THE MODERN COMMERCIAL VEHICLE CHASSIS.

By V. W. PILKINGTON (Manager, Engineering Dept., Leyland Motor Co.)

Introduction.

The title of this paper suggests that in the short period of time available a complete resume of the technical aspects of each unit of the complete vehicle, as indicated by the large number of good, well-designed vehicles on the market to-day, can be proffered for discussion. This is not the case and the author does not propose to treat each individual unit on a general scale, except where other types of unit can be referred to which show some definite trend in development. Further, it is the author's intention to confine himself to a resume of the products manufactured by the Company with whom he is employed, not as essentially by so doing as a means of advertising their products, but simply because that particular range of products can be taken as representative of contemporary manufacture to-day.

Transport resolves itself into two distinct grades, one for the conveyance of passengers and the other for the carrying of goods and merchandise. Further, these grades can each be split up into (a) trunk transport of a range not say under fifty miles radius, and (b) local service.

The history of grade (a) can be amply covered by the development of railways and coastwise shipping; but (b), with which this paper is more intimately connected, is covered almost entirely by the development of the commercial vehicle, although, of course (a) has been touched to a certain extent by the attributes of the commercial vehicle, e.g., its mobility and flexibility.

We must not forget the valuable services of the Road Engineer, without which such progress as has been made would have been considerably restricted.

There is no doubt that the inception of rail-borne transport commenced the era of rapid transport; the splendid isolation of the principal cities and towns was quickly broken down and the benefits to the community are too obvious to refer to here in detail. Yet rail-borne transport has a great inherent defect, that is; its lack of flexibility. The termini or stations must of necessity be situated at some position almost central to the populated or industrial areas they serve, and feeder services, or more colloquially, local services, necessitate a large capital outlay which demanded a reasonable return in revenue to warrant their becoming an economical proposition.

It was this defect in the lack of a feeder system which promoted the extensive development of commercial vehicle transport.

We cannot depart from the fact that in essence a commercial vehicle consists of a structure, say a frame, to which is attached sundry units, such as the power unit, transmission, axles, wheels, steering gear and brakes, together with a body suitably built to convey merchandise or passengers.

One would have thought from this description that the problem was relatively simple; it is, but the Ministry of Transport have formulated certain regulations, and as the Chancellor of the Exchequer must also have his little quota in the form of revenue, the initial stages of design at Home are controlled entirely by Regulations and Taxation.

For colonial conditions it is necessary of course to consider the various regulations in force at the different places at which the machines will operate. Again, road conditions vitally affect certain details of the chassis, so that to arrive finally at a standard vehicle necessitates considerable detail design.

It is obvious that if weight limitations are involved, the vehicle having the highest ratio of pay-load maximum gross weight will be the most attractive proposition, as the revenue earning capacity depends to a large extent on this ratio.

This factor of weight/ratio has been the most difficult problem to meet and has been responsible for the most intensive researches in the metallurgical laboratory, resulting in higher specific output of the power unit and improvement in chassis and body design.

The most highly developed alloys only are used in the construction of the chassis and body, in order to minimise weight and at the same time provide for the condition that fatigue failures will not occur, even under the most arduous conditions of overseas service.

When it is considered that the price per cwt. of a complete vehicle, which has to give a life of, say, 200,000 or more miles, which has to be backed by a complete service organisation all over the world so that parts can be supplied from stock which will fit, is only in the neighbourhood of £16 5s. od. for passenger vehicles, and £10 0s. od. per cwt. for goods vehicles—(Home prices), it compares more favourably with the ordinary mass-produced motor car having a value of, say, £14 5s. od. per cwt., but which has a useful life of, say, 80,000 miles.

To maintain a specified service time table, the passenger vehicle must have good acceleration, whereas in a goods vehicle the ability to haul a trailer (further to increase the revenue earning) and climb any gradient on main roads with ease, and yet not have the same acceleration, indicates that an engine of the same specific output can be utilised.

Experience has shown that for both types of service an engine having an output of 85-100 h.p. at 1,800/2,000 r.p.m. and a torque of, say, 300 lbs./ft. at 900/1,000 is eminently suitable, but for certain specialised forms of transport it is necessary to
consider engines with a torque output up to 500 lbs./ft.

Whether the power unit will be petrol or oil depends entirely on the customer’s economic viewpoint, based on initial capital cost and annual mileage.

From a revenue earning capacity there is no doubt that the oil engine scores heavily, and the high degree of development of the high-speed oil engine of small capacity has caused a change in policy which must have a far-reaching effect on taxation revenue and on the petrol distribution system.

PETROL ENGINES.

Engineers will appreciate the fact that the modern petrol engine is one of the highest speed prime movers in general use; further, that it is self-contained, including as it does its own cooling system, generating set, etc.

Briefly to consider the salient points we must have:

(a) High power output.
(b) Must be smooth running.
(c) Economical on both fuel and lubricating oil.
(d) All details must be as accessible as possible.
(e) Must be short and compact.
(f) The auxiliary equipment should be on one side.

It is well known that the best form of combustion chamber for a petrol engine is one where the surface volume ratio is a minimum, where a high degree of turbulence is attained and where the plug position is such that its distance from remote corners of the chamber is approximately equal. Further, in a multi-cylinder engine each combustion chamber should be dimensionally the same to ensure equal output per cylinder. Freedom from hot spots and adequate cooling of the exhaust valve are also essential features.

The spherical combustion chamber yields no doubt good all round results, but here inclined valves and twin camshafts are indicated, with consequent rise in production costs. It has been shown that the combustion chamber can be of lozenge form and yield results more than comparable with the spherical chamber. A problem in this form of chamber is its machinability, but it can be arranged to operate with a single camshaft which is a decided advantage. A compromise can be effected and the combustion chamber may consist of a flat machined surface of the head and a convex topped piston, the compression ratio being about 5:1:1.

Referring now to the question of the position of camshaft, it will be agreed that from the view of the minimum number of moving parts, accessibility, etc., the camshaft located in the cylinder head is good. It is a sine qua non that the valves shall be in the head because of the simplicity of construction, the manifolds are higher thus leaving more space for auxiliary equipment, ease of adjustments of tappets and the major point that if exhaust valve seat trouble is experienced the cost of renewal is less and the defective part more easily replaced.

To provide for the less intricate casting of the cylinder head and also to facilitate to a certain extent ease of valve grindings there is much to be said for placing the camshaft down in the crank case and operating the valves by means of push-rods; although this construction involves the use of a larger number of parts, yet the advantages are all in its favour and there is no doubt that this type of construction will be used more freely in the future.

The maximum compression ratio is dependent on the detonation characteristics of the fuel and this to a large extent is governed by the temperature of the exhaust valve. Until such time as salt sodium or copper cooled valves are generally adopted we must content with compression ratio values of about 5 to 5.4 to 1.

OIL ENGINES.

The author does not intend to give an historical resume of the development of the high speed oil engine, as this was very ably covered in a paper read by Mr. C. F. McLean before the Conference last year. He will therefore refer briefly to an attempt to produce a low compression oil engine and then deal with the process of combustion and the types of combustion chambers commonly employed for commercial road vehicles.

Whilst the compression ignition type of high speed oil engine was still in the early stages of development an attempt was made to produce a low compression oil engine, which whilst not being so efficient a form of prime mover as the high compression type due to the lower expansion ratio, would enable commercial vehicle operators to reap the benefits of using a cheaper fuel than petrol, although the consumption in m.p.g. would be about the same as for the petrol engine unit of the same capacity. On account of the low compression pressure, slow rate of pressure rise and low maximum pressure many standard petrol engine components could be employed in the manufacture of such an engine which would have been a very important feature in production.

Petrol assistance was required to obtain satisfactory starting with a cold engine and the auxiliary equipment consisted of a form of carburettor, sparking plugs, magneto, fuel atomisers and fuel injection pump. After considerable research and service testing had been carried out on an engine of this type it was found advisable, from the experience so gained, to confine oil engine development to the compression ignition type.

GENERAL FEATURES OF DESIGN.

In general design and external appearance the C.I. engine closely resembles its prototype, the
petrol engine. Major modifications include increased bearing areas, crankshaft, piston and con­necting rods of stronger section to withstand the higher combustion pressures of the C.I. engine, and a general increase in the dimensions of scantlings subject to increased loadings.

Manifolds are simplified by the omission of the carburettor with its necessary hot spot, and careful designing of the exhaust manifold is seldom necessary on account of the lower temperature and consequently a smaller volume of exhaust gas passing. The only reason air is admitted through a manifold at all is to provide a means of cleaning and silencing the air entering the engine cylinders.

Carburettor and ignition units are, of course, dispensed with, and in their stead a fuel injector pump and and fuel atomisers are substituted. Whilst many systems of fuel ignition have been designed, the self-contained unit pump of the jerk type is now almost universally adopted, and in most cases a high and low speed governor are incorporated in the pump. The unit pump and self-contained governor make a very neat lay-out and dispense with the necessity of external control rods, which always encourage tampering by unskilled persons. Atomisers of both open and closed type may be used, but the latter are more universally favoured.

Control of engine load and speed is effected by regulating the quantity of fuel injected per cycle, and as there is no throttle valve in the air manifold, a full air charge is always admitted into the cylinder.

**COMBUSTION.**

Having briefly described the main mechanical features in which the oil engine varies from its petrol counterpart it would be advisable to examine the process of combustion.

In engines working on the 4-stroke cycle (and the lecturer proposes to confine his remarks to this type), air is admitted on the suction stroke, either through poppet valves, or ports in the case of a sleeve valve engine. The valve timing is substan­tially as for the modern petrol engine, i.e., inlet open around T.C. and close about 40° after bottom centre. On the compression stroke the air is compressed to a volume of about 1/16 of its original volume. The resulting rise in pressure also involves a corresponding rise in temperature.

About 20° or so before the top centre is reached the fuel valve opens and a spray of finely atomised fuel is injected into the compressed air charge over a period of 5 to 20 crankshaft degrees, depending on the engine output.

During the first few degrees after the commencement of injection the fuel spray is absorbing heat for vapourisation until the self ignition temperature of the fuel is attained. Combustion then starts, presumably, at the finest particles of fuel. Once combustion has started the flame spreads with lightning-like rapidity, although this is kept under partial control by the rate of fuel injection and general design of the combustion chamber. The temperature and pressure decrease due to expansion as the piston descends during the working stroke, and when the exhaust valve opens about 40° before bottom centre the gas temperature is about 500° C.

This cycle of operation appears to be simple and certainly is until it is desired to obtain high power output, low fuel consumption and a clean exhaust. Then it becomes necessary to take care in proportioning the sequence of operations so that practically all the available oxygen in the air drawn into the cylinders is utilised and combustion is complete before the exhaust valve opens.

**COMBUSTION CHAMBERS.**

Many and varied are the types of combustion chamber which have been designed to obtain satisfactory combustion of the fuel injected into the engine cylinders, and a complete paper on this subject alone would be necessary to describe the functioning of some of these types. It will suffice to briefly describe two combustion chambers of the direct injection type and the general form of indirect or antechamber combustion chamber. The direct injection combustion chamber may be defined as one in which the piston crown forms at least half of the surface of the combustion chamber and is in free communication with the whole of the cylinder head, any motion of the air in the engine cylinder has to be induced by the method of directing the air into the cylinder during the suction stroke.

The combustion chambers of the direct injection type which will be considered are, firstly, those having a deep cavity of approximately cylindrical shape formed in the crown of the piston and, secondly, those having a shallow or saucer shaped cavity.
In the deep cavity type of combustion chamber the valves are located vertically in the head and open directly into the cylinder bore. The inlet valve has a screen extending about 180° around its periphery and the inlet port is suitably shaped to promote a rapid rate of rotational air swirl in the cylinder. The combustion chamber in the piston crown is shaped substantially as a tea-cup, and the spray is injected close to and parallel to one side of the combustion chamber. A single-hole atomiser is employed, and it is desirable to have a rotational air speed such that the air makes one complete circuit of the combustion chamber during the period of fuel injection. As the fuel is injected at right angles to the air swirl and into the densest part of the air charge a fairly coarse spray of very high penetrative value may be employed.

