

ACCESSIBILITY AND CLEANLINESS,
AND THE
BEST MEANS OF ATTAINING THEM.

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IN tackling a paper on this subject I have endeavoured to put before you the ideal to be aimed at, and to indicate how this ideal may, in some degree, be attained. In doing this I have taken the liberty of laying down the law on one or two points. During the preparation of the paper, certain points cropped up which more or less bear on the subject, such as the number of cylinders to be used, but these I have eliminated entirely from the subject-matter of the paper. It will be found, too, that it deals only with petrol motors and motor cars. I have tried to consider each item from the standpoint both of the vertical and horizontal engined car; my difficulty usually has been that the horizontal type can be made so much more accessible in almost every detail that my remarks will be found generally to apply to that type. I must apologise for the shortness and incompleteness of this paper.

As regards the two points in the title "Accessibility and Cleanliness," they are so intimately connected the one with the other that I have had to consider them together.

To begin with the ideal of cleanliness, it is, I think, that the whole exterior of the car should be smooth and easy to clean; that no mud or dust should be able to be thrown by the wheels on to any part of the mechanism, on to the steps or the carriage body; that all working parts should be thoroughly protected from grit;

and that all oil drippings from the engine and gear should be caught and retained in a detachable receptacle easy to remove and clean out.

The great question on which the whole problem of accessibility hinges is this :—Why is it needful to be able to get at any parts of the mechanism ? If it were not, the matter of cleanliness would be an easy one, as one could seal the whole mechanism up like sardines in oil and let it look after itself and yet always keep the exterior spick and span. Under these circumstances it would necessitate the designer so proportioning the various parts of the car that nothing ever wanted adjusting or replacing, and the end of the car would be like the one-horse shay, which collapsed into nothingness after its period of life was fulfilled. Unfortunately for us, it is impossible so to foresee the very varied conditions of working and the attention, or, rather, lack of it, bestowed upon our productions by those responsible for the running of them, that they will wear out evenly, nor is it possible to provide absolutely against accidental breakages.

This being so, it may be necessary to remove or adjust any part, and so, to obtain the ideal of accessibility, we may lay it down as an axiom “that we ought to be able to remove any one part without disturbing any other.” This ideal, like all ideals, is practically impossible of attainment ; to approach within reasonable distance of it would necessitate every part being exposed and in view, which would prevent us obtaining efficient means of protection, and jeopardise our ideal of cleanliness. The best we can do, therefore, is to study the easy removal of those parts liable to wear and to use as a foundation on which to build up these parts all pieces not so liable.

The very first thing to consider, therefore, is the general scheme of the whole car, and in this the body which is to be used is the item of greatest importance.

What is the use of having an engine nicely housed in a bonnet in front, easily opened and inspected, if the gear box and other vital parts are covered up and made inaccessible by the carriage body, as on a car I found stranded by the roadside the other day. In this one of the gear wheels was pushed into mesh by a fork which, having got strained, refused to work ; it was almost impossible to do anything to it, as the carriage body was in the way of the cover of the gear box, and was fixed so that it would have taken a long time to remove.

The body, undoubtedly, should be easily raised or moved so that all running gear can be easily and efficiently inspected.

Now, the position of the carriage body depends principally upon the permissible wheel base. What is the maximum wheel base which is easily handled and utilised in all districts? I have come to the conclusion that 9 ft. is the maximum, and I derive this figure from experience of cars of various wheel base on the roads around my home in Devonshire. Here a car with a width of more than 5 ft. 6 in., and of more than 12 ft. in length over all, is impossible, as the following details of typical roads may show :—

There are two roads by which the house can be approached. The one is up an incline of 1 in 6 to a right-angle turn, then 1 in $5\frac{1}{2}$ to another like turn, then a few yards of 1 in 5 to finish. This road varies in width from 10 ft. to 16 ft. The other road only rises 1 in 12, but is in some parts only 8 ft. wide. Luckily it is straight. This is rather a digression, but it shows what in ordinary every-day work a car may have to contend with, and so it fixes the maximum length of a car for every-day use.

Having the size of a suitable carriage body, we can ascertain the amount of available space for engine, &c. Take a landaulette body, the type most in vogue. This to be really comfortable must have a total length from dash to back of 108 in., which, you will notice, is the same as the wheel base.

As it should not project behind the centre of the rear wheels to give absolute comfort to the passengers on the back seats, the dash will come level with the centre of the front wheels. This does not give enough room for an engine of the ordinary accepted vertical type in a bonnet in front; it is thus imperative to adopt some other position for the engine or curtail the seating accommodation. If the engine is a vertical one, it can be placed in a bonnet between the driver and passenger in front, or it can be arranged under the driver's seat. Another way out of the difficulty is to utilise a horizontal engine. I, personally, have chosen the latter, as by so doing one leaves an absolutely flat surface for the carriage builder to work upon and every part can be made very easily accessible.

To render every part accessible the body can be made to rise on hinges at the back, which done, the whole of the running gear, and not merely the engine, is at hand and in view. Should not the gear-box, &c. be cleaned and inspected just as often as the engine?

To inspect the engine and gear-box separately the front and back floor boards can be removed, the former for the engine and the

latter for the gear. As to the removal of the floor boards for inspection purposes, if these are made to lift out there is a greater liability of the mud and dust collected on them being emptied on to the parts below. I am therefore making them to slide out of the way under the seats and yet arranging them so that they lift up with the body.

These few remarks, I think, indicate how the body may be made so as to minimise its interference with the accessibility of any part. I will, therefore, proceed with the chassis.

As a general practice, it may be laid down that the whole of the chassis should be erected and every part should be accessible from above. The true meaning of this is that with a car so designed a pit is no longer a necessity, and also that the most perfect cleanliness can be arranged for, as the undershield can be made absolutely continuous and permanent.

There are certain items which, although at first sight they appear to have no part in the making of accessibility, yet in reality they do so. One of these is the method employed of locking nuts, and another is the size of nuts used and the position of them. Dealing with the latter point first, it should not be necessary to use special spanners for any nuts. Every nut should be arranged so that it can be got at either with an ordinary tubular box spanner or an ordinary flat spanner. Personally, I favour making all possible nuts to be done up with a tubular box spanner, as this tends to lessen the weight to a large extent by curtailing the size of boss necessary, and also, by preventing damage to the nuts, makes them easier to handle after much use.

The number of sizes of nuts used in a car should be reduced to a minimum; in fact, I settle on the sizes to be allowed before the car design is even started. I am now using only five sizes on the whole car, which means that the total number of spanners necessary to undo any nut is greatly reduced. To deal with any nut will require only three tubular box spanners, two double-ended and one single-ended, and three ordinary flat spanners, two double-ended and one single. How very different from the kit necessary with one well-known make of car, which consists of seven sizes of ordinary spanners, a jet spanner for the carburettor, a hub spanner, and two adjustable spanners—eleven in all. Why these last should be necessary is a mystery, unless to use on some accessories, of which there are too many on the market, with odd sizes of nuts. Why they should not be standardised I don't know, and I think it would

be a great and good work if the Institution were to go into the matter carefully with a view to the reduction in the number of sizes of hexagon nuts used. As an example of the state of affairs now, I must mention a carburettor I purchased recently to try; on it I find there are no less than five different sizes of hexagons and some slotted screws. Three sizes would have done everything.

Of the spanners which I have mentioned as necessary for my car, the jet spanner is the smallest, and this is now being made to fit all nuts on the ignition parts. All screws on the carburettor, &c. are also being made with hexagon heads to fit this spanner as well as a screwdriver slