it powers, largely determines the success or otherwise of the whole unit depending upon the degree of reliability with which it operates over a period of years. This is not to deny that the unit may also be seriously prejudiced by poor performance of other equipment, such as the transmission and particularly the various auxiliary apparatus including control gear, which tends to be complicated and somewhat troublesome on a locomotive. Nevertheless, the engine itself is of fundamental importance and the greatest care is necessary in making a wise choice in its selection.(1)

The British Standards Institution, in its Specification B.S. 2953, and the International Union of Railways in its corresponding document, U.I.C. Specification No. 623, have defined, specially for rail traction, engine type tests consisting of 100 hours' running on the test bed, followed by a strip down and examination under the users' inspection. The former provides for 12 complete 8-hr. cycles, each comprising successive periods of idling, and partial, full and overload power output, whereas the U.I.C. test requires 80 hours of full power, followed by shorter periods of partial, intermittent and overloads.

Whilst British Railways have required that main line engines should meet one or other of these tests, it is realized that these do not in themselves ensure that the engine will be fully satisfactory in traction service, in which it is desirable to obtain some 12,000 hours of reliable running between top overhauls, and several times this figure between complete overhauls. Needless to say, some major defects, especially those associated with fatigue may only come to light after engines have been in service for two or three years. Such trouble at that stage is likely to be serious and expensive, especially if it is fundamental in nature and there is a large number of engines concerned. It is therefore prudent to purchase engines only from manufacturers who have an extensive and direct experience both with the design and building of engines for traction applications. Each of these functions has been mentioned intentionally, since it has been found that it is not necessarily enough to have an established design of engine, if the manufacturer building it has not the most intimate knowledge of its design and development. Especially in the case of a foreign design built under licence, troublesome defects and difficulties can occur because of shortcomings in the selection of equivalent materials and tolerances, coupled perhaps with some lack of the fullest and most up to date "know how", despite the best efforts and intentions of the manufacturer.

Application of Engines

On the bulk of British Railways' railcars the practice has been to fit small high-speed engines ranging from 125 to 238 h.p. driving through gearbox or torque converter transmissions, all this equipment being mounted on the vehicle underframe so that there is no loss of revenue earning space in the body. The control gear is so arranged that a train containing several of these powered cars can be operated by the driver located in the leading cab. Since these designs of automotive engines are widely used also for road transport and other applications, the first cost of the engines themselves and of replacement parts is relatively low. The engines, on account of their small size and position, can be readily removed from the vehicles at depots, and replaced by overhauled engines.

For shunting locomotives, the main aim is that the engines should be economic, robust and reliable, and there is no particular need to seek light weight, since adequate locomotive weight is necessary for adhesion during starting and acceleration. In consequence most shunting locomotives have naturally aspirated medium-speed engines with maximum r.p.m. ranging from 680 to 1,200. All three types of transmission are widely used on these locomotives.

In the case of main line locomotives, on the other hand, the situation is somewhat more controversial, since there are two divergent schools of thought, each having its supporters in various parts of the world. One claims that high-speed engines with crankshaft speeds of some 1,500 r.p.m. should be used in order to gain the advantages of appreciably less engine weight for a given power output, which in turn can often mean that the transmission and the locomotive structure can also be made smaller and lighter than otherwise. The resultant saving in overall locomotive weight thereby achieved should theoretically provide a somewhat better performance and fuel consumption in train operation, especially during acceleration and operation at high speeds. Another claim is that engine components are smaller and more easily handled, and that complete engines may be interchanged more readily. High-speed engines are often particularly associated with hydraulic transmissions where these are used, since the hydraulic torque converters and fluid couplings need to operate at high revolutions for maximum effect. In view of the present limits of output for an individual high-speed engine, where these are employed in locomotives of 2,000 h.p. or more, it has been necessary to fit two engines per locomotive. This in itself represents a serious complication from various points of view, although it does provide the safeguard that if one engine should fail, the locomotive can be operated at up to half power by means of the other engine. This may seem an obviously wise policy but, in fact, if one engine fails experience has shown that only in a small proportion of cases does the locomotive complete its diagrammed working.

The other choice open to a railway is to select a medium-speed engine, which for corresponding power, generally has a smaller number of larger bore cylinders. Such an engine is appreciably heavier than the high-speed counterpart, but on the other hand is likely to be more robust and straightforward in design, and in general less critically affected by any variations and shortcomings in maintenance, lubrication and cooling water treatment. Although individual components such as pistons and connecting rods are more bulky, the effect on maintenance is offset by the reduced number of cylinders in the locomotive.

British Railways have now accumulated appreciable experience with large numbers of locomotives having each of these alternative engine types, and have come to the conclusion that at the present time medium-speed engines associated with electric transmissions represent the best proposition for all but the smallest main line locomotives. Accordingly this arrangement has now been adopted for all new orders of locomotives above 1,000 h.p. consisting of the Types 2, 3 and 4 standard classes. High-speed engines are still favoured for the two Type 1 designs of 900 h.p. and 650 h.p. On these two classes headroom within the engine housings is at a premium in order to provide good driver's visibility from the single driving cab, and two types of Paxman engines rated at 450 h.p. and 650 h.p. have been adopted, the latter in conjunction with hydraulic transmission.

In the last few years, development and uprating of medium-speed engines incorporating turbocharging and intercooling have enabled more than one well established make to develop a traction rating of 2,700 h.p. or more per engine, and at least one further design is opening up the prospect of obtaining up to 4,000 h.p. from a single Vee-type engine sufficiently compact to install in a locomotive built within the British load gauge. It is envisaged that such power represents all that is likely to be required from an individual locomotive in this country in the foreseeable future.

It should be pointed out that the pursuit of minimum locomotive weight is not as advantageous in this country as on certain other railways. This is because of the continued operation of a considerable number of unfitted or partially fitted freight trains, for which the locomotive itself must provide either all or the greater proportion of the braking effort during deceleration periods. In consequence adequate locomotive weight must be available to give sufficient adhesion for braking purpose.

TABLE I.—COMPARISON OF TYPE 3 DIESEL LOCOMOTIVES

Builder	English Electric	Hymek (Beyer Peacock)
Transmission Type	Electric	Hydraulic
Engine horsepower	1,750	1,700
Maximum tractive effort, lb.	55,500	49,700
Continuous tractive effort, lb.	35,000 at 13·6m.p.h.	33,950 at 12·5m.p.h.
Locomotive weight in working order, tons	102	74
Nominal force on brake blocks, tons	84·7	55·2
Length over buffers	61ft. 6in.	51ft. 8½in.

Table I compares the weight and characteristics of two Type 3 locomotives of similar power, each widely used for both passenger and freight services. The locomotive having a high-speed engine coupled to an hydraulic transmission has achieved a considerable reduction in weight and size over the other, powered by a medium-speed engine driving through electric transmission, but it will be noted that the latter has the superior braking effort. The reduction in locomotive weight and size of the Diesel hydraulic locomotive is attributable not only to the lighter weight of the engine and transmission

TABLE II.—COMPARISON OF TYPE 4 DIESEL LOCOMOTIVES

Builder	Brush	British Railways
Transmission type	Electric	Hydraulic
Engine horsepower	2,750	two at 1,350
Maximum tractive effort, lb.	55,000	66,770
Continuous tractive effort, lb.	30,000 at 27m.p.h.	45,200 at 14·5m.p.h.
Locomotive weight in working order, tons	114	108
Nominal force on brake blocks, tons	99·5	82·7
Length over buffers	63ft. 6in.	68ft. 0in.

themselves, but also to the fact that this reduction made it possible to design the locomotive on four instead of six axles without exceeding permissible axle loads.

In the case of the more powerful Type 4 locomotives of 2,700-2,750 h.p. compared in Table II, the weight reduction provided by the high-speed engines and hydraulic transmissions is much more marginal. This is due to the need in this power range to duplicate not only the engine and transmission set but also various associated auxiliaries, whereas on the corresponding Diesel electric locomotive, one large medium-speed engine generator set alone provides the power. In each design six axles are necessary, so that there is no substantial variation in locomotive structural weight.

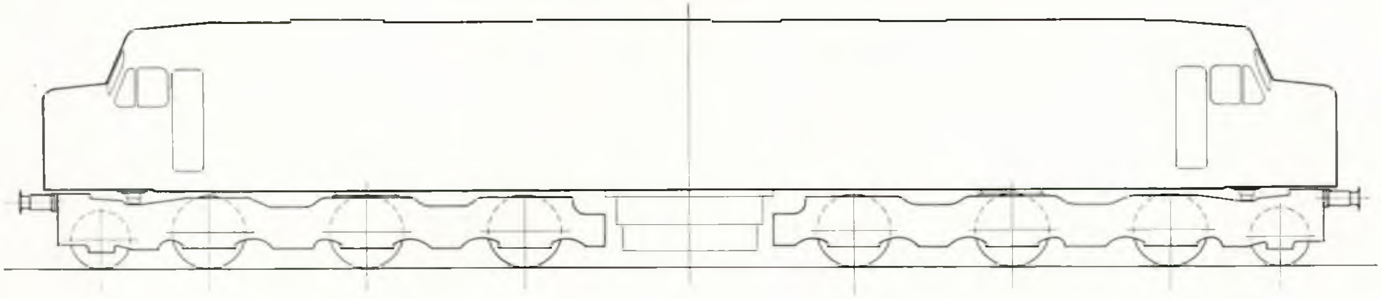
The traction engines in use on British Railways cover a very wide range of power output and size, extending from the 150 h.p. automotive type engines, fitted to hundreds of railcar units, to 2,750 h.p. twin-bank engines powering the new Type 4 Diesel electric locomotives now being constructed in quantity. Within the confines of a single paper it is not practicable to discuss details and experience with the full range, and it would seem most appropriate to concentrate on the engines for main line locomotives, as this application would appear to have most affinity with marine conditions, and therefore hold the most interest for the Institute.

DEVELOPMENT OF ENGINES FOR MAIN LINE LOCOMOTIVES

Form of Engines

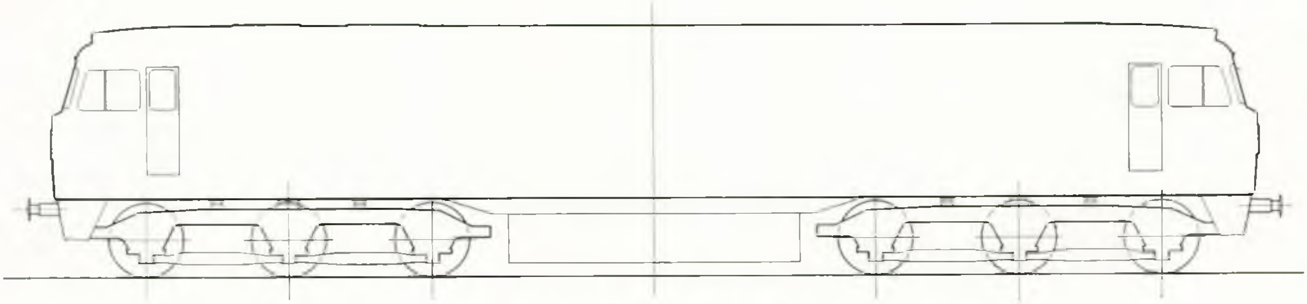
In this country, as on many of the Continental railways, four-stroke engines are predominant, whereas in North America the situation is reversed because there the principal manufacturer uses a range of two-stroke engines which has been highly developed on the strength of very extensive resources and experience. Only a small minority of British Railways' locomotives are fitted with two-stroke engines, the most interesting of these being the Napier "Deltics", remarkable on account of their novel cylinder and crankshaft arrangement exploiting the opposed piston arrangement, thereby offering an exceptional power/weight ratio. The specific dry weight is only 6lb./b.h.p. for the 18-cylinder engines used in pairs on twenty-two 3,300 h.p. Type 5 locomotives. This engine is, however, highly complicated mechanism and whilst giving notable service under close supervision on the East Coast main line, is not altogether suitable for run of the mill railway

TYPE 4 DIESEL ELECTRIC MAIN LINE LOCOMOTIVES



2,300/2,500 H.P. I.C.C.I. LOCOMOTIVE

Length over buffers 67'-11"
Weight in working order 136 tons
Engine h.p. per ton of loco. 17



2,750 H.P. C.C. LOCOMOTIVE

Length over buffers 63'-6"
Weight in working order 114 tons
Engine h.p. per ton of loco. 24

FIG. 1—*Comparison of standard design of 2,750 h.p. locomotive with earlier counterpart of 2,300 h.p.*

service. For instance in this particular case it has been agreed that the manufacturer should undertake the maintenance of these engines, as an exception to the British Railways normal practice of carrying out engine overhauls in its own workshops.

The numerous four-stroke engines of 800 to 2,750 h.p. used by British Railways have either the Vee or vertical "in line" arrangement of cylinders, the latter in case of the highest power engines being incorporated into a twin-bank layout having two crankshafts, each driving through step-up gears the output shaft coupled to the traction generator.

All these types are pressure-charged in view of the need to obtain an adequate power output from an engine of reasonable proportions, and in recent years charge-air cooling has been incorporated in several classes.

Over the last ten years various manufacturers have been able to raise considerably the rated outputs of their same basic designs of engine. In most cases the increase has been mainly attributable to substantial improvements in turboblower design, allowing pressure ratios to rise from 1·3 : 1 to 2·3 : 1 or more, associated also with charge-air cooling which has now become an accepted feature. These developments have raised the maximum b.m.e.p. of representative British traction engines from the order of 120lb./sq. in. to over 160lb./sq. in. In some cases maximum crankshaft speed has also been stepped up.

By such means, combined with improved design of components, particular types of engine are now offered with a continuous traction rating 30 per cent or more above that when the first orders under the modernization plan were placed. This increase, where it has been accomplished without worsening the reliability of the engine, has been a most welcome advance for obtaining a powerful locomotive in a compact form. As an example Fig. 1 compares the standard design of 2,750 h.p. locomotive with the earlier counterpart of only 2,300 h.p., which is appreciably larger and heavier. The increase in the power/weight ratio which has risen from 17 to 24 h.p./ton of locomotive weight is, however, also partly attributable to improvements in the design of the locomotive structure, as well as items of the power equipment besides the engine itself. The 2,750 h.p. locomotive is, incidentally, able to outperform even the most powerful of British steam engines.

Engine Construction

On the majority of engine designs developed since 1950, the structure is fabricated from steel castings and plate, in order to exploit the better strength/weight ratio as compared with cast iron. This is, unfortunately, an area where serious trouble can sometimes arise unexpectedly after engines have been in service perhaps several years, due to the onset of fatigue cracks in certain sections of the structure: repair and rectification may well involve completely stripping the engine.

Bearings

Thin-wall, copper lead precision bearings with a steel backing, adopted in the 1950's, represented a great advance by eliminating the specialized fitting and frequent attention which had been necessary with the former thick white-metalled bronze bearings. Certain builders apply a thin lead alloy flash to provide a soft running surface suitable for use with a non-hardened crankshaft.. Experience is indicating that this flash can have a very long life, because the flash absorbs dirt and reduces wear of the crankshaft journals. It is in fact hoped that crankshafts in future may prove able to last the engine's life of twenty or more years without needing to be re-machined or perhaps even to be removed from the engine.

A principal feature of one of the Continental designs of high-speed engine is the tunnel arrangement, wherein the main bearings of the crankshaft consist of roller bearings mounted on its circular webs. This design provides a very rigid and compact crankshaft, but so far it has not been altogether successful in British Railways experience, since there has been considerable trouble with shelling of the roller bearings and fretting of the crankcase housings. When trouble of this nature occurs with such an elaborate arrangement, rectification is both onerous and costly, and the expensive design refinement, far from being justified, becomes a distinct liability.

Cylinder Heads, Liners, Pistons and Rings

In many designs of engines, these items are amongst the most critical in view of the combination of high thermal and mechanical stressing which occurs in this area. There have been several epidemics of failures due to shortcomings in design, quality of materials, or manufacture, either separately or in combination, and these have become manifest particularly upon any uprating of the engine or extension of periods between top overhauls.

To obtain reliable service it is vital that proportions, wall thicknesses, fits and clearances are properly selected and achieved by accurate control of manufacture, and that there are no severe stress raising features at critical locations. Engine manufacturers have had to give very close attention to this aspect, and in certain cases carry out campaign changes in the course of widespread experience with their engines in service. For the same reason, it is necessary for the user to ensure regularity of maintenance and close control of the quality and cleanliness of the lubricating oil.

Whilst piston, liner and cylinder head defects have involved several types of engines, it is on some of the high-speed engines that the trouble has been most serious and persistent, and cracked heads and liners have been a serious problem. These failures in turn have in some cases allowed water to enter the cylinders which has caused some connecting rods to be overloaded and damaged.

On one of these types of engines, severe cavitation erosion of the water side of the cylinder liners was overcome by chromium plating the liners, but it was then found that the corrosion effects transferred to the crankcase surfaces.

Design trends in recent years, influenced by the general uprating of engine output, include the widespread use of oil cooling for the pistons, which are generally entirely or mainly aluminium, and the provision of four or more valves per head in the more highly pressed engines.

LUBRICATING OIL

Adequate quality of lubricating oil for highly rated pressure-charged engines is obviously essential(2) and the Supplement 1 detergent type H.D. oils used are covered by the railways specification incorporating the requirements of Defence Specification DEF-2101.B.

There can, however, be practical difficulties in using and mixing specification oils purchased from different suppliers, and under particular circumstances it is sometimes found preferable to employ proprietary grades which have been approved both by the user and the engine manufacturer.

Engine designers have had to devote very careful attention to the question of piston lubrication, to ensure that this is satisfactory both at full load and also for long periods of idling or very low load. At the same time they have naturally sought to keep lubricating oil consumption to a minimum, and to prevent undue coking.

Lubricating oil consumption varies considerably between different makes and designs of engines, but by far the lowest rate has been achieved on some of the medium-speed engines, whereas the consumption tends to be much higher on all the high-speed types. Over a two-year period, the best and worst average consumptions for individual locomotive classes were 0·38 per cent and 3·7 per cent of the corresponding fuel oil consumptions, applying respectively to a medium-speed and a high-speed engine design. For the majority of classes, however, the figures ranged between 0·7 and 1·8 per cent, embracing both medium and high-speed engines.

Apart from the direct consumption of lubricating oil due to it passing the piston and being burned, a major loss occurs when it becomes necessary to change the engine oil for any reason such as the build-up of sludge or acidity level, or the deterioration in its detergent properties. Generally, however, so long as the oil filters, normally of the bypass type, are performing effectively, the make-up oil is able to restore and maintain satisfactory oil quality for long periods, perhaps for 18 months or more.

A major cause of oil changing is dilution by fuel oil and certain types of engine have been particularly troublesome in this respect, and it has been necessary for the makers to introduce modifications to minimize the possibility of fuel leakage from the high pressure fuel system. The ideal solution is for the engine to be so designed that any fuel leakage which does occur cannot find its way into the sump.

All locomotives in service have engine oil samples extracted at regular intervals of every few days, depending on class, and these samples are subjected to the following simple tests at the depot:

a) Viscosity is checked by the rolling ball method, in which a comparison is made of the time taken by identical metal balls to roll down inclined tubes containing respectively the sample of engine oil and one or more standard samples, all held at the same temperature.

If this test shows the viscosity to be outside the limits, the crankcase oil is changed before the locomotive returns to service.

b) Water content is checked approximately by immersing electrodes in the oil sample. If the electric bulb in the circuit then glows there is at least ½ per cent of water in the oil, and the crankcase oil may need to be changed. An oil sample is sent to the Area Chemist for analysis, and the source of water leakage in the engine is investigated.

c) A blotter test indicates whether the dispersant properties of the detergent oil are being maintained in service. If after 30 minutes an outer ring of light coloured oil has formed round where a sample drop was applied to the paper, an oil sample is forwarded to the Area Chemist, but the oil is not changed unless the Chemist advises subsequently that it should be.

Spectrographic analysis of crankcase oil has also been given a wide trial, and although it is now being continued on a limited scale, there has so far been insufficient promise to justify the installation of further spectroscopes.

Where a mechanical failure of a component is preceded by a period of abnormal rate of water, corrosion or ingress of extraneous material into the engine, this analysis is able to give some prior warning, and enable remedial action to be taken before serious damage occurs. On the other hand, a number of mechanical failures occur more suddenly and cannot, therefore, be forecast by this means. Furthermore, experience has shown that random exceptional analysis figures sometimes arise which are not, in the event, indicative of any defect needing attention and therefore represent a false alarm.

As the system is essentially based on cumulative trends with the aim of showing up any substantial change from normal conditions, by far the most useful results are obtained when it is applied to a substantial fleet of identical engines maintained and sampled in a consistent and similar way. It is also evident that engines which use little oil are more appropriate for this analysis than others which use a lot of oil or need frequent oil changes. For this reason worthwhile results have not been obtained with high-speed engines which tend to fall into the latter category.

FUEL CONSUMPTION

Diesel fuel used by British Railways is purchased to B.S. Specification 2869:1957 Class A, but with a limitation of sulphur content to not more than 1 per cent.

Specific fuel consumption of traction engines has shown a steady improvement in recent years, and present day representative full load values of 0·36 to 0·37lb./b.h.p.-hr. are some 7 per cent better than the average for ten years ago. This is attributable to developments in fuel injection and combustion, and better gas flow, together with the fact that engines of a given size and form now carry a higher rating due to the general increase in b.m.e.p. and therefore the incidence of friction losses is not so great in proportion.

A characteristic of the Diesel engine is that generally its specific fuel consumption does not vary appreciably over the greater part of the working range, nor all that much between one make of engine and another. As a result fuel consumption is a much more predictable and consistent quantity than it was in the case of steam locomotives.

COOLING SYSTEM AND WATER TREATMENT

All engines are cooled by water, the temperature of which is controlled by means of thermostatically-operated valves which allow the radiator to be bypassed when the coolant temperature is below a given level, and this feature provides for quick warming up. Radiator fan speed is also controlled thermostatically in many cases. For regulating the lubricating oil temperature the modern trend is to incorporate a heat exchanger in the coolant circuit rather than pass the oil through an independent set of elements in the radiator.

In general, the use of anti-freeze is not considered justified for main line locomotives, in view of the expense of treatment for the large quantity of coolant involved. However, a degree of protection is provided by the incorporation of either self-draining radiators or external radiator shutters.

Cooling water treatment is a subject that has given rise to much consideration and controversy, in view of the complexity and variations in the problems which arise depending on engine types and, also, local conditions. It is generally acknowledged that a suitable treatment is highly beneficial in order to avoid serious deterioration of waterway surfaces caused by a combination of erosion, electrolytic corrosion and cavitation, the incidence of the latter being greatly influenced by the effects of vibration of particular components.

Whilst sodium bichromate treatment was widely used initially, it has been discontinued on account of the medical risk of dermatitic infection. Alternative treatments by sodium benzoate/sodium nitrite and by soluble oils have been employed by different Regions in the meantime, but it is now proposed to standardize on soluble oil treatment. This, however, involves fitting oil-resistant grades of flexible hosepipes throughout the locomotive fleet.

PROTECTIVE DEVICES

Safeguards are provided to prevent the continued operation of the locomotive when abnormal conditions occur which could cause damage to the engine or other equipment. The engine is automatically shut down and the driver warned by the shining of a red alarm lamp on his desk if the engine overspeeds and, also, on most classes, in the event of low lubricating oil pressure or low coolant level or pressure. Another alarm lamp, blue in colour, gives a general warning to the driver without any automatic shut-down in the event of various fault conditions with the lubricating oil, cooling system or electrical equipment, etc. A further series of indicator lamps elsewhere in the locomotive enables the nature of the trouble to be identified, and appropriate action to be taken.

ENGINE MAINTENANCE

To obtain good availability and utilization, which is so essential with an expensive machine like the Diesel locomotive, there is a constant endeavour to increase the inspection intervals and periods between engine overhauls. Much improvement has already been made partly as a result of various design and manufacturing refinements introduced by the engine manufacturers, and partly by the steady development of optimum schedules for inspection and preventative maintenance. These schedules, which stipulate the nature and frequency for attention at depots to the various individual items, are issued for each main type of engine, and are revised from time to time in the light of experience previously gained.

The railway has established that, under the conditions prevailing, it is in general more economic to have engines overhauled in its own workshops than by contractors, and this is the policy which has been adopted, except in certain instances for very specialized engine types such as the Napier "Deltics". To rationalize this work in the future, the overhauling of each make of engine is being concentrated at particular works.

In the case of Diesel electric locomotives, top overhauls are normally carried out with the engine in position in the locomotive. Furthermore, when it is necessary to remove the engine for a heavier overhaul, this is done only at main workshops, so as to avoid the complication of providing extensive lifting facilities at the various depots. In view of these practices it will be appreciated that any extension in engine overhaul periods is likely to provide a direct improvement in the availability of the locomotive itself. At the present time, the established types of medium-speed engines are achieving 8,000 to 12,000 hours between top overhauls, and further extension is envisaged. Table III sets out the two broad classifications of works overhauls and the approximate frequency with which it is anticipated they should occur in the future when teething troubles have been fully overcome.

TABLE III—CLASSIFICATION OF WORKS OVERHAULS TO ENGINES

i) *Intermediate Overhaul*: *48-60 months*
Overhaul of cylinder heads, pistons and connecting rods. Check crankshaft alignments. Examine main and big end bearings. Overhaul intercoolers, turboblowers, governors. Change fuel pumps and water pumps.

ii) *General Overhaul*: *96-120 months*
Complete strip-down and overhaul of all components. Re-assembly and load test.

The situation is somewhat different in the case of the Diesel hydraulic main line locomotives, all of which are allocated to the Western Region. These locomotives are fitted with high-speed engines which are relatively compact and light-weight, and furthermore are not encumbered with the integrally mounted main generator of the Diesel electric locomotive. In consequence, it is common practice for these engines to be exchanged at depots and the displaced engines sent to Swindon Works for overhaul and, in fact, about half the engines of this type overhauled there have been removed from the locomotives at depots rather than the works. Against the high proportion of the engines on Diesel hydraulic which are changed each year, only a very minor percentage of medium-speed engines are removed from Diesel electric locomotives.

The facilitity for quick interchange both at depots and works fortunately offsets broadly the adverse effect on locomotive availability which would otherwise arise from the distinctly inferior reliability and overhaul period of the bulk of the high-speed engines as fitted to the Diesel hydraulic locomotives, and which is emphasized by their much higher incidence of locomotive casualties in service on a mileage basis, attributable to engine defects. Furthermore, the total engine maintenance cost for these locomotives is much above that for the principal classes of Diesel electric locomotive, not only because of the frequency of attention needed by these high-speed engines, but, also, on account of the additional work in dismantling and assembling the more complex design of engine.

It is still too early to quote reliable figures in the foregoing comparison, since insufficient experience with full repair cycles has yet been obtained to be sure that such values have stabilized at true levels. Nevertheless the trend to date is so decisive that, although the comparison may alter in degree, there is no reason to suppose that there could be any reversal in the relative merits. It should, however, be added that whilst this is the conclusion for the types of high-speed engine at present in wide use on British Railways, it is appreciated, and indeed hoped, that certain other designs of high-speed engines may be able to compare more favourably with the medium-speed engines. In this connexion, trials with several engines of a British design have so far shown most promising results, so much so that a smaller version of the engine is being incorporated into the new design of 650 h.p. Type 1 locomotive. In this particular case, it is considered that the combination of this engine and hydraulic transmission will prove very suitable and economic for the type of service involved.

CONCLUSION

This paper has touched upon a number of aspects, several of which could each form the subject of an entire paper, but the main purpose has been to indicate the broad requirements and features of railway Diesel traction, with particular emphasis on experience to date with the application of different types of engines in main line locomotives.

Now that a high proportion of the Diesel units required under the modernization plan has been delivered, the emphasis of the next stage will be to consolidate. As a range of standard types of locomotives has been established, design developments for the next few years are likely to be mainly confined to details, so as to improve reliability, reduce maintenance requirements and extend overhaul periods. It also envisaged that the specific rating of engines will continue to rise still further as a result of higher pressure charging and increased mean effective pressures made possible by developments in the design and manufacture of such components as cylinder heads, pistons and bearings in particular.

Diesel traction has already established itself by the higher level of traction performance it has provided, and by the very substantial economies produced particularly in respect of expenditure on fuel and on servicing and maintenance facilities hitherto required all over the country for steam locomotives. The next few years should show still further substantial advantages, as certain lingering teething troubles are finally overcome, and as all the staff concerned become proficient in exploiting to the full the operational advantages of this type of traction.

ACKNOWLEDGEMENT

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Discussion

Mr. J. Calderwood, M.Sc. (Vice-President) congratulated the author on an ideal paper which gave a large amount of information, without padding, in the minimum of space. It was an example that he hoped other authors would follow. The presentation was almost another lecture in itself, and there would no doubt be a number of points that speakers would wish to raise on what had been said as well as on what had been written.

The author stressed the need for reliability in locomotives, and everybody would agree with him, but the meaning of the word "reliability" was rather different in a locomotive context from the meaning in a marine context. The worst that could happen with a locomotive breakdown was that many people might be seriously inconvenienced. In a marine sense it could mean the loss of a ship and of lives. Further, the locomotive would never be far from some place where it could be repaired, whereas in the case of a marine engine it might be thousands of miles away from the nearest repair depot.

There was no doubt that there was an increasing interest in the higher speed engines for marine work, large and small, and the paper was very appropriate at the present moment.

One aspect in which the locomotive engine suffered more than the marine was what the author had described as the dynamic effect of running on steel rails. Many white metal bearings which were perfectly satisfactory in other forms of service broke up in a month or two when used in locomotives. Perhaps the author had some experience which confirmed this. Welded frames which stood up well under marine conditions were very liable to crack when put into locomotives. This had occurred with quite a number of engines of different types in different countries.

He was grateful to the author for having made perfectly clear what "availability" and "utilization" meant. It was amazing how many people confused the two; in fact, he had heard a very senior person (in the locomotive world) refer to the "availability" of Diesel engines on a particular service of British Railways as being 6 per cent. It was, in fact, actually a reference to the "utilization" on this particular section of line, where the "availability" was over 80 per cent. He was pleased that the author had put down something perfectly clear that people could read and understand.

The author referred to the fact that the internal combustion engine had been first tried on railways in the last century. The first of which he had personal knowledge were on the Egyptian State Railways. They had two railcars with 20 h.p. petrol engines about 1905-06 which ran for some twenty years afterwards, grossly under-powered.

Further on in the paper the author referred to the fact that hydrostatic transmission had had no success. This was, he believed, mainly because it had not been developed to any extent. The only place he could recall where it had been tried was Buenos Aires Great Southern Railway, where a locomotive was fitted with hydrostatic transmission in 1927, and according to the information he had, the hydrostatic transmission worked extremely well and effectively. Unfortunately, the locomotive itself failed, but the failure was not due to the transmission. It had always surpised him that more work had not been done on this possibility. There were difficulties and snags but it was worth further study. The author's opinion on this would be interesting.

Mr. Harrison had referred to the control gear of the Diesel electric being more elaborate than the others. This was rather surprising; he would have said that as compared with the multi-engined railcar, and the control gear associated with the gear changes, etc., electric transmission was not very complicated. Perhaps the author would make some more observations.

Most marine engineers' mouths would water at the reference in the paper to 12,000 hours between top overhauls, which was much more than was generally possible in ships. However, turning to Table III, which stated what was involved in a top overhaul, most marine engineers would regard this as a major overhaul and not a top overhaul. He was sure that much work of a minor nature was done between top overhaul on fuel pumps and various other things which the marine engineer would rate as top overhaul.

Turning to the question of oil, much attention was paid to small quantities of water in the oil: when there was ½ per cent of water it was thrown out. Experience had shown in the marine field that water in considerably larger quantities did not do the slightest harm in crankcase oil so long as the engine was running. He recalled one case where a vessel crossed the Atlantic with something like 50 per cent of water in the oil without any trouble. He would have thought that in the case of locomotives it was possible to be a bit more liberal in the allowance, whilst at the same time having an indication that something was wrong, so that an investigation could be made as to the source of the water.

The author did not appear to be very enthusiastic about spectrographic analysis, but it had been shown to be of some value in finding trouble.

With regard to water treatment, he was very surprised that sodium bichromate was dropped "on account of the medical risk of dermatitic infection". He would have thought that with the variety of waters that locomotives had to put up with it was very dangerous to use bichromate as with certain impurities in the water it could greatly accelerate corrosion.

The author referred to protective devices, and particularly signal lamps. It would be of interest to know how their signal lamps worked. If the lamp bulb happened to be defective what happened then? The best system he had seen on a locomotive was a bulb which was in series with the resistance and kept a small light normally, and if there was a fault the resistance was cut out, so the light became bright and it was possible to see the fault and to know at any time whether in fact the lamps were working.

Finally, he wished again to congratulate the author on a most interesting and instructive paper.

Mr. C. C. J. French (Member) said that it was always valuable for those engaged in the design and development of Diesel engines to hear of the experience of operators. As the author had pointed out, British Railways had in the past ten years built up a large fleet of power units utilizing the whole range of Diesel engines from relatively heavy, slow speed models to the high speed, ultra-lightweight Deltic engines. Although it was understandable that there was less incentive in this country for the reasons the author had explained, to use lightweight engines which offered very considerable specific weight advantages, it would appear from the paper that it was due to service experience that the high speed engine was out of favour. Although the author did not list the faults of the various designs (in fact, he had given rather more in his presentation that evening than in the paper), it was interesting to consider in more detail, the various problems he mentioned.

Apart from the special problem with the main bearings of the Maybach engine, it would seem that cylinder heads, liners, piston and rings had been the major causes of trouble, especially with the high speed engines. Engine loading would be a function of peak gas pressure, of piston speed and of b.m.e.p. Peak gas pressure was primarily a function of boost pressure, since the compression ratio was set by starting considerations, although it could, of course, be trimmed by adjustments to injection timing and injection rate. There was no reason why the speed of the engine should have any great effect, and in fact the high speed engines with indirect injection would have lower maximum pressure than the medium speed engines. Piston speed tended to be set by breathing considerations and there was no large difference between the various locomotive Diesels. The Maybach and M.A.N. engines, at 1,500 r.p.m., had piston speeds of 1,965 and 2,065ft./min. respectively, that of the Deltic, at 1,500 r.p.m. was 1,810ft./min. Of the medium speed engines, the English Electric, at 850 r.p.m., had a piston speed of 1,700ft./min. and the Sulzer, at 800 r.p.m., had 1,888. Incidentally, the new Sulzer Vee-engine at 1,050 r.p.m. would have a piston speed of 1,925ft./min. The high speed engines then, from these figures, had piston speeds 10-15 per cent above those of the medium speed engines, which was not a large difference.

If the answer to the service problems with these components was not found in gas or inertia loadings, it must presumably lie with thermal loadings. Tests by his company, with direct and indirect injection engines at ratings up to as high as those used at present in locomotive service, had shown that thermal loading with any one type of combustion system was primarily a function of b.h.p./sq. in. piston area, i.e., the combination of b.m.e.p. and piston speed.

Considering the published values of b.h.p./sq. in. area, for the high powered Diesel engines, the English Electric 16CSVT, of 2,700 b.h.p., had a figure of 2·15. The twin-bank Sulzer for a similar horsepower was somewhat higher, at 2·41, and would seem to give satisfactory service, since the author said that it had been ordered in quantity. The two high speed engines, the M.A.N. and Maybach, had b.h.p./sq. in. piston area of 2·65, and this figure was some 10 per cent up on the Sulzer engine. The Sulzer Vee-engine, however, which he had already mentioned, but which was not yet, he believed, in service with British Railways, would still be a medium speed engine at 1,050 r.p.m., but the b.h.p./sq. in. would be appreciably higher still, at 3·11. Hence one could either predict that the Sulzer Vee-engine would run into service troubles, due to its high thermal loading, or one could believe that the reasons for such troubles in the high speed engines had not yet been uncovered. He believed the latter to be probable.

So far as thermal loading was concerned, it was not the gross heat losses which were important, apart from their use in radiator design; it was the local heat flows which occurred in various parts of the wall of the combustion chamber. It was known from experimental work that these heat flows could be very high at the ratings being considered, and this was especially so in the indirect injection engine. Both the Maybach and M.A.N. engines used indirect injection, and this imposed more severe problems on the designer, especially in the effective cooling of the cylinder head. These problems could be overcome. For example, with the Comet, at these high ratings it was sometimes found necessary to recommend the use of coolant drillings through the head deck, between the valves, in order to get satisfactory cooling. It was somewhat easier to do this on a Comet with a combustion chamber at the side and a clear space in the centre of the head than it was in engines with a central combustion chamber.

In connexion with the problems of cooling highly rated engines he had noted with interest, the author's section on cooling systems and water treatment. While he appreciated that high speed, lightweight, engines did have a special problem so far as cavitation erosion of cylinder liners was concerned, and that water treatments had been devised to mitigate this problem, it was somewhat alarming that a variety of substances were in many cases added to coolants without much appreciation of the thermal effects of these additives.

His own company, for the past three years or so, under a research contract from the British Ship Research Association, had been carrying out an investigation into the transfer of heat from metal to the coolant under a wide range of conditions. They were at the moment in the process of setting up a number of rigs for life tests with additives in the coolant, and he was not therefore able to give any detailed results. Enough was known, however, to say something concerning one soluble oil which had been tried in a concentration of 1 per cent. Shortly after the soluble oil was added, the metal temperature at the points of highest local heat flow would have gone up by 30 deg. C. or so in a direct injection engine at these ratings. In the indirect injection engine, with appreciably higher local heat flows, the increase in metal temperature might well be 50-60 deg. C. It was quite possible that long-term effects might be much worse than this.

Some other additives on which preliminary tests had been carried out had given similar results. The tests were being continued in the hope that an additive would be found which was an effective inhibitor without serious heat transfer side effects.

From their limited experience, however, he would have thought that, if soluble oils were used as additives in an attempt to reduce cavitation erosion on the high speed engine mentioned by the author, or for other reasons, it would have added greatly to the thermal problems of the cylinder head and liner. He realized, of course, that inhibitors might have to be used, but it was hoped that one could be found that was not an appreciable thermal barrier.

Commander E. H. W. Platt, M.B.E., R.N. (Member) said that going casually through the first part of the paper he had been struck by the similarities between the requirements for marine propulsion engines and locomotive engines. Clearly reliability was the first essential, although, as Mr. Calderwood had said, the yardstick might be somewhat different between marine and locomotive application. Capital costs and running costs, including fuel costs carried probably very similar importance in the two cases. However, having read the paper and thought more about it, he was struck by the enormously different reasons for the adoption and growing use of the Diesel engine in the merchant ship from that which had influenced its introduction on the railways.

If he had read correctly between the lines of the second part of the paper, total electrification seemed to be the ultimate economic propulsive method for a fully rationalized railway network with system layout and operating schedules providing the highest possible utilization. Under such conditions the reduction in availability inherent in Diesel engine maintenance requirements seemed to be liable to make inroads into utilization, but clearly with a system in an intermediate stage of development, such as British Railways at present, where the utilization was inherently somewhat low, the Diesel locomotive provided an excellent means of improving the efficiency of the locomotive force with a substantially lower capital expenditure than that required for wholesale electrification. Hence he concluded that the Diesel entered the locomotive field primarily because it achieved high availability with a smaller labour force than the coal-fired locomotive, with a low capital outlay and reasonable running costs. In contrast, in ship propulsion the field had been held in a large range of shipping until recently by steam turbines, but now, primarily because of its low fuel consumption, the Diesel engine was beginning to replace the turbine in a number of ships which traditionally had been propelled by turbines in the past. Provided that Diesel engines could be kept running efficiently whilst maintaining availability closely approaching that of the steam turbine plant, they would continue to be used in increasing numbers. This was digressing somewhat from the subject but he could not help speculating as to what might have happened on the railways if steam turbines, in association with perhaps oil-fired boilers, had been developed, perhaps reaching the degree of sophistication which they were to have in marine plants today. One could perhaps envisage such locomotives achieving a very high degree of reliability, perhaps higher than that inherent in Diesel locomotives. At the same time, he wondered what had happened to the gas turbine locomotives a small number of which appeared on British Railways some ten years ago. Not much was seen of them now.

Just before coming to the meeting he had been handed a note by one of his staff on quite another subject which concerned America. It mentioned that some General Electric industrial gas turbine units had been burning residual fuels in the Union Pacific locomotives, 55 of which had been built and operated and between them had covered 24 million miles, with total turbine fired hours of about 1·3 million. It would be interesting to know what considerations had influenced British Railways away from gas turbines, about which they appeared to be enthusiastic a few years ago. The answer might be that in the United States there were very long hauls at sustained high speeds which were more suitable to gas turbines than the relatively short hauls of the British railway system.

Mention was made of the shock and vibration from rails, and Mr. Calderwood had also referred to it. This must be a problem with locomotive application. However, he felt that in this case perhaps the marine engineer was in a slightly worse position than the railway engineer, in that the external forces to which he was subjected were solely in the control of nature, whereas the locomotive engineer was able, through liaison with his track engineers, to do something about this. Was Mr. Harrison's department able to specify maximum loading requirements and to work in association with the track engineers to avoid these difficulties?

When he compared his daily experience as a commuter with the smoother ride he had on the French main lines he wondered whether more could be done in this respect on British Railways.

Returning to questions of utilization and maintenance, he shared the envy expressed by Mr. Calderwood concerning the 12,000 hours between top overhauls and the five and ten year interval between major overhauls (which Lloyd's Register of Shipping were not able to grant in the marine field); but, seriously, quite apart from the difference in the actual overhaul routine to be carried out, there was the question of the rating of the engine and the proportion of service during which the engine ran at a specified continuous service rating. In ships with a high utilization, such as tankers and bulk carriers, the proportion of time at the specified continuous service rating was often as much as 88 per cent of the total running time. Would the author indicate what proportion of time locomotive engines spent at their specified service rating, and also, if this was applicable, the percentage rating at which the maximum amount of work was carried out?

With regard to protective devices and warning lights, he had been interested to notice that there was only rather casual reference to the action which might be taken by the crew, and in his lecture Mr. Harrison pointed out that the locomotive crew were not normally technically trained. One wondered whether there should not in fact be a separate man on the locomotive, to replace, as it were, their old friend the fireman, who could well be of higher technical calibre than the driver. He would be rather more equivalent to the flight engineer on an aircraft, and able to go back into the locomotive and deal with trouble as it was indicated on a warning device. He was not, of course, suggesting that there should be alongside the driver a man with a degree in mechanical engineering; he would not wish to see that rugged character, the engine driver, losing his authority altogether. He had not been able to find anything in English literature on the subject but there was that American classic, Casey Jones:

> "Put in your water and shovel in your coal,
> Put your head out of the window and watch the drivers roll,
> I'll run her till she leaves the rail,
> Because we're eight hours late with the Western Mail".

With locomotive affairs in such capable hands as those of Mr. Harrison there was no likelihood of the mails running late. Any man who could give a paper containing so much information in such a short space was an engineer whom marine engineers were proud to have in this hall.

Mr. R. H. Chamberlin said that he thought the author had given an excellent survey of the entry and first decade of usage of Diesel engines in quantity service on British Railways.

With regard to the author's comments on Deltic engines and the Type 5 locomotives, it was his feeling that rather less than justice had been done. He did not expect that everyone would agree with him but there were a few points that he wished to make in this connexion.

In the paper "high speed" engines suffered somewhat, and he wished now to think aloud about the question, "Is the Deltic a 'high speed' engine just because its crankshafts rotate at 1,500 r.p.m.?" The Deltic's mean piston speed was only 1,810ft./min. compared with the "slow speed" Sulzer engine's piston speed of 1,890ft./min., and the Paxman's 1,940ft./min. Its crankshaft journal rubbing speed was 1,670ft./min., which was the same as the Sulzer engine and well below the "slow speed" E.E. 16CSVT's speed of 1,836ft./min. Considering the maximum r.p.m. components, one found that the blower speed of the Deltic was 8,580 r.p.m. compared with the turbo-blower speeds of 17,500, 16,200 and 28,000 for English Electric Co., Sulzer and Paxman engines respectively.

Most engineers would probably agree with him that with regard to engineering parameters that really mattered, the Deltic was not a "high speed" engine.

He would leave any comments on high speed engines, therefore, to other people.

With regard to Mr. Harrison's comments that "the most interesting of these (two-stroke engines) being the Napier Deltic's . . . offering exceptional power/weight ratio . . . 6lb./b.h.p. . . . used in pairs on the twenty-two 3,300 h.p. Type 5 locomotives", he could only modestly concur; but the author then went on to add, "This engine is a highly complicated mechanism", and he disagreed with this. Two pistons in a ported cylinder liner were hardly complicated when contrasted with one piston in one cylinder liner with a cylinder head with complex cooling passages housing two or four poppet valves made of special heat-resisting steels, stellite welded on valve seatings, valve springs, tappets, adjustments, push rods and valve-operating camshafts. If nothing else, the opposed piston two-stroke engine was basically simple.