With this type of chamber combustion knock is reduced to a minimum, due to combustion starting near the centre of the chamber at the finer drops and progressing outwards towards the coarser drops, which tend to burn more slowly and so retard the rate of flame propagation. Cold starting is good and fuel consumption low. Speeds of 2,000 r.p.m. appear to be the limit possible with the larger sized engines, but with a very small bore engine speeds up to 2,500 r.p.m. have been successfully attained.

A typical combustion chamber of the shallow type is one in which the shape of the piston crown is that of a deep saucer with a raised conical centre. Valves are located vertically in the cylinder head and open directly into the cylinder bore. The inlet valve is either provided with a screen or the inlet port is so shaped that the incoming air is made to enter the cylinder tangentially and so rotates around the vertical axis of the cylinder.

The spray or atomiser is centrally placed between the inlet and exhaust valves. Usually three or four-hole atomisers are employed with this type of chamber, injecting fuel approximately through the centre of volume of the annulus formed in the piston; the rate of rotation of the air charge is proportioned so that the air rotates from the centre of one spray to the centre of the next adjacent spray during the fuel injection period.

Due to the fuel spray being directed outwards centrifugal action assists the penetration of the sprays and atomisers have to be designed to give a very fine fuel spray of low penetrative value.

The antechamber type of combustion chamber in its usual form consists of a small spherical space of volume approximately equal to the compression space, or about 1/16 to 1/18 of the swept volume of the cylinder, formed in either the cylinder head or the cylinder-block, separate from the engine cylinder but connected to it by a short passage having a tangential entry into the antechamber. The valves, as hitherto, open direct into the cylinder but there is no necessity to guide the direction of the incoming air.

On the compression stroke the air is compressed into the combustion chamber through the tangential communicating passage and thus made to rotate at great speed inside the combustion chamber. During the period of injection fuel is sprayed into this whirling air-stream in the combustion chamber. The type of spray employed is relatively unimportant as both pintle type atomisers producing a conical fan-like spray, or two-hole atomisers may be employed. Mixing of air and fuel is not necessarily completed in the combustion chamber as a further mixing occurs in the communicating passage as the gases expand back into the cylinder on the working stroke.

The features of this type of combustion chamber are excellent mixing of the air and fuel, which coupled with the very high air volumetric efficiency obtained, due to the use of plain valves, permits reasonably high power outputs to be obtained, and the brake mean effective pressure is maintained at...
the high speeds. On the other hand, the pumping losses through the communicating throat are considerable, and result in a somewhat higher rate of fuel consumption than with the direct injection type. The larger surface to volume ratio and the high air turbulence conducts the heat of compression to the walls of the combustion chamber and results in poor cold starting. It is therefore necessary to use heater plugs or a very high ratio of compression to counteract the heat loss and to obtain satisfactory cold starting.

The foregoing remarks afford a brief review of three well known types of combustion chambers, and even such a scantly description gives some idea of the problems confronting the oil engine designers and development engineers. The ideal oil engine combustion chamber should give:

1. Easy cold starting.
2. Quiet running at all loads and speeds.
3. Smokeless and regular idling.
4. A power output and range of speed comparable with that of a first class petrol engine.
5. Low rate of fuel consumption.
6. Smokeless combustion at all loads.

It is of interest to note that the Leyland Company, with which the author is connected, have been able to fulfill these conditions to such an extent that over 47 per cent of the Municipal passenger vehicles registered in the United Kingdom on December 31st last which employed engines as the power unit were fitted with Leyland oil engines. Although this in itself is an achievement yet extensive research work is being carried on further to improve the performance.

INJECTION EQUIPMENT.

The design and manufacture of injection equipment and the proportioning of such equipment to suit individual engines are other problems which require the most careful consideration, but this subject is rather outside the scope of a general description of C.I. engines.

PERFORMANCE DATA OF C.I. ENGINES.

It would be of interest now to discuss some of the outstanding characteristics of the C.I. engine and to see how it varies from the petrol engine.

For two engines of the same capacity the H.P. curve for the C.I. engine is just below that of the petrol engine over the entire speed range. This is due to the output of the oil engine having been limited to that at which a perfectly clear exhaust is obtained at all speeds, and is the useful maximum output for the engine.

By permitting discolouration of the exhaust gases it is possible to obtain a considerably higher power output from the oil engine, but under these conditions valves and pistons will rapidly soot up, and such a practice is detrimental to the successful operation of the engine.

The most striking difference in the performance of the two engines is in the rates of specific fuel consumption. The petrol engine averages 0.36 pints per B.H.P. hour over the speed range, whilst the C.I. engine averages 0.43 pints per B.H.P. hour. Thus a considerable saving in fuel consumption is achieved on full load, and if the fuel consumption curves of the two engines are compared on a load basis at constant speed the difference is even more pronounced, the fuel consumption curve for the C.I. engine being much flatter than that of the petrol engine.

The reduction in fuel consumption is the greatest advantage which the oil engine has to offer, and careful records taken in England on engines in almost every type of road service show that the oil engine will run approximately 1.8 times the mileage of a petrol engine on a gallon of fuel.

RUNNING COSTS.

Accepting the basic figure of 1.8 for the ratio of the M.P.G. and taking average bulk prices in South Africa for fuels on the basis of 8d. per gallon for gas oil and 1/4d. per gallon for petrol at coast an interesting comparison of the saving in fuel costs for a typical passenger vehicle is given on page 51.

FUEL.

There has been a popular conception that the C.I. engine can be run successfully on almost any grade of fuel down to boiler oil or even crude petroleum. Such a conception is entirely wrong and if allowed to remain uncorrected it will eventually do the oil engine much harm in this country.

In the development of these engines fuel supply companies have co-operated very closely with the engine manufacturers and the type of fuel which
## COMPARISON OF PETROL AND OIL ENGINE RUNNING COSTS.

