portion of a main road, and, leaving his gear in, found it impossible to shift a large 'bus; he telegraphed "broken down," and another car was sent out to bring him in, when it was found that the mica in one of his plugs had burnt out. The cylinder was disconnected at the 'bus bar and the car moved to a wider stretch of road under its own power, where a new plug was inserted and the car driven home. The tappets need adjustment about once a week to synchronise the firing in all the cylinders, but where a number of cars are concerned the individual cost is negligible, as a good mechanic soon becomes very quick, doing the work in two or three minutes per car. From the point of view of sound practice one cannot regard as such a system that requires a mechanical device subject to the great heat that exists inside the cylinder. Lastly, but by no means least, there is the great difficulty of starting a "sluggish" engine, frequently leading to the employment of a second car to push or tow the first one, a process now commonly forbidden by large companies. It is still more difficult to start an engine that has been taken to pieces and had its bearings let together. With neither of the other systems do these drawbacks exist, or where they do are much more easily dealt with. With all high-tension systems (where sufficient pressure has to be employed to make a spark jump one-eighth of an inch under pressure) it is difficult to sufficiently insulate the leads to prevent "shorting." On one occasion the author was called a distance of 30 miles from London, to where a bad break-down had occurred, to see that a new engine had been properly fitted. Being in somewhat of a hurry, a test was ordered at once, to see that the van was fit to resume its journey, without the bonnet having been fixed. After about three miles a shower of rain came on suddenly, causing a short circuit, and consequent stoppage, with the result that three boys

had to be chartered to hold coats over the engine whilst the return journey was effected. The arrangement of the "leads" in fibre tubes has done much to obviate this sort of thing, and the continual improvement in the high tension magneto is making that daily a more and more desirable instrument. As regards the accumulator, a company working a fleet comprising upwards of 100 'buses uses these exclusively and finds them cheaper, but then a competent man is kept to supervise recharging and cleaning, and where current is cheap this must make a great difference. Few will dispute, however, that the future lies with the high tension magneto.

Petrol and Carburettors.—When the motor omnibus first made its appearance the "light" petrol only was employed, with the natural result that its price advanced rapidly. Refiners of motor spirit therefore endeavoured to get motorists generally to adopt a spirit with a specific gravity of .760 instead of .700 to .720, and at the same time assured the public that a plentiful and cheap supply of that quality of spirit would be obtainable. Omnibus and cartage companies gradually adopted it, and found that it went further and yielded more power. This spirit has not yet reached Australia, the nearest approach to it being that which in England is termed motor-car spirit, and here benzine, and is used in motor launches, etc. The considerably lower price for which the .760 spirit can be purchased makes it a valuable consideration in the working of "heavy" motor cars.

Even as far back as 1906 the Paris 'Bus Company was very successful in working its Brillie 'buses, fitted with an ordinary carburettor on a compound of alcohol and benzol, mixed in equal proportions. The results were most satisfactory, and it was found that a car fitted with a 35 horse-power engine and fully loaded would run a kilometre on half a litre of this mixture,

which works out to about seven miles to a gallon. It is estimated that alcohol might be produced on a large scale for about 9d. per gallon.

The fact that crude paraffin is unobtainable in Australia, and seems likely to remain so, makes it useless to discuss prospects of carburettors designed for its consumption. It may be stated, however, that many experiments have been made with it in England, and a number of "heavy" cars are now run with it. The objection to it is its unpleasant smell, and the inability to start the engine, which necessitates the provision of a separate tank for petrol; the carburettor, too, is invariably larger and more heavy.

Returning to petrol consumption, the distances run on a gallon of spirit by London 'buses is very interesting. Of the earliest, one engine regularly ran eight miles to the gallon, but no other came near it, the next being five, and one type rarely managed to exceed three. Many carburettors were tried, but ultimately one standard type was adopted—the Maybach—and with the heavier spirit that had then come into vogue, enabled the cars to travel on the average 5⅞ miles to the gallon. There is no reason why eight miles should not ultimately become the average distance for a gallon, and in Australia rather more, the dryer and clearer atmosphere permitting a greater proportion of air to mix with the gas.

Cooling.—The arrangements for cooling the engine are only now emerging from a state of extreme inefficiency. The system consists, apart from pipes and water jackets, of a pump, fan, and radiator. Of these the water jackets in the early days were much too short, and many were the broken cylinders resulting therefrom; large owners soon had cylinders specially cast for them with water jackets twice the size of those originally

supplied, resulting in a wonderful decrease in the number of cracked or broken cylinders.

The worst feature of the pump and the fan is the arrangement made for driving them, a fibre pinion being usually employed for the former to induce silent running, and a leather belt for the latter. Probably an easily adjusted friction drive from the fly-wheel will be found more suitable for actuating the pump, and the fan might with advantage disappear altogether, or those who consider it indispensable could construct it with the fly-wheel, a quite practical arrangement where the engine is efficiently increased as it should be.

Many types of radiator have been tried, but only the tube and honeycomb types have been largely used. The former is built for hard wear, and the latter for appearance, although its cooling properties are somewhat superior. These, however, are insufficient to compensate for the costliness of repair and the difficulty of keeping the radiator perfectly clean. When a honeycomb radiator becomes choked, the water is drawn from the bottom and returned to the top by the pump much more quickly than it is able to percolate through the partly closed crevices, with the result that very few minutes suffice for the greater part of the supply to escape through the overflow (which is not visible to the driver), thereby causing overheating and damage to the engine. The tube radiator may easily be kept clean, and it is repaired without difficulty. In the event of a collision, it is a comparatively simple matter to block the damaged tubes and to run home with the remainder.

Clutches.—Although one naturally regards the clutch of a car as of minor importance, it is nevertheless a source of much trouble and worry to operating engineers, quite as much on account of its effect on the other parts of the machine as for the manner in which it sometimes does its work; the usual difficulty is that of keeping it

so adjusted that it will work with regularity and efficiency. Of the many types of clutch that have been put forward, the leather-faced cone clutch is by far the commonest, although it is doubtful whether it will remain so for much longer; it is undoubtedly seen to better advantage on van work than on public service, where stopping is frequent. It is principally recommended on the score of simplicity, but is liable to slip, and badly, too—through stress of weather, overflow of oil, or the sudden wearing away of one of the ridges, which invariably appear on the leather surface. When any of these happen most drivers will cheerfully allow the slipping to continue, and in many cases even the smell of burning leather does not impress on them the fact that all is not as it should be. New leathers have then to be fitted, a proceeding requiring considerable skill.

The De Dion metal disc clutch, although more complicated and costly, has invariably proved excellent in practice, and many engineers are prepared to meet this extra trouble in return for the sweeter and more regular service which they give. The Multiple disc clutch was used for some time, but, what with broken springs and scored plates, was too costly, and disappeared from "heavy" work, to the regret of most. Two years ago figures were obtained to show the types of clutch in use on London motor omnibuses, and of nearly 900 then in service, 725 were supplied with leather-faced cone clutches, 118 with the De Dion metal disc type, whilst five others had clutches of other types, the remainder of the cars being steam.

It is the aim of responsible engineers to do away with the clutch and gear box, but up to the present no suitable substitute has appeared on the market, although excellent devices have been designed and patented. If an internal combustion engine could be invented with

the flexibility of the steam engine and able to start regularly on the switch, the troubles of the petrol motor would be quickly at an end, but, unfortunately, there is no chance of such a thing happening.

The introduction of a strong and powerful coiled spring between the clutch and the road wheels would do much to improve the starting of these heavy cars, and would enable them to be started without undue jerk. The author is not aware of any such arrangement having been tried, and it is surprising that no experiments in that direction have been made. Such a device would certainly protect the engine, permit the use of a much more crude form of clutch, and also reduce the tyre bill.