With regard to Mr. Harrison's comment that the Deltic in the Type 5 locomotive was "giving notable service", he wished to quote the "locomotive" and "both engines serviceable" availabilities for the past two years in support of the statement, whilst at the same time thanking him for making the railway records available for this purpose.

From August 1961 to August 1962 the Deltic "twin-engine" availability figure was 96·3 per cent. For August 1962 to August 1963 it was 97·8 per cent.

The corresponding Type 5 locomotive availabilities were 80 per cent for the first year and 88½ per cent for the second year of operation. It might be of interest to record that from August 1962 to August 1963 the Type 5 locomotive ran 3,750,000 track miles. The gross operating hours of Deltic engines in British Railways as of August 1963 were 300,000.

Returning to the paper there was the statement that the Deltic, whilst "giving notable service under close supervision on the East Coast main line" was "not suitable for run of the mill railway service".

He was quite unaware of any special treatment, or enhanced supervision, or difference in personnel between Eastern and other Regions, and could not see any reason for the Type 5 locomotive not being suitable for "run of the mill" operation. The only pertinent comment he could make was that the Type 5 locomotives were so heavily utilized on their present diagrams that no other duties could possibly be fitted in at present without increasing their numbers; and, of course, this would be a very good idea.

With regard to the decision concerning overhaul at the makers' works, this exception to usual railway intentions was surely just sound finance; it was much cheaper not to set up facilities for overhaul in the railway work shops but to drop the Deltics in at Liverpool instead, as the number of engines involved was only 50.

With regard to lubrication, the use of a Supplement 1 oil conforming to DEF. 2101B requirements was in general suitable for all modern railway Diesel engines.

He had a warning, however, for those makers using copper-lead bearings, copper oil cooler tubes and "bronze" caged ball and roller races. At oil temperatures not far above those at which many present components were now operating, the oil additive zinc-di-thiophosphate was waiting to start corrosion problems for the unwary, which category included his own company with their copper-rich alloy piston crowns.

For all other known oil additives indium infusion of the "attacked" copper alloy surface gave a very good standard of protection up to 250 deg. C., which was generally more than adequately high.

For oil consumption measurements of Deltic engine No. 422 before and after 4,000 hours of service use, the typical figures of 5·0 pints/hr. new and 6·68 pints/hr. after service at 1,650 b.h.p. and 1,500 c.r.p.m. were obtained. Expressed as a percentage of the fuel consumption these oil consumptions were just below and above 1 per cent respectively.

It was hoped that the Deltic element in these comments would be forgiven, but until a few years ago he was exclusively an aero-engineer, so it was only of Deltic experience in the Type 5 locomotive that he could speak with some assurance.

Finally, he wished to record that all comments expressed were entirely his own, and did not necessarily reflect the views held by his employers.

MR. V. H. F. HOPKINS said that the author had chosen well to concentrate on main line engines, particularly of the medium speed class, as having most affinity with marine conditions. The two applications had one need in common, outstanding among several listed, namely, reliability, leading to long periods between overhauls.

The medium speed engine referred to in Table I, for Type 3 locomotives, which was of 10-in. bore, had adequately demonstrated its distinction in this regard, in both rail traction and marine service. If wear rates had a bearing on reliability, as obviously they had, the longevity of the major running components was remarkable. To quote just a few facts, with average maximum cylinder liner wear of 0·001in. in 4,000 to 5,000 hours, less than one-sixth of the maximum permissible wear would be reached in a 30,000 hour general overhaul period, equivalent to about ten years rail service, and this without water side attack. Since this type of engine had been in service no cylinder liners had been replaced purely for reasons of wear, so far as he was aware. The same remarks applied to crankshafts, with an even longer life, and other typical figures included main bearings for 70,000 hours and big end bearings for the ten-year life.

Intermediate overhauls were now being considered for establishment at half the major period mentioned, i.e. 15,000 hours. When piston rings were changed and although ring groove life averaged 20,000 hours, it might be economically sound to deal with some cases at the 15,000 hours period with the first "over-width" ring. Following on Mr. Calderwood's reference, this 15,000 hour major overhaul period would be accompanied by cylinder head attention at half that time, and, of course, the other routine maintenance and things of that sort to be carried out weekly or monthly as the case might be.

In the case of marine applications, something like half the number in service were running on Class B fuel, and a difference in reliability and life was indiscernible. Incidentally, the fuel cost saving which these engines enjoyed, if it could be applied to British Railways, would certainly provide economies in the seven figure range. However, since railcar engines might not digest Class B fuel so well (although he wondered about this), two fuel storage systems would be necessary, with all the attendant complications, and the author might not wish to countenance this. His comments would be appreciated, and perhaps some information was available from France, where he understood some fuel grades inferior to Class A had been in use.

On the high speed engine, it seemed hard that the author had had to indict the type because of the failure of the foreign designs to compare satisfactorily with the medium speed types. However, it was noted that the door had been left open a little for certain other British four-stroke designs to compare more favourably. Not only was the higher speed engine more suitable for hydraulic transmission but its cost per h.p. should show to advantage. Its fuel and lubricating oil economy could be of the same order as for the medium speed engine.

With regard to the author's conclusion that the specific ratings of engines would continue to rise still more in the next few years, it was of interest to record that over the last 25 years, during which the b.m.e.p. had been about doubled in engines of the same basic type as the 10-in. bore class to which reference had been made, the life and reliability values had also been enhanced, and he saw no reason why this relationship should not continue to hold at the present level whilst the turbocharge-cooling "avenue" recently entered was exploited to the economic and technical limits imposed by the present orthodoxy of design. This would certainly embrace another 25 per cent increase in b.m.e.p. and possibly some 10 per cent in mean piston speed, but maybe in the meantime the high speed engine would "come into its own".

MR. L. R. C. LILLY said that he would like to comment on the exhaust smoke from Diesel-engined locomotives. This was not in fact mentioned in the paper, though clearly in such a comprehensive survey the author could not be expected to include everything.

One had hoped that the amount of smoke given off by Diesel locomotives would be a much greater improvement over that emitted by steam engines than in fact had proved to be the case, and the smell was, in his opinion, no improvement over that of steam and coal: indeed much less pleasant.

Whenever he had boarded a train headed by some type of Diesel locomotive that he had not met with previously he had attempted to examine the exhaust as the train moved out of the station, and later, when cruising at speed. When pulling out of the station the smoke from all types was considerable, but it appeared to him that the Western Region locomotives fitted with Maybach engines with pepperpot pre-chamber combustion systems gave less smoke when pulling out, and a clearer exhaust when cruising than the locomotives fitted with English Electric or Sulzer direct injection engines. The direct injection two-cycle Deltic locomotives appeared about equally as good as the Maybach engines when cruising, but there was much blue smoke when pulling out from rest.

If eventually the rulings concerning smoke that were soon to be applied to road vehicles in this country came to include locomotive engines, it might be that the cleaner exhaust given by pre-chamber engines using pepperpot systems (e.g. Maybach, Mercedes Benz or M.A.N.) or compression swirl combustion systems such as that of the Ricardo Comet (e.g. Werkspoor-Cockerill-Ougrée) might become necessary, unless the direct injection systems could be improved to give less smoke. Otherwise it might even be necessary to use electric traction entirely and so eliminate all smoke.

With regard to twin-engined versus single-engined locomotives, the author stated in the paper that the advantages of still having one engine if the other failed was not very important, since the train could rarely complete its diagrammed working on one engine only. However, it could at least get off the main line and wait for a replacement locomotive, and this surely was an important point.

Furthermore concerning the use of the twin-engined locomotive with two small high speed engines versus the single-engined with one large medium speed engine, it appeared to him that the case against the high speed engine was simply less reliability (he said "simply" with his tongue in his cheek rather because this was a very important point). This reduced reliability was, in some instances, due to increased complication and increased sensitivity to any deviation from the correct conditions of operation, such as small changes of injection timing, a high ambient temperature leading to too high a crankcase oil temperature, or a slightly worsened degree of air filtration. However, it seemed to him that it was only a matter of a few years time before these faults would be rectified, and then the advantages of more room, less weight, and the easier removal of the smaller engine for maintenance would become more obvious.

Mr. A. J. Edwards (Graduate) said that one of the slides showed a cylinder liner which had been subject to cavitation. The actual cavitation marks were a longitudinal line. He had been led to believe that this kind of cavitation was due to one or two modes of liner vibration. What was the author's opinion? There had been mention that evening of vibration induced from the actual railway lines themselves. He wondered to what extent vibration problems were due not to poor, but to inadequate engine balancing.

Mr. J. H. Aubrey, B.Sc. (Hons.) (Associate Member) and **Mr. T. L. Wynne** in a joint contribution presented by Mr. Aubrey, said that in writing the paper the author must have been aware of the unique position he had held in recent years as the engineering leader in the dieselization programme. Considering the large number of "dyed in the steam" railway engineers who were still with British Railways, it must have been no mean feat to change a whole course of history in railway engineering over a matter of ten years. The change from some 18,000 steam locomotives to 9,000 Diesel locomotives in this period of time spoke for itself.

Mr. Aubrey raised a number of technical points, speaking as a marine engineer who had had contact with the dieselization programme through the building by his company of over 800 engines for the Type 2 and Type 4 locomotives. These engines were to a foreign design, and despite the considerable technical liaison and co-operation with the engine designers, even to the extent of the designers approving material specifications and production techniques in some cases, minor troubles had still been experienced. The greatest difficulties had occurred with material specifications, particularly for grey iron castings, and, as every engineer knew, with highly stressed components, even minor changes in specification could cause a considerable change in the life of a component. He agreed, therefore, with Mr. Harrison's general remarks that the fullest "know-how" was necessary in the building of locomotive traction engines to ensure the highest degree of reliability, which was the prime consideration of a locomotive engine no less than with a marine engine.

Bearing in mind the considerable flexibility of the locomotive frame, and the very high acceleration and deceleration rates to which it was subject, he asked what were Mr. Harrison's views on the "stiff" as against "soft" mountings for engines in locomotive frames. Most of the engines in the present Type 2 and Type 4 locomotives were mounted on a $\frac{9}{16}$in. rubber pad which must constitute a very "stiff" mounting, which would not isolate the engine from the larger distortion movements or shock forces in the locomotive. A very considerable amount of experience has now been accumulated on the soft type of mountings in ships, where the Diesel engines were isolated against extremely high shock conditions, and Mr. Harrison could be assured that the reliability of this type of mounting was very high.

Again following the marine analogy, what was the author's view on the two-stroke versus the four-stroke engine, since it appeared that railways in North America had tended to opt entirely for the two-stroke, which accorded with present marine engineering experience, and yet British Railways had standardized on the four-stroke. Would the reason be that no suitable medium speed two-stroke engines were available in this country?

With regard to fuel consumption, it was noticed that a limitation of 1 per cent on sulphur content was put on all Diesel fuel used by British Railways. There was no doubt that the use of such a fuel with a low sulphur content would be beneficial to the operating reliability of an engine, but in view of the success in recent years with Diesel engines burning the heavier grade of fuel, was it Mr. Harrison's intention to allow this type of fuel to be used in the future, and would he indicate whether the resulting economy could be justified by British Railways?