**Basis of comparison:** Six-ton lorry or City Service 'Bus giving 6 m.p.g. fuel consumption with petrol engine and 11 m.p.g. fuel consumption with oil engine.

Petrol taken at 1/4d. per gallon.

Fuel oil taken at 8d. per gallon.

**Engine Costs (Assumed):** Additional cost of 6-cylinder Oil Engine, £300.

Assume life of Engine will be as follows:

- At 10,000 miles per annum 10 years
- Additional depreciation with Oil Engine: 10 years £30 per annum

**Additional depreciation with Oil Engine:**

<table>
<thead>
<tr>
<th>Annual Mileage</th>
<th>PETROL ENGINE</th>
<th>OIL ENGINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual cost of Petrol (App.)</td>
<td>Annual Total</td>
</tr>
<tr>
<td>10,000</td>
<td>£111</td>
<td>£122</td>
</tr>
<tr>
<td>20,000</td>
<td>£222</td>
<td>£243</td>
</tr>
<tr>
<td>30,000</td>
<td>£333</td>
<td>£364</td>
</tr>
<tr>
<td>40,000</td>
<td>£444</td>
<td>£485</td>
</tr>
<tr>
<td>50,000</td>
<td>£555</td>
<td>£607</td>
</tr>
<tr>
<td>60,000</td>
<td>£666</td>
<td>£728</td>
</tr>
</tbody>
</table>

**Maintenance:**

- Petrol engine: 0.25 pence per mile.
- Oil engine: 0.375 pence per mile.
has been final evolved is a light paraffinic base gas oil, a typical specification of which is as under:—
Specific gravity at 60° F.: 0.84 to 0.86.
Distillation range: 200° C. to 380° C.
Closed flashpoint: 170° to 200° F.
Viscosity Redwood at 70° F.: 40 to 45 seconds.
Calorific value around 19,000 B.Th. U. per lb.
Water: Nil.
Hardness Nil.
Ash: Nil.

Although the flashpoint of the fuel is high, the self ignition point is considerably lower than that of an average petrol. This feature is necessary to the successful running of a C.I. engine in order to reduce the combustion delay angle to a minimum, thereby giving quiet combustion and easy cold starting. Presence of water in the fuel must be prevented or sludging troubles in the fuel filtering element will be experienced.

Additional to obtaining the correct type of fuel, it is also essential that the fuel should be handled and stored correctly and it should be free from contamination before being put into the engine fuel supply tank as is commercially possible. Barrel storage is condemned unless the barrel is stillaged some 24 hours before use and the fuel syphoned off. For bulk storage, dry tanks only should be employed and these should be tilted and fitted with an adequately sized sludge-cook at the lowest point, so that periodically sediment can be run off. The tank outlet pipe should not reach within 3in. of the bottom of the storage tank and a filter of at least 200 mesh (preferably of monel metal) should be included in the delivery line. As a further precaution a fuel filter, usually of the cloth or felt type, is fitted between the engine supply tank and the fuel injection pump. A similar filter of this type is always supplied by the engine manufacturer.

If these simple precautions for correct storage and filtration are adopted much trouble with dirty atomisers and injection pumps will be avoided.

MECHANICAL DETAILS.

Corrosion and oxidation of the valve neck and seat are important factors to contend with; austenitic steels, while giving good results in other directions, are not entirely satisfactory as regards corrosion. Imperfect seatings and high flame temperatures are the cause of much trouble, resulting in radial cracking of the head and broken valves.

The best material appears to be an alloy steel of the silicon-chrome type; it retains a reasonably high tensile strength at elevated temperatures and has a good corrosion-resisting value.

Valve seat wear in high duty engines has been another problem; it is due to three causes (a) pounding, (b) corrosion, (c) erosion. It is difficult to assess the effect of each individual cause, but a cure appears to have been found in the use of inserted valve seats, either of tungsten steel, or better still, a mild steel seating having a stellited facing. This material is welded on and consists of a cobalt base with inclusions of chromium (32%), tungsten (14%), and carbon (2%). It is extremely hard and can only be touched with Widia tools, the diamond hardness figure being approximately 650.

For inlet valves a straight nickel-chrome steel can be used, but must on no account be of an air-hardening quality.

Much controversy has raged around the question of piston design; there is no doubt that the aluminium alloy piston of the die cast type is the most suitable. This can be of either the "pot" or split skirt type. For good oil consumption it is essential for the piston to remain free from distortion, it should be so proportioned as not to tilt, the rings should be of the hardened and tempered type, lapped on the groove faces. Scraper rings are now generally of the slotted type.

Cylinder block castings are now of very clean and simple design, due to the camshaft being located in the cylinder head, and even on the pushrod type of engine previously referred to the block can still be kept extremely clean by virtue of the fact that the adjustment is carried out at the valve end of the push-rod.

The merits of "wet" vs. "dry" liners is a controversial point but there is no doubt that from conditions overseas there is much to recommend the fitting of wet liners, as these can be completely machined at the works and sent out as replacement parts together with pistons and no machining need actually be done at the place of repair.

The relation between cylinder liner material and piston from a wear figure point of view is one which has engaged the attention of manufacturers for some considerable time past and it has now definitely been established that liners manufactured from an iron containing nickel chrome and molybdenum used in conjunction with piston rings of a hardened and tempered type can produce extremely good wear figures, particularly where means are adopted to prevent the ingress of abrasive matter such as by the use of air filters of the oil bath type.

Experimental work at the Institute of Automobile Engineers Research Department indicated that corrosion was a contributing factor to cylinder wear and service tests are in hand to establish the extent to which the wear figure is affected by corrosion.

Bearing areas of main and big ends should be as generously proportioned as the design will permit. Trouble has been experienced due to the white metal fatiguing, causing cracks and total disintegration of the metal. Whilst this is only a minor trouble on petrol engines, the high speed oil engine has suffered considerably. Many theories have been put forward for its causation, but it is sufficient to say that a shell of lead-bronze, copper cadmium or 

Rk.56 is not prone to this fatigue effect. Unfortunately the wear values of either of the above alloys on a soft steel shaft are not as good as with...
white metal and this has forced some manufacturers to the use of case-hardened or nitrided shafts.