Transmission and Final Drive.—From the consideration of clutches one naturally proceeds to that of the transmission necessary for the petrol engine, which eats up a large part of the power developed. Few thought seven or eight years ago that the gear box with its variety of sliding gears would survive for more than two or three years, but to-day it is as supreme as then, notwithstanding inventions of high efficiency, which, however, from one cause or another, have never appeared on the market. The sliding gear of to-day is a better made and more efficient article than that of even four years ago. Whereas in those times few claimed a higher efficiency than 29 or 30 per cent., to-day, with direct drive and the splendidly-finished hard steel gear-wheels, 50-60 per cent. is invariably claimed. The introduction of the "gate" system of gear changing has also done much to lengthen the life of gears, which in 'bus work has increased since 1904 from about 5000 miles to between 30,000 and 40,000 miles, whilst cases are on record of 50,000 miles having been exceeded, or ten times that of the early ones. The object of the "gate" is to enable the driver to change from any one gear to another without the necessity of bringing any

third one into mesh first, as was the case with the old sliding type.

Other types of transmission which have had practical test in heavy work are various forms of electric drive, both with direct and alternating current, and Hall's hydraulic gear. The former, although silent and smooth in working, proved costly, and now only one out of several tried remains in service, and that seems likely to be the only one of its type. The hydraulic gear proved most successful, and under test gave an efficiency of 92.7 per cent., which all will agree was very high. Being absolutely variable, the clutch became unnecessary, as any possible ratio between zero and the maximum could be obtained. The only apparent reason for this gear not coming on to the market was the severe terms demanded by the inventor, who preferred to let the matter go rather than give way.

After the gear box the subject of final drive to the road wheels demands attention, and to effect this four separate types continue to bid for supremacy. These are: (1) The chain drive; (2) the propeller shaft; (3) the rack and pinion; and (4) the worm drive and live axle. All these systems have their advocates, but it is hardly likely that the chain and rack and pinion will survive. Of these the former is noisy and inefficient, and if silent chains are used costs ¼d. per mile for upkeep; on the other hand, road shocks are taken up by it and not transmitted to the gear box. The latter is extremely noisy, and consequently inefficient where the centres are not made to register accurately, which is the case with all such types except the De Dion.

Of the other two the worm drive as at present made is unsatisfactory and costly; little or no provision is made to take up the end thrust, and the worm consequently wears very fast. It is estimated that it costs quite ½d. per mile for upkeep, which, notwithstanding

its silence, is prohibitive. Several rack and pinion driven 'buses were altered to this form of drive, but as the direct line could not be maintained, a universal joint had to be used, working at an angle of some 30 deg. from the horizontal, which wore so quickly that the "improvement" had to be quickly abandoned. The live axle drive is quiet and efficient, but needs to be so strong and heavy to stand the work that few manufacturers care to face the task of designing one strong enough.

Up to the present the chain drive has proved most satisfactory, and further trial of other types is needed before they can be deemed effective substitutes.

Tyres and Wheels.—This subject is worthy of careful consideration, if only on account of the heavy cost of tyres. It has been the practice of many operating companies to hire their tyres, paying for them by the mile, and leaving the actual cost per mile to the tyre companies to defray. These contracts have cost 'bus companies between 1½d. and 2d. per car mile, and cartage companies according to the weight and power of their machines. There can be no doubt that to-day the correct way to obtain tyres is to buy them outright for cash, thus avoiding the trouble caused by checking mileages. When this is done, the contributory causes to wear of tyres will come in for greater consideration. These may be stated to include the relative width of tyre to the weight of the car and the diameter of the wheel, the distribution of the weight, the efficiency of the clutch, and the general power of acceleration of the vehicles. In addition the life of a tyre is affected by the use of steel or wooden wheels. Except for light van work, the use of steel wheels is recommended, especially in Australia. They provide a solid bed for the tyre, do not start and become uneven, are more silent in running, and last almost indefinitely. A number of manufacturers

use them exclusively now, and others are showing a tendency to adopt them.