It was presumed from the author's remarks in the conclusion that he considered future development to lie in increasing b.m.e.p. as distinct from increasing crankshaft speed, and in view of the tremendous advances in this respect in recent years, did Mr. Harrison consider that the economic life of the present engines having 160lb./sq. in. b.m.e.p. was likely to be affected by this rapid technical advance? The operating life of the present engines was, of course, designed for 20 years and was not in doubt.

With regard to water treatment for the cooling system (also touched on by Mr. French), it was noted that the soluble oil treatment had now been standardized. Recent work had shown that the thermal barrier built up on the surface of the liner by the use of this oil was very considerable and would inevitably lead to higher operating temperatures in the liner wall. Had this factor been fully considered by British Railways, since with the more highly rated engine the temperature of the liner wall in contact with the ring approached the critical maximum value above which scuffing would tend to occur, if lubrication conditions were marginal? Admittedly, higher wall temperature would minimize corrosive wear, but considering the low sulphur content of the fuel used this was not likely to be a critical factor.

Correspondence

Mr. L. Irvine-Brown (Member) wrote that the very nature of the paper allowed the author to steer clear of the more controversial questions such as whether or not the modernization programme was necessary or done in the correct manner—the writer's view being that every effort should have been made to electrify and that the policy carried out had given the system an enormous number of Diesel locomotives of little real value. Whether or not this view was justified was difficult to say, but the fact remained that dieselization had been accompanied by a fall in traffic and a catastrophic rise in the loss on the railways, and the two could be linked.

Discussing the financial angle, the author left out two quite large items on the capital side which could not be separated from the cost of dieselization and they were the track and the new maintenance facilities. On the first, many railways had found that track which had been perfectly sound under steam, became dangerous when subject to the punishment of the motored bogie and this did not exclude the U.S. In Malaya, Diesels had to be withdrawn until the track had been reconstructed. In Queensland they managed no less than 33 severe derailments on their main line in one year. On work shops, the smoky caverns which served for steam would never do for the new era which called virtually for air conditioning for the finer work.

On performance the author made the almost incredible statement that the latest mark of Type 4 Diesel was "able to outperform even the most powerful of British steam engines". This was a comparison between the latest and most highly developed form of the Diesel engine worth something of the order of £120,000 and a 1938, hand fired, coal burning steam unit which represented a capital outlay of about £10,000. Nor was the statement necessarily correct. The writer would suggest that if one took a Stanier "Pacific", converted it to oil burning and gave it the same standard of maintenance as the Diesel, it would more than match the performance of anything short of the Deltic. Furthermore, such a machine could be bought today from scrapyards for £3,000, it could be put in "as new" condition, converted to burn oil and decked in gold leaf for a total of less than £10,000, so that even if one accepted an availability ratio of 90/60, the capital outlay would run at £120,000 against £15,000. It was, of course, important to appreciate that steam locomotives did not wear out, so that a machine which would give a certain performance in 1938 would give the same—or better—in 1964.

Finally, in his review of the history of the Diesel, Mr. Harrison missed out one rather important landmark and that was about 1949 when his predecessor, after nearly a year of tests, announced the new motive power policy which called for twelve standard types of steam locomotive. Answering criticism that this was contrary to what was happening abroad and mainly in America Mr. Riddles declared that his policy would provide the greatest amount of tractive power for the money. The writer had always felt that this policy, although correct in principle, should have been based on the use of oil fuel, that more use should have been made of existing power similarly converted and that the main effort should have been directed towards electrification.

Now it would appear to be too late and the modernization programme had produced hundreds of small and ineffectual Diesel engines and Beeching.

Author's Reply

In reply to the discussion the author said that he was not an engine designer but would do his best to try to answer some of the questions with regard to what had been observed, and what British Railways' experience had led them to do.

Mr. Calderwood had referred to instances where components such as white metal bearings and welded engine frames, which had given good service in other forms of service, including marine conditions, soon gave trouble when used in a locomotive, due to the dynamic effect of running on steel rails. Whilst the author was not familiar with the particular bearing trouble mentioned, he could think of innumerable other items, many of well established proprietary makes, which soon failed when first used for rail traction. The inevitable remedy was a review of the design and general increase in robustness, and countless suppliers had had to learn their lesson the hard way. This also helped to provide an answer to the critics who tended to deride the size and weight of various components, including bolts, etc., normally used on rolling stock. The examples of cracked fabricated frames further emphasized the need for traction engines to be most carefully designed to withstand railway conditions. Where this had been done, welded frames could, and did, give excellent service.

Mr. Calderwood had mentioned the confusion in some minds between "availability" and "utilization". The former was the one which directly involved the engineering departments, whereas utilization was primarily an operating function. For example, a Type 4 locomotive must be out of service for 17 per cent of the time to enable adequate maintenance to be carried out. The availability was then 83 per cent, and utilization was a measure of how much the operator made use of the unit when it was available.

The first applications of internal combustion engines for rail traction, as far as he could trace, were by Daimler of Stuttgart and Richard Hornsby and Sons Ltd. of Grantham, both in the 1890's. However, the Egyptian vehicles mentioned by Mr. Calderwood could well have been amongst the very first to operate on proper railways.

The reference to the locomotives with hydrostatic drives in Buenos Aires was most interesting. Other limited trials of this transmission were known, but the fact remained that it had never got well established, even for road vehicles. Whilst railway engineers would, in their hearts, like to explore all sorts of alternatives, such as this, it was not generally practicable or economic to do so, especially at the present time when the emphasis on railway operation in this country was on eliminating a deficit of some £150,000,000 a year. This obviously did not give much scope for trying out novel transmissions which had not been proven.

Regarding the control gear required for the different forms of transmission, it would seem that a more refined system was generally required with electric transmission to ensure proper control and matching of engine and generator output and speed. Each type admittedly had its complications and drawbacks, and even a Diesel hydraulic locomotive often had several miles of electric cables. The railcars mentioned had engines on various vehicles down the train, but their control was not difficult. The most elaborate part comprised the jumper connexions which contained nineteen wires. Top overhaul, as understood on the railways, was an engine repair undertaken at main works, and not at service and maintenance depots. So far as the piston, valves and cylinders were concerned, the aim was to run 12,000 hours before giving attention to those parts. This was not possible at present with all engines, but it was on some. Maintenance of a lesser nature was scheduled to be done at maintenance depots at regular intervals, and this included such items as inspecting fuel pumps and changing injectors, checking clearances of valve tappets, and examining cams and followers.

He agreed that it was remarkable what could at times be done with water in the crankcase oil, but it was important to know where it was coming from and cure the leakage. As water in the crankcase of a working engine tended to boil away, an oil sample from an incoming locomotive showing a water content of ½ to 1 per cent usually indicated a more serious amount of contamination. Water in the oil promoted sludge formation and could interfere with the dispersion properties of the detergent additive, hence further operation with an oil so contaminated was not considered advisable.

He had not intended to give the impression that he did not like spectrographic analysis, for this was not so, and it had a very useful function. But with a fleet, such as there would eventually be, of over 3,000 main line locomotives, the volume of work involved in keeping a case history of each of them was formidable, and spectrographic analysis was of little worth without these records. It was, however, giving help in certain areas and was a useful yardstick, but he would not care to say that it was an essential part of maintenance or would justify universal adoption.

Regarding water treatment, the views of the various engine makers and the Research Department had been taken into account in establishing the policy, which for the future was to use soluble oil on the majority of locomotives. Sodium bichromate had in the past provided generally a very effective treatment and had many supporters, but it had to be discontinued because of strong medical objections.

The warning indication lamps for the driver were arranged to show "dim" for normal conditions and shine brightly in the event of a fault. This feature, therefore, safeguarded against a bulb failure.

Mr. French had given an interesting dissertation on the relative piston speeds and b.m.e.p. of various engines, and it was only possible for the author to state what the experience had been on British Railways. His classification in the paper of "high speed engines" covered those engines with a crankshaft speed of 1,500 r.p.m. or more, whereas "medium speed" had been applied to those engines with lower crankshaft speeds, and which tended to have larger diameter pistons. As Mr. French had pointed out, there was not a substantial difference in piston speeds between the two ranges.

Although there was much scope for discussion and controversy on the best type of engine for the purpose, what seemed to him to be really important was whether the engine would do what was asked of it, and this could only be found out properly by experience, and it did not necessarily follow that what looked theoretically right was the answer. This had been the case in experience to date with certain of the high speed engines and hydraulic transmissions.

He was most interested in the point made about the thermal effect of additives in the cooling water, particularly that of soluble oils. It was, perhaps, significant that in the case of the Maybach and M.A.N. designs of engines, soluble oil treatment had been used from the start at the makers' recommendation. He would be most interested to learn in due course the outcome of Ricardo's research into inhibitors.

Commander Platt had raised some interesting points, including the reasons for adoption of Diesel power on the railways. At the time when British Railways decided to change their motive power, apart from the engineering and financial reasons, they were also encouraged by the public, who required a higher level of cleanliness and amenity than was possible with the dirt and smoke associated with steam locomotives. The latter could be replaced either by Diesel or electric traction, or by both, which in the event was what happened. In view of the high capital cost of all the various fixed equipment required with electrification, the justification for this depended upon the traffic density of a particular route. Under present conditions the choice in many cases was very close indeed, and it was not easy to prove that a fairly well loaded line should be electrified, as a very good argument could also be put up for dieselization. It was fuel costs in particular which now tended to lead one away from electrification, although if it seemed likely that electrical energy would come down in cost, and that the price of oil would rise, this would influence the decision. It was not, however, clear that this would be the case.

Commander Platt had also mentioned steam turbines and gas turbines. The former had been tried in various forms over the years, but the locomotives concerned had seldom proved at all successful. The potentially high thermal efficiency could only be exploited in association with condensing, and this was not very easy to arrange within the space limitations of a locomotive. On any type of steam locomotives, boiler inspection and maintenance had always handicapped availability, and various trials of special boilers had been short-lived. Gas turbines had also been tried on British Railways, but the locomotives concerned had now been withdrawn. The thermal efficiency did not reach the same level as that of Diesels, and was particularly inferior at part load. Commander Platt was correct in assuming that the long heavy hauls at speed possible in America were more suitable for the gas turbine, but even there this form of power had been adopted only by the Union Pacific Railroad.

Consideration of these alternative prime movers, had, of course, to be associated with the basic need that motive power units must be effective and reliable. Whilst it would be most interesting to himself and his staff to develop and try out all sorts of alternatives, the one priority in life was to make the railway run efficiently, and that meant punctuality and reliability. This led him to the general question of "riding" of vehicles. The trouble here was that when a problem like "riding" on coaching vehicles was solved, it was necessary to apply the solution to some 31,000 vehicles. This involved a great deal of money and time, and it was, therefore, a long while before the general public was aware of the improvements made. In design, the "riding" of locomotives and vehicles did not present a difficulty, as the bogie features promoting a good ride were now known. His civil engineering colleagues knew full well how to maintain a track without argument as to whether a particular difficulty was due to mechanical or civil engineering shortcomings. Jointly they were able to provide and maintain the track and vehicles to give a suitable ride, and this meant a comfortable ride for six to eight hours whilst sitting at one place.

The speaker had also asked about the percentage of time that locomotives were under full load conditions in a given diagram. This could vary enormously depending on the service and the route, but on some main line express passenger duties could reach between 40 and 60 per cent depending on circumstances. Moreover, the tremendous influx of Diesel power had meant that the user had to train himself how best to use these locomotives, namely how to diagram and operate them. There was probably still more progress to make in this respect, as the performance capacity of these machines was no doubt much better than the operator often expected.