The general use of case or other form of hardening crankshaft will undoubtedly come, and will considerably increase the life of the engine.

The crankshaft itself should have pins and journals of ample section, both for purpose of bearing areas and torsional rigidity of the shaft.

A bad torsional period in the shaft, within the normal working range, is both annoying and dangerous. Continuous running on the period, unless some means of damping is utilised, will tend to rapid fatigue failure of the shaft.

Lubrication is an important feature and considerable care must be taken to ensure a copious supply of lubricant to all moving parts under all conditions. The latter is mentioned because on one engine built some few years ago it was found that lubrication to the big ends ceased entirely at some critical speed of the engine.

The sump should have a capacity of not less than 3/5 gallons and must have a good filter provided. Filtration and cooling on the pressure side is an advantage.

The foregoing facts with regard to the engine are of necessity brief, but must suffice, as a brief survey of current practice and the all-important question of transmission will occupy the next section of this paper.

TRANSMISSION.

It is a significant fact that a transmission system consisting of a fabric lined clutch and a parallel shaft gearbox has survived so long as standard practice, when it is considered that of all the units comprising the complete chassis, this was and has been more attacked by the lay inventor and technician than any other. Devices of all kinds to attain automatism have been produced and equally quickly have been forgotten.

It should be borne in mind that the petrol engine, or its prototype, the high speed oil engine, is essentially a constant torque prime mover within its working speed range, and to adapt this characteristic to the requirements of the vehicle it was very early discovered that some form of torque multiplier or variant was necessary. It was not long before the parallel shaft three or four speed box made its appearance. Naturally as there had to be a means of breaking the drive to engage a gear the clutch followed.

There is no doubt that the arrangement was eminently satisfactory and development was confined entirely to efforts which lead to a smooth operating clutch with light pedal pressure and a gearbox which was quiet throughout the range of gears and on which gear changing was not a tedious operation.

The advantages of the plate over the cone clutch for rapid disengagement are smooth operation and are patently obvious.

It is safe to say that up to 1928, standard practice was the use of a single dry plate clutch and a straight spur toothed gearbox. From that date onward, however, there have been rapid changes.

American practice, where fuel is cheap and taxation on a different scale than in England, produced cars with large capacity engines. The high roads are mainly level and consequently gear changing is hardly necessary and the clutch is used merely as a means of starting the car from rest. In the Home country conditions were such that the designers concentrated on the small capacity, high output, engine, due to the governing factor of cylinder diameter in the taxation rating. Consequently the gear box was an essential part of the chassis.

Commercial practice followed car practice fairly closely and the early developments of 1928/30 were readily adopted, confined mainly to the introduction of helical gears.

Fig. 4.
Leyland Clutch showing Ventilated Pressure Plate.

Fig. 5.
Four-speed Leyland Gear Box with Helical Silent Third Gear.

About this time—1928—and with the advent of the low-priced mass-produced car, the public
became car-minded, and the general owner-driver, particularly of the female species, began to resent the bugbear of gear changing.

The use of the free wheel behind the gearbox for ease of changing and economy in fuel consumption had a considerable vogue. Vacuum-assisted clutch operation appeared on certain American cars, together with synchro-mesh gears, and about this time the appearance of a fluid transmission was becoming obvious.

The term “fluid” implies shockless transmission and the introduction of the Puttinger coupling in the form of the “fluid fly-wheel” coupled with the Wilson type of gearbox started a new era.

This combination, which in practice has proved reasonably satisfactory, is a cumbersome way of doing the job, but it should be realised that on the average bus service of to-day the driver has to change gear say six stops per mile on a fourteen/mile/hour time table on a shift of, say, eight hours, then at four clutch operations per stop he has operated the clutch 2,240 times, simultaneously operating the change speed lever the same number of times, steering the vehicle and at the least applying his brake 560 times. Further, he sub-consciously is working out how to change gear without unduly alarming the passengers. It will be appreciated that a system of pre-selected gears with a fluid clutch presented many advantages.

However good the design of a clutch and a gearbox it is obvious that this means hard work. The Fluid/Wilson combination enabled ex-tram drivers to take over bus driving with a reasonable degree of safety, but some form of controlled automaticity pre-supposes itself.

We will now consider the application of a system suggested in the preceding paragraph and eminently suitable for passenger work. We have shewn in the development of the subject that a perfect transmission should be:

(a) Noiseless.
(b) Effortless.
(c) Able to operate under all conditions without shock.
(d) Efficient.
(e) Of the controlled automaticity type.

A system has been developed by the author’s Company to meet the exacting demands of double-deck city bus service operation and to comply with the principles referred to above, and which has been wholly adapted to passenger work.

The torque converter consists essentially of a centrifugal pump mounted in a single casing with a three-stage turbine. The drive from the engine flywheel is taken through one or other of two friction clutches, a single lever control being used to operate both clutches through a simple toggle mechanism. The clutch disc nearest to the engine is mounted on a shaft passing through the converter, connecting the engine direct to the transmission line. The second clutch is mounted on a splined hub rigidly connected to the pump shaft and provides the drive to the hydraulic converter. Although two clutch discs are necessary and may appear to add complication to the unit, it must be pointed out that they are not subjected to the slipping torque of a conventional clutch owing to the square law torque characteristics of the pump member.

Fig. 6.
The Leyland Torque Converter (Lysholm-Smith Patents) replacing Conventional Gear Box.

Fig. 7.
Torque Converter Unit opened up to show Hydraulic Elements (a) Pump; (b) Rotor; (c) Starter Casing.

The pump member is similar in form to the impeller of a centrifugal pump. The turbine rotor is equipped with three separate rows of blading fixed in such a manner that two rows of stator blades are interposed between them when the rotor is installed in its casing. The drive from the turbine rotor is taken through a free wheel of the roller type to the transmission line. The free wheel is necessary to isolate the converter when direct drive is engaged, and to prevent churning losses on over-run. Fluid leakage from the converter is prevented by using sealing joints mounted on bellows.