As an example of the relative life of a large and small section tyre, one may consider the case of a 4½-ton van, which was originally fitted with 4¾-inch tyres, two sets of which ran 20,500 miles, or 10,250 miles each. These cost £97 per set, and consequently 2.33d. per mile. Following the advice of the tyre manufacturers, the third set used had a cross section of 5½ inches, and cost £120, but they ran for 17,200 miles, which worked out at 1.68d. per mile, a saving of ¾d. per mile. The same invariably applies to all such tyres. No more foolish policy can be imagined than that of purchasing cheap or small tyres with a view of keeping initial cost as low as possible; any firm might easily ruin itself in a few years of such policy. One can only say that owners would be well advised to purchase the best available tyre and of ample size, and would only be acting in their own interests by paying marked attention to securing a regular and smooth-acting clutch and by encouraging their drivers to start and stop as gently as possible.

Pneumatic tyres were tried in 1906 on the front wheels of a 'bus belonging to the London Road Car Company, but owing to the extreme difficulty experienced in steering the car, they were removed after only two or three days' trial, several drivers flatly refusing to continue their journeys. The experiment has not been repeated since, to the author's knowledge, with any vehicle built to carry a load over 10 cwt.

Before leaving the subject, it is necessary to refer to wheel diameters, where "heavy" motor car work is showing that present design is wrong. Designers have followed pleasure car standards, where every effort is made to keep everything as low as possible, to ensure stability at high speeds. Apart from the reduced wear

on roads, it is now certain that wheels of larger diameter are both smoother running and lighter on tyres. This was discovered where two competing 'bus companies in the South of England tried to outdistance each other in point of speed. One of them hit on the idea of increasing the diameter of the driving wheels by two inches to get more pace. The ruse was not only effective, but made the 'buses more comfortable to ride in, and the life of the tyres greater.

Standardisation.—It will be readily understood that in the early days of motor omnibuses each designer followed his own ideas of what was right, with the result that from engine to wheels no two makers agreed in size in one single particular. When placing orders operating companies watched this, even at first, with the result that some excellent makers were passed over on account of their inability to supply quantities at short notice, and some orders undoubtedly were placed more with a view to large and rapid deliveries than to the actual excellence of the machine.

Thus after a short time efforts were made to bring about greater standardisation of parts throughout a fleet comprising probably as many as five or six different makes. Wheels were first attended to, and even where they themselves could not be interchangeable on account of the arrangement of their final drive, their widths and diameters were made so, in order that the uniform size of tyre might be fitted. The same was applied to radiators, lubrication, and ignition. At one time it looked as if the honeycomb type of radiator was going to triumph, but later more and more gilled tube radiators appeared, and now as those of the honeycomb type wear out they are being superseded by the other.

In some yards high tension ignition has been altered to low tension, on account of the large majority being of that type, and its being undesirable to have several

types in the same yard, more particularly because men used to working with the one frequently fail badly when they come in contact with the other.

A great desire undoubtedly exists to similarly treat lubrication systems, but on account of the great cost of alteration and inefficiency of all, little or no progress has been made, although the next twelve months will see much done in that direction.

Complete engines, too, are being made of standard type, and when engines wear out or are unsatisfactory rebuilds have been effective—and with a large measure of success, too. A general scheme of standardisation on these lines will not be effected during the life of present machines, as it is certain that future orders will be placed only for one standard throughout—at any rate, where large companies are concerned.

The Driver Question.—Amongst those responsible for the vehicles themselves there has been considerable argument as to the training that should be given to drivers before putting them in charge of a van or 'bus. Such training must undoubtedly vary according to conditions. In places like London, where services are frequent and the distance to the depot never great, men who are merely trained to drive their vehicles are preferred. Such men are more easily obtained, usually more effectively disciplined, and, having no mechanical knowledge, do not attempt to interfere with delicate parts of the machines, whereby much damage might be done in a very few minutes. The so-called motor mechanic, on the other hand, will not only require a higher wage, but will be more difficult to manage, and be likely to interfere with the machinery while on the road, thereby seriously jeopardising the regularity of the service; in fact, cases are on record where such men have dismantled an engine or taken a magneto entirely to pieces, and then have been unable to re-assemble the