It had been suggested that it might well be a good plan to have a technical man on the locomotive instead of a "fireman". However, one of the advantages it was hoped to derive from Diesels was to have one man on the footplate instead of two, and this already applied in a number of cases. From an engineer's point of view it would be very satisfactory to have an engineer on board, but the accountants might not like it. He understood that in the earlier days of Diesel power in America, that practice had been followed, but subsequently appeared to have been dropped. Incidentally, he too had always been an admirer of Casey Jones.

Mr. Chamberlin had been concerned with his comments on the Deltic, and had suggested it was not really a high speed engine, at least so far as essential characteristics were concerned. This might be so, and the figures quoted were most interesting, but with a crankshaft speed of 1,500 r.p.m. it fell within the author's classification of a "high speed" engine. Whilst he noted the point made about the simplicity of the valve arrangements, he still considered that the layout of the three crankshafts associated with their gearing, and the large number of pistons represented a rather elaborate system.

The engine availabilities quoted by Mr. Chamberlin were impressive, but the main concern of British Railways was locomotive availability. Admittedly the quick interchange of the lightweight engines permitted engine attention to cause little loss of the latter.

He had not wished to be unfair about the Deltic locomotive when he said that it would not, in his view, be suitable for the run of the mill work. By that he meant that it would not take its turn in heavy freight as well as passenger work, as it was not really designed for the former.

The twenty-two locomotives on their particular duties were maintained with a great deal of special care by the manufacturers at a very limited number of depots, and in his view this attention could not be considered as representative of the kind of service normally expected or obtained from any fanufacturer during the ordinary operation of a transport undertaking. The fact that the English Electric Company maintained the Deltic for the Railways was not only a question of finance, it was also associated with the fact that the Railways had not necessarily got the appropriate staff to undertake that kind of specialized repair in very small quantities and at infrequent intervals.

Mr. Hopkins had mentioned various points concerning the English Electric medium speed engine and its rate of wear, with all of which he agreed. Mr. Hopkins had asked whether consideration had been given to the use of inferior fuels. This had in fact been done and, although theoretical savings were available, there were also various difficulties, such as the consistency of supplies, and the use of the same oil for the train heating boilers whose operation could be affected by fuel quality. However, in any case the Railways were concerned in getting all their engines into such a state of reliability that it would be safe to say "we will now take the next step" in such matters as experimenting with lower grade fuels.

Mr. Hopkins was correct in assuming that the Railways had left the door open for certain high speed engines if they proved their worth.

Mr. Lilly had raised various questions concerning exhaust smoke and smell, all of which were very troublesome. Some engines were bad in this respect, and with some it was difficult to overcome excessive noise. The Deltic, for instance, was one of these. It was always difficult to avoid noise and smoke, and they seemed to be synonymous. The problem was present all the time and had not yet been solved, and no doubt it worried other systems as well. There had been various suggestions, including one that sweet smelling scent should be put in the oil, but this was expensive, bearing in mind the total annual consumption of fuel. He would not have thought it was true to say that English Electric or Sulzer medium speed engines made a lot of smoke, unless the injection system was not in good condition.

Another point mentioned concerned the use of two engines versus one, on the ground that if one engine failed the other could always be used. His view was that it was wrong thinking to design a locomotive on the basis that it was better to use two engines in case one went wrong. He preferred to say "I will have one engine, and I will have confidence in the thought behind one engine and design accordingly" but there were other views as well as his own on that. With two engines there could be, for instance, 32 pistons and 128 valves. Why do it that way when it was possible to have only 12 pistons and 48 valves? Why go on adding complication with a multiplicity of cylinders, pistons and rods, and more chances of putting the latter through the crankcase? He personally was not attracted by the argument in favour of two engines.

He could not readily give Mr. Edwards any explanation on the cavitation of the particular cylinder liner, but it was likely that vibration played a significant part. There were one or two types of engines that did not show any signs at all of cavitation on the liners, and whether or not they had any water treatment did not seem to matter too much. He did not think that the makers concerned could really say why this was so. On most engines, however, water treatment was required if erosion and corrosion were to be kept down. He agreed that the vibration could be associated with the engine balancing and also the dynamic effects of the engine being mounted in the locomotive. This raised the question of mountings, and it was interesting to note that the most successful American Diesel engine was complete in itself and did not incorporate a bedplate common with the generator. Whilst the whole engine was rigidly mounted on the locomotive frame, the stiff cylinder block with integral main bearings was supported on a relatively flexible sump. It was claimed this was the answer in eliminating fatigue problems in the engine design. It was a point worth thinking about, especially as the complete engine could be lifted out of the locomotive separately from the generator, an operation which was not possible with other engines except some of the high speed ones.

He wished to correct Mr. Aubrey concerning quantities. The figure of 9,000 quoted in the paper referred to individual Diesel engines, not locomotives, these engines being fitted to locomotives, both main line and shunting, and also to multiple unit train power cars. Most of the latter and certain of the former each carried two engines apiece. He was interested to hear Mr. Aubrey's examples of the difficulties in matching material specifications as between one country and another. On the question of soft versus hard mountings, there were a lot of views on this, and somebody could well give a paper on this subject alone. It was, of course, essential to isolate the important parts of the engine from the flexing of the locomotive structure, and this could be done in various ways, such as by three-point mounting, soft mountings, or by a semi-flexible sump as used in America and mentioned in the author's reply to the previous speaker. There were pros and cons for each method, and what was best for one application might not suit another so well. Most engine makers had their own preferred method.

With regard to two-stroke and four-stroke engines, European manufacturers of rail traction engines had generally concentrated on the latter, although the principal American make, which was used in various other countries as well, was two-stroke. Certain two-stroke engines had been tried by British Railways, apart from the Deltic, but they had not been very successful, and therefore engines of the more numerous ranges of four-stroke types had been adopted in this country.

Regarding the sulphur content of fuel, and the possibility of using lower grades, he had already touched upon this in reply to a previous speaker. Apart from any effect on the Diesel engine, a high sulphur content could cause difficulty with train heating boilers which drew on the same fuel supply.

Regarding future rating improvements to engines, whilst in the conclusion to the paper higher b.m.e.p. had been mentioned, he agreed that higher crankshaft speeds could also be employed where appropriate. By which means, or both, a certain engine could best be up-rated would normally be for the engine manufacturer to decide in relation to the particular design and its characteristics. He could not see why with a b.m.e.p. of 160lb./sq. in. the life of the engine should be short, if the various components concerned were matched to this pressure. There were some engines which had been running for twelve years in other countries of the world, particularly America, on b.m.e.p. approaching that figure.

He had already spoken on the subject of water treatment, which was a very complex one in view of the advantages and drawbacks of the existing treatments.

Mr. Irvine-Brown's written communication suggested in paragraph one that the very nature of the paper allowed the author to steer clear of the more controversial questions:

1) whether or not the Modernization Plan was necessary;
2) whether the Plan, if necessary, was carried out in the correct manner.

These questions did not form part of the subject matter of the paper, and he could not therefore see why anyone should raise them in reference to this particular paper and suggest, at the same time, that the author was avoiding some point or points.

With reference to paragraph two, tests had been carried out to find the effect on the track of bogie locomotives having two and three axles each with both nose-suspended and axle-hung motors to determine which of these combinations was least detrimental to the track, and whether any, or all, of these combinations damaged the track more than steam locomotives. The answer to this question was that none of the above combinations were as severe on the track as the steam locomotive of the past.

The financial effects covering the change of motive power from steam to Diesel showed conclusively that on a like for like basis, and having full regard to the interest and renewal charges on capital outlayed on modern motive power depots, the costs were very clearly in favour of dieselization.

In paragraph three, Mr. Irvine-Brown said that the author made "an almost incredible statement". Did Mr. Irvine-Brown think the statement was incredible because he believed it to be untrue, or did he think it was a statement which was incredible to him because it made clear to him some facts which had not been understood by many steam enthusiasts before now? For his information there was plenty of published evidence from well known locomotive authorities on steam and Diesel performance in this country which would support the author's official statement. There was a multitude of factual evidence in his hands to prove the statement which he was prepared to give Mr. Irvine-Brown if he cared to come and see the author.

He did not intend to comment on the right or wrong of his predecessors' motive power policy.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting Held at the Memorial Building on Tuesday, 25th February 1964

An Ordinary Meeting was held by the Institute on Tuesday, 25th February 1964, when a paper entitled "The Development of the Diesel Engine for Rail Traction" by J. F. Harrison, O.B.E., M.I.Mech.E., M.I.Loco.E., was presented by the author and discussed.

Commander F. M. Paskins, O.B.E., R.D., R.N.R. (Chairman of Council) was in the Chair and sixty-five members and guests were present.

In the discussion which followed eight speakers took part.

The Chairman proposed a vote of thanks to the author which received enthusiastic acclaim.

The meeting ended at 7.30 p.m.

Section Meetings

North East Coast

Joint Meeting

A joint meeting with the North Eastern Branch of the Institution of Mechanical Engineers was held on Monday, 6th April 1964, at the Rutherford College of Technology, Newcastle upon Tyne, at 6.15 p.m.

The occasion was the Annual General Meeting of the North Eastern Branch of the Mechanical Engineers, with its Chairman, Dr. A. T. Bowden, B.Sc. (Member), presiding. As the business conducted was significant and interesting the members of the Institute were doubly pleased in being permitted to be present.

Mr. G. Yellowley (Chairman of the North East Coast Section) was invited to take the Chair at the joint meeting and after acknowledging the honour in accepting, introduced the speaker, Mr. P. Jackson, M.Sc. (Member of Council), who read his paper "Developments in the British Large Marine Diesel Engine During the Past Decade". In his introductory remarks the Chairman mentioned that Mr. Jackson was the joint winner of the James Clayton Award for his work on the design and development of large marine Diesel engines and for the part he had played in keeping British engines abreast of foreign equivalents.

Following the reading of the paper, Dr. Bowden led the discussion followed by Messrs. W. Francis (Member of the Section Committee), E. C. Cowper (Local Vice-President), W. H. Menzies, Dr. Dollin, Mr. Watson and Mr. Bennett. The discussion was lively being critical, complimentary and entertaining and suitably parried by Mr. Jackson.

The Chairman proposed a vote of thanks and after cordial applause the meeting, which had been of great interest to the 120 present, closed at 9.15 p.m.

General Meeting

A general meeting of the Section was held on Thursday, 23rd April 1964 at the University of Newcastle upon Tyne, Stephenson Building, Newcastle upon Tyne, at 6.15 p.m.

Mr. G. Yellowley (Chairman of the Section) was in the Chair and the audience numbered eighty-seven.

The Chairman introduced Mr. A. Norris (Member), who presented his paper "Developments in Waste Heat Systems for Motor Tankers". Mr. Norris devoted an hour to a very arresting presentation which was followed by contributions or questions from the Chairman, Professor G. H. Chambers, D.S.C. (Members of Council), and Messrs. Crowdy, Francis, Butler, Irvin, Taylor, Bennett and Menzies.

Mr. Norris ably dealt with the contributions as they arose and invited speakers to write in, if they so desired, for fuller replies.

Mr. Yellowley proposed a cordial vote of thanks to the speaker and closed the meeting at 8.35 p.m.

Scottish

A junior meeting of the Section was held on Wednesday, 11th March 1964, at the Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2.