The converter must not be confused with a fluid flywheel, which is merely a fluid slipping clutch and can only transmit as a maximum the torque at engine crankshaft.

The “no-step” acceleration curve of a bus fitted with the torque converter is really remarkable and shows up as a definite advantage in close town service operation.
As regards consumption, based on the efficiency curves shown, it is sufficient to say that on many hundreds of thousands of miles of service tests the fuel consumption is proved to be comparable with the conventional gearbox bus.

Of coupling shafts between gearbox and driving axle little need be said. The tubular type employing universal joints of the Hardy-Spicer Needle type are in general use. As a rule these are about 3 in. diameter tube in lengths up to 7 ft. and are all dynamically balanced to ensure that the whirl speed is well outside the normal working speed range of the system. They have their little problems such as the torsional oscillation set up between engine and axle, but as a rule this can be neutralised to a certain extent by the use of an oscillation damper.

Although attempts have been made to find a counterpart to the differential, so unsuccessful have they been that the complete rear axle to-day is essentially the same as it was when first introduced.

Refinements have been made to detail design, but it is a fact that the unit still consists of a casing, hubs, driving shafts, differential and drive.

The design of the rear axle virtually decides the floor height of a passenger vehicle when considering the present modern design. It is obvious that if the differential were placed on the centre line, then allowing for wheel radius and bumping clearance under laden conditions the floor height is merely a simple sum of wheel radius plus top half axle dimension plus clearance plus thickness of floor. Adding on to this the regulation headroom for upper and lower saloons it will be seen that the minimum height of a bus results. The fact that the floor can be downswept at each side of the axle is of no moment as the overall height would still be the same.

In 1927 the Leyland Company introduced the design in the manner shown and this inaugurated the era of the real low floor bus. So successful has the design been that it is now universally adopted for both double and single-deck bus work.

Detail design of the rear axle resolves itself into three classes, thus:

1. Worm versus Bevel.
2. Semi-floating or full-floating.
3. Forged or cast axle casing.

In case (1) there is no doubt that the worm axle has definite advantages for classes of work such as passenger vehicles; it is definitely quiet, cheap to manufacture by modern gear hobbing plant and is easily assembled. Further, wide ranges of gear ratios are possible without alteration to overall dimensions.

Lubrication is of vital importance when considering continuous operation of heavy duty worm gears, and it has been found that with a high grade mineral oil reasonable life can be expected (150,000 to 200,000 miles). Castor base oils can be used with success but if polymerisation of the oil occurs the gear will completely fail.

Mineral oils can be used with safety up to a temperature of 100° C. and with propeller shaft torque of 1,500 lbs./ft., but in excess of these conditions the use of a germ compound oil is recommended.

Chill cast Phosphor bronze worm wheels with nickel chrome steel case-hardened worms appear to give the best all round results.

Turning now to bevel axles, it is almost impossible to obtain the desired ratio within the dimensional restriction on the vehicles and therefore a double reduction bevel spur gear suggests itself.

This double reduction gear is much more costly and heavier than a worm gear and its use is confined entirely to vehicles of exceptionally heavy duty, where long periods of bottom gear torque are necessary such as, say, a two-axle goods vehicle and trailer having a gross weight of 22 tons.

In case (2) little need be said; the principal advantage of the semi-floating axle lies in its quality of cheap production, small dimensions and reduced weight. Its disadvantages outweigh its advantages and the fully floating axle is now generally adopted.

Turning to (3) the use of the one-piece nickel steel forging has merits which cannot be approached by the cast construction for heavy duty work. Its obvious strength for limited sections suggests itself at once and this fact alone justifies its use against the additional cost of its manufacture.

The question as to whether an axle should be under or over-slung is decided entirely by the type of chassis under consideration. In passenger vehicles the obvious position is under-slung, whilst on goods vehicles the straight frame chassis in general use necessitates the use of an overhead gear and also provide maximum ground clearance.

As most conventional chassis of to-day utilise longitudinal semi-elliptic springs in their construction the front axle is of the usual beam type of "H" section between spring fixings.

**SUSPENSION.**

No reference will be made in the paper to the subject of steering as the principles of design in this unit are well known. It will be sufficient to state that to obtain the utmost ease of steering a steering box employing a gear of the cam and roller type is necessary in conjunction with a well laid out steering arrangement.

Here the earlier developments have retained their identity and present day chassis of the heavier types generally utilise the well-tried and proven semi-elliptic spring suspension for both front and rear axle. In the consideration of this subject it should not be forgotten that the tyre itself as a part of the suspension has undergone very important changes in the course of the last few years and if this had not been the case, then, of course, the springing proper would have had to receive
In the consideration of this subject it should be observed that what is required as an ideal is that the chassis proper, e.g., the sprung portion, should ride along under all conditions so that it is undisturbed in the vertical or transverse planes by impressed forces on the unsprung portion, e.g., the axles and a portion of the springs. Unfortunately energy cannot be destroyed except by doing a certain amount of work, which work must be eventually supplied by the chassis, so that certain fundamental principles are immediately suggested.

It will be seen at once that speed of operation is a principal factor and vertical accelerations which at low speeds are of such a value as to be imperceptible, cause, to all intents and purposes, shock loads at high speeds. Therefore, the first condition is that the springs must be considered for the type of service on which they are to operate.

Secondly, the retention of the chassis proper in its free position at rest necessitates the use of a given spring and when considering the chassis between light and laden conditions certain deflections only are permissible within the limitations of design.

Lancia made a very serious attempt to solve the problem of elimination of transverse oscillation of the front axle by means of independently sprung and damped wheels, coupled with high deflection rear springs, and this was a contribution to the service of spring suspension. Gilford attempted all independent air-springing in 1929, Alvis, Tracta and others produced about this time independent springing on front wheels.

Yet even in the car world no serious attempt had been made on general standardisation until 1933, when American practice appeared to indicate that 1934 would show its general adoption. Constant periodicity springing will no doubt appear for car work, but it is doubtful whether the large fluctuation in loading will permit it on a heavy commercial vehicle, although there is no doubt it is a desideratum.

Having said this much, the principal features of a spring suspension on a modern vehicle will be described.

The first and foremost is safety, and therefore the stability of a double-deck passenger vehicle and a goods vehicle carrying high loads rules out the possibility of employing springing which is ideal. The double-deck passenger vehicle must in the first place pass a regulation test under the worst conditions which will prove that the vehicle can safely tilt to an angle of 28°, the angle measured between the plane through the axles at the instant of instability being reached and the level road surface.

The centre of gravity is fixed and the only variant is the springs, consequently springs having a reasonable degree of stiffness only can be utilised. The tyre, therefore, plays an important part in comfortable riding at low speeds, and when high frequency vibrations, such as when running on badly laid setts or a road surface with innumerable small pot-holes, have to be damped out, hence the development of the giant low pressure tyre with inflation pressures in the region of 50/60 lbs./sq. inch only.

Why also, if it has been proved that independent suspension has merit, have not commercial vehicle manufacturers adopted this on a more general scale, and retained the time-honoured semi-elliptic spring?

The answer is simple: In the first place large diameter and section low pressure tyres are in themselves independently sprung for small deflections; secondly, the application to the rear axle on a single power unit chassis presents great difficulty; thirdly, the operating speeds are very much lower than on car work. Fourthly, road surfaces, particularly trunk roads where it is only possible to operate at speeds in excess of 30, are particularly well laid and, lastly, the semi-elliptic spring is lighter, stronger, cheaper and easy to maintain.

Considering the front axle only, all parts from the beam eyes outwards will still have to be used; therefore it is necessary to replace a very simple forging in the way of the end of an axle beam by some mechanism which under no circumstances will be as light and cheap to manufacture as the beam. Again the semi-elliptic spring picks up the frame at two points, say, 3ft. 6in. apart, which assists considerably in the reduction of stress at this point. The number of working joints is also kept to a minimum by the use of semi-elliptic springs.

A consideration of the state of affairs as existing on the springs when a heavily loaded vehicle is retarded at the rate of 12/15 ft./sec., will show that the static stress is really no criterion as to whether the spring will survive. Under these conditions the static loading on the front axle is suddenly increased due to the load transference by anything from 50 to 100%. The axles themselves want to stay where they are while the chassis proper moves on and causes a high longitudinal loading on the master leaf, and under torque influence the springs "ess" and produce a further stress increase, due to the additional deflection. It will be seen that the leading half of the master leaf is left unsupported, and if some means of support were not adopted the life would be negligible. Various means have been tried from time to time to counteract the effect on the springs of brake reaction.

The objections can and have been removed, however, by simple means. An anchor plate is arranged over the spring eyes in such a manner that when the spring "esses" the leading plates are prevented from opening out by the clip and the
top plate is thus supported by the corrected effect of the four neighbouring subsidiary plates.

Any angular deflection between chassis and axle causes the spring to twist; within small limits this is not a serious objection, but in the case of rigid six-wheel vehicles operating under Colonial or rough country conditions, the degree of twist would cause high stresses and rapid failure. The trunnion end eliminates this twist and has been a particularly successful application on War Office vehicles of the single rear spring type.

The use of rubber, which has, of course, the maximum resiliency, has not been considered as a general application; as a secondary means it is used for buffer blocks so that in the event of the deflection of the spring being in excess of that calculated a limiting stop is introduced which arrests the further deflection without shock or noise. Again, the use of rubber for spring mountings has been used extensively in American car practice, and in this country in the form of silent bloc attachments; either of these applications necessitates a heavy construction and the use of well lubricated shackle pins running on phosphor bronze bushes continues to be extensively applied.

Reference has been made in the foregoing remarks to the high retardation figures which are now in use on high class commercial vehicles. Public safety depends almost entirely on the ability of a column of traffic moving at a given speed to stop in a given distance when an emergency arises. It does not matter, therefore, whether the vehicle in question is a light car, one ton lorry, passenger vehicle or twelve-ton gross vehicle with trailer; if the column is moving then each vehicle must come to rest in the same interval of time.

It was quickly realised, however, as traffic conditions and density reached what they are to-day, that the limitations of the driver as regards his power application proclivity was concerned, necessitated some assistance; in a given time interval the driver can push his foot with a certain force through a given space and pull or push with one hand with a certain force through a given space.

All petrol engined chassis have a potential source of power which is free and is always there provided the engine is running—that is the induction manifold vacuum which under closed throttle conditions approached a figure of 20/22 inches of mercury.

In 1926 the vacuum brake motor, or booster as it is now more commonly called, reached a stage in production which definitely settled the problem of servo-assisted brakes. The hunting valve with which it was fitted gave the driver controlability of the brakes which he had not previously experienced. The single motor generally applied all four wheel brakes through the medium of a non-compensated rigging.

Brake compensation is a desirable feature provided that equal conditions pertain on each brake drum and that the failure of any one part of the system does not immediately place the whole braking system out of action.

A compromise has been effected whereby additional assistance is provided, some degree of compensation is effected and yet some of the features of the non-compensated system have been retained. It should be pointed out at this stage that mechanical rigging for the hand brake is compulsory and is in existence on every chassis. The simplest and most effective means of producing the desired effect, therefore, is to provide supplementary operating cylinders mounted on each stub-axle and operated by the master booster which actuates the hand brake cross shaft and consequently the brakes in the rear wheels.

The economical length of lining appears to be that subtending an arc of about 100° on each shoe and liniers thicker than ½in. are not economical due to the high percentage of wastage when worn down at the centre of the shoe.

Lining pressures are therefore relatively high to produce the torque necessary for retardation.

Under severe operating conditions the lining and drum temperatures attain a high figure and it is very necessary to allow in the leverage calculations a sufficient margin to provide for drum expansion and to utilise a lining which has a reasonably constant co-efficient of friction over the temperature range.

A simple means of providing a fully compensated working system lies in the application of hydraulic brakes: here a booster cylinder is actuated by a foot pedal and the fluid under pressure is taken to small operating cylinders between the tips of the brake shoes. The system in itself is not given a boosting effect, it is merely a case of the simple law of mechanical advantage; its frictionless operation does, however, provide a better net result, and there is no doubt for light cars and certain difficult applications on commercial vehicles it is ideal.

When, however, considering it on a general scale for commercial vehicles the immediate necessity for a vacuum booster becomes apparent.

The same principles of braking have been applied to the heavy goods vehicles, a further advantage of the vacuum-assisted brake on this class of work being that where trailers are used it is a simple matter to provide a connection for vacuum assistance to the trailer brakes.

**FRAME.**

Not the least important unit in the chassis, although it has been left until the last for a brief survey, is the chassis frame: important it is, due to the fact that the various units secure their entity from its careful design and ability to with-
stand the terrific wracking strains which it is called upon to resist under strenuous conditions of operation.

When considering a chassis of the passenger type, on which has to be mounted a body of delicate construction, insofar as it constitutes merely a skeleton covered with a large percentage of glass, it is essential that the chassis frame be constructed in such a manner that torsional or wracking strains shall produce minimum distortion and yet not be unduly heavy.

In a goods vehicle it is not of the same importance to provide a rigid structure in torsion, as a general rule flat platform bodies are used: in this case channel bracings can conveniently be used.

The Leyland Company, by virtue of the extensive facilities available, such as their own modern steel, iron and non-ferrous foundries, body shops, etc., are enabled to manufacture such specialised vehicles, as instance the fully articulated six-wheel rigid frame chassis for war requirements. Such a vehicle is of course eminently suitable for operating conditions on virgin country, as is very often the case overseas.

Vehicles of this type are manufactured with a carrying capacity of 8,000 lbs. and engines of 70 H.P.—up to 30,000 lbs., with engines of 150 H.P., the necessary tractive effort being obtained where necessary by the interposition of an auxiliary gear box in the transmission line. Heavy vehicles of this latter type are operating in South Africa and in Persia, where they are employed in conveying large capacity tanks, steel pipes for oil-well pipeline work and multifarious other duties.

For fire fighting work the modern passenger chassis lends itself to a very attractive vehicle. In this case an auxiliary drive is taken from the gear box through which the power is taken to drive a two-stage turbine pump. Such pumps are capable of delivering up to 900 gallons of water per minute and up to heads of 180 lbs./sq. inch.

City growth demands equipment capable of dealing with buildings of over 100ft. in height, and for this purpose a fully mechanically operated escape of over 100ft. extension, complete with life-saving lines, telephone and monitors is produced.

Considerable controversy is sometimes raised over the merits of the tram-car as compared with that other electrically propelled vehicle, the trolley or trackless 'bus.

The ability to flatten out the output of a Municipal generating station, resulting in a higher load factor and cheaper units compels many Municipalities to consider this form of transport.

Such a specialised chassis is constructed from standardised units used in conjunction with series wound motors of 80 H.P. A compound wound motor can be utilised in place of the series wound for purposes of regeneration where this is considered necessary, such as descending long hills.

Time does not permit of a more extensive treatment of these specialised chassis, but before closing reference must be made to the use of standardised units for installation in a form of transport which has been extensively tested and of which, no doubt, far greater use will be made in the future. This
is the light rail-car for use as a feeder service on suburban lines and where the use of a steam train is economically prohibited.

![Light Forty-Seater Rail Car](image1)

**Fig. 10.**
A Light Forty-Seater Rail Car produced entirely at the Leyland Factory.

The high speed petrol or diesel engine in conjunction with a torque converter makes a most attractive power unit for cars of this class. Such units of, say, 150 H.P. can be used single, or duplicated to each bogie, depending upon the gross weight of the car and gradient to be climbed. The controls are arranged in such a manner that driving is a case of extreme simplicity.

**BODY WORK.**

When buying the average car it is very rarely that the owner-driver decides to have a special body built to his own ideas, knowing full well that the manufacturer with all his experience behind him can be relied upon to produce cheaply and more satisfactorily a body to suit his particular requirements, and for this same reason it has been found very desirable for the commercial vehicle manufacturer to concentrate on the production of the completed vehicle such as in the case of the Leyland Company.

Although the greatest care is always taken in selecting the finest seasoned hardwoods for timber construction, yet the continuous wracking, susceptibility to dry rot and miscellaneous items of damage received in service, prompted manufacturers seriously to consider the use of all metal bodies.

Spasmodic efforts were made some two to three years ago with composite bodies, but 1934 indicated that only all-metal bodies made from alloy steel sheets and sections, Bounderised to prevent rusting, would be used for general service work.

A body of this type, being as it is of bolted and welded construction, is very strong; further, fire risk is eliminated, it is practically free from the annoying squeaks and rattles which arise in service, is comparatively light, and above all the materials used are of a known standardised quality. The Company with whom the author is connected have standardised on bodies of this type, which include many novel and distinctive features.

![Thirty-five Seater “Tiger” Bus](image2)

**Fig. 11.**

In conclusion I would like to offer my thanks to my Company for permitting me to read this paper and for the production of the many slides with which it is illustrated; and also to my colleagues for the valuable assistance they have given me in offering various suggestions and checking the subject matter.

The CHAIRMAN: We are very much indebted to Mr. Pilkington for the very interesting paper he has given us on this subject of motor transport. The commercial motor vehicle has become such a commonplace in our modern life that few of us stop to realise what a complete triumph of mechanical engineering it has become. The use of these commercial vehicles, in the form of heavy lorries, tractors, and so forth, is gradually finding its way into the sugar industry. No doubt in a few years time we shall find them practically catering for all the transport problems of a sugar estate. The manufacture of motor vehicles has never been attempted in this country; we have only assembly shops, where vehicles are built from parts manufactured elsewhere. We regret that time has been so limited that Mr. Pilkington has not been able to give us his paper more completely.