Chairman of the Section, Mr. L. D. Trenchard, presided at the meeting and extended a warm welcome to the members, students and guests present.

The Chairman introduced Mr. J. J. W. Byrne who showed two films, "Frontiers of Friction" and "Cavitation". The first dealt with the conventional methods of combatting friction. The film was mentally stimulating and showed that the conventional lubricant was impractical, inadequate and impossible for certain particular applications.

"Cavitation" was an outstanding film in which the formation of cavities containing vapour and gas were seen. It showed how cavitation-erosion could be held in check by design and by the materials used.

A vote of thanks to Mr. Byrne was proposed by Mr. D. S. Macfarlane and was carried with great enthusiasm.

The meeting closed at 8.30 p.m.

West Midlands

A general meeting of the Section was held on Thursday, 19th March 1964, at the Engineering and Building Centre, Broad Street, Birmingham, at 7.0 p.m., when a lecture entitled "The Development of the Diesel Engine for Rail Traction" by J. F. Harrison, O.B.E., was presented by Mr. E. S. Cox.

Mr. G. H. Cornish, B.Eng. (Vice-Chairman of the Section), was in the Chair and thirty-nine members and visitors attended.

With the aid of slides Mr. Cox showed the different types of engine which have been used for rail traction, together with the problems which have been associated with the various engines from a maintenance aspect.

A very lively discussion followed, all questions being ably dealt with by the speaker.

On behalf of the members and visitors present, the Chairman thanked Mr. Cox for a most interesting lecture.

The meeting closed at approximately 9.0 p.m.

Election of Members

Elected on 13th April 1964

MEMBERS

Tom Fyffe Annan
Howard Elliott Broe, Lt. Cdr., R.C.N.
Desmond Clifford
Arthur James Cogman
James Robert Dougherty
Garth Edwards
Peter George Elliott, Cdr., R.N.

Harold Roy Embleton
Ian Harold Hallam
Alfred Hill, B.Sc. (Dunelm)
Lino Antunes Lopes, Cdr., Port. N.
Lionel Trevor Midford
Harold Nance
Harry Desmond Nixon, Capt., M.V.O., R.N.
Thomas Edward Prior
Frangiskos Revidis
Herbert Alfred Seamarks, Eng. Lt. Cdr., R.N.
Cecil Harold Sagar
Alan Joseph Webster
James Liddle Whyte

ASSOCIATE MEMBERS
Allan Ashurst
Hubert Michael Benians, B.Sc. (Eng.) (Lond.)
Albert Edward Bower
Keith Bridge Byrom
Peter Jui-Shan Cheng, B.Sc. (Glasgow), Ph.D. (Glasgow)
Robert Steadman Cumming
John Michael Daniel
John Eustace Davey, Eng. Lieut., R.N.
Kenneth Ellis
Sandy Falconer Campbell Fleming
Peter Grady
Terence Taylor Hibbs, B.Sc. (Dunelm)
Alexander McFarquhar Hogarth
William Russell Irvine
Hugh Alan Jenkinson
Mahammad Zakeria Khan-Majlis
Wesley Laws
Donald James Macleod
Demetre Miliotis, B.Sc.
Per-Olof Olcen
E. C. F. Ruelle
Madhusudan Sarkar
George Brian Saunderson
Charles Penman Smellie
Donald William Taylor
Ronald George Tennison
Wouter Alexander van Leeuwen

ASSOCIATES
John David Broadley
Jean Rene Henri Jegoudez
Arthur William Lamb, Cdr., R.N.
Paul Derek Pritchard
Thomas E. Stott, Jr.

GRADUATES
Ronald Bruce Halstead
Anthony Arthur Larner
Geoffrey William Leggett
Albert Peter Martin
George O'Brien
Donald Young

STUDENTS
John H. Ackrill
William Waller Allonby
Ross Balaam
Anthony David Bancroft
David Barnard
David Stuart Bibby
Francis Edward Bowman
Michael Shaun Bradley
Alwyn Coates
Barry John Cort
Denys Frederick Cox
Sylvester A. A. Forya
Michael Emmet Hayes
Patrick Pearse Hayes
Edward Alan Howard
Geoffrey Michael Hunt
Robert Lewers Hunter
William John Huyton
Abdulla Mohamed Issa
Sonnie Ayanakamina Bobo Jama
Mohammad Mujtaba Khwaja, B.Sc.
Gordon Lane
Kenneth Wallace McBride
Brian Morris
John Naisbitt
Peter Otuomasirichi Ninosuagwu
Alan A. Rae
David Arthur Robinson
John Arthur Sellars
Robert Swinburne
David Albert Taylor
George Akpan Ukpong

PROBATIONER STUDENTS
Roderick King
Bruce Alan Lewis
Jamie Prout
Paul Simon Ross

TRANSFERRED FROM ASSOCIATE MEMBER TO MEMBER
Ernest Albert Adlington
John Campbell
Richard Charles Dean
George Terence Holford Flanagan
Frank Alexander Griffin
Thomas Kenneth Harper
Brinley Pugh, Ph.D. (Leeds)
Kocherlacota Ramakrishna
Gordon John Roy
Alan James Weddle

TRANSFERRED FROM ASSOCIATE TO MEMBER
John Dennis Ashton Bright
John Charles Dosie
Secondo Follo, Capt.
Alexander Gilmore
Arthur Victor Heighton
Richard Ulick Noel Murray

TRANSFERRED FROM ASSOCIATE TO ASSOCIATE MEMBER
Leonard Mills

TRANSFERRED FROM GRADUATE TO ASSOCIATE MEMBER
Bruce Rodney Jenvey Allen
Colin Patrick Burke
John Wallace Driscoll
Anthony Vivian Fuller
Richard Max Kohler, Lieut., R.N.
Daniel Frederick Lott
David John Morris
William Pemberton
James Francis Troy
Sydney John Wheaton

TRANSFERRED FROM STUDENT TO ASSOCIATE MEMBER
John Michael Evans
Roy Edward Lacey

TRANSFERRED FROM PROBATIONER STUDENT TO STUDENT
Peter Douglas Astles
Allen Edward Brooks
Lance Butler
Colin Clegg
Paul Martin Dangerfield
Daniel W. B. Fru
Stephen Patrick Keene
Richard Wells Park

OBITUARY

Christopher Bull (Probationer Student 27586), of Herne Bay, Kent, died on 13th January 1964, from acute myeloid leukaemia. He was in his seventeenth year and had been elected to membership of the Institute only a few weeks earlier.

John Clark (Honorary Life Member 2690) died on 16th December 1963, in New Zealand. He had been associated with the Institute for many years, having been elected a Member in 1912 and made an Honorary Life Member in 1963.

He served his apprenticeship with the Ovenstone Engineering Works at Anstruther, Fife, after which, in 1907, he commenced his seagoing career. During his sea service, Mr. Clark gained a First Class Board of Trade Certificate.

In 1952, he retired from his position as District Manager (Hawks Bay) for James Niven and Co. Ltd. and, in 1960, relinquished his practice as an engineer and ship surveyor at the port of Napier.

John Charles Dua (Member 17193) died on 20th June 1963, in his sixty-eighth year. He served his engineering apprenticeship, from 1909-1913, with Beliard Crighton and Co. and A. Bouhoulle Guthrie, Murdoch and Co., and attended technical evening classes during this period.

In 1913, he became assistant engineer, Armement Deppe, Antwerp, leaving the company as third engineer. He commenced service as fifth engineer with Compagnie Maritime Belge in 1915, becoming chief engineer in 1921. He continued to serve the company, as chief engineer, in both steam and motor ships, until 1952, when he was appointed superintendent engineer. He retired in 1960. His maritime career, afloat and ashore, received recognition by the award of several honours, including the Order of Leopold II and the Medalie Koloniale Inspanning.

Mr. Dua was elected a Member of the Institute on 6th February 1956. He leaves a widow and a daughter.

John Harle (Member 9665) died on 10th February 1964, at the age of fifty years.

He served his apprenticeship with J. Readhead and Sons and Hawthorn, Leslie and Co. Ltd., after which he joined the Anglo-Saxon Petroleum Co. Ltd., in 1935, and served at sea for approximately eleven years. He obtained his First Class Ministry of Transport Certificate of Competency in January 1939.

During 1946, m.s. *Auricula* was fitted with experimental equipment so as to burn high viscosity fuel in the Diesel engines. Mr. Harle was appointed as chief engineer and remained with the ship during the early development of this equipment.

He served ashore from 1947, in Fuel Oils' General Department of the Shell Petroleum Co. Ltd. and later was transferred to Fuels and Light Oils. He was serving with Marine Bunker Sales, in the same organization, until his death.

He played a very active role in the Twickenham and District Society for Mentally Handicapped Children, of which he was chairman, putting in many hours of hard work, which were greatly appreciated. He also took a very keen interest in the Bowls Section and other activities connected with the Shell Lensbury Club.

Mr. Harle was elected an Associate of this Institute on 20th July 1943 and transferred to full membership on 20th September 1948. He leaves a widow, two sons and a daughter.

Sidney Beckett Hirschfeld (Member 6890), a Member of this Institute since 2nd November 1931, died on 18th January 1964.

Born on 4th July 1889, he served his apprenticeship with J. and E. Hall Ltd., from 1903-1908, and during that time studied at Dartford Technical Institute. He went to sea in 1912 as a junior engineer with the Royal Mail Steam Packet Co. and served with that company until 1915. In the latter year he was commissioned as an Engineer Lieutenant in the Royal Naval Reserve. He was demobilized in 1919 and returned to the R.M.S.P. Co. to serve in the grades of third and second engineer. He gained a First Class Board of Trade Certificate with Motor Endorsement and, at the time of his election to membership of the Institute, was serving as chief engineer in m.v. *Caronic River,* a vessel owned by Houlder Brothers and Co. Ltd.

He left the sea to accept a position as Resident Engineer to the Kent County Council and later became Group Engineer to the Leybourne Grange Group Hospital Management. He retired from this appointment in 1950, to look after his wife who was ailing and who predeceased him by about six years. His son had been killed in the Second World War; for the last few years of his life, when he was severely handicapped by arthritis, Mr. Hirschfeld lived with a sister. Several of his former colleagues have paid tribute to the manner in which he bore up to the troubles and tragedies of his life.

Farquhar Matheson McLellan (Member 4075), whose death occurred on 23rd January 1964, had been a Member of the Institute since 2nd November 1920.

He was born on 3rd February 1881 and, from 1897 to 1903, served an apprenticeship with Rankine and Blackmore, marine engineers of Greenock; he spent five years in the fitting shop and one year in the drawing office. On completion of his indentures, he remained with the company, on the drawing office staff, for a further 2½ years, thus gaining 3½ years experience as a draughtsman. In 1905, he left Rankine and Blackmore to go to sea, resuming his career ashore in the following year, when he joined Denny's of Dumbarton as an engineering draughtsman. Four years later he entered the drawing office of John Brown and Co. Ltd., Clydebank, with whom he remained for ten years, latterly in a leading position. He had charge of the arrangement drawings for machinery and boilers of all classes, including battleships and cargo vessels.

In 1920, he accepted an appointment with the "All's Well" Oil Co. Ltd., to promote the sales of their marine oils and when, in 1922, the company was acquired by Shell Mex Ltd., he took over the marine contacts of the parent concern. He was the first Marine Sales Supervisor in the Shell General Oils Department and was engaged on this work until his retirement in 1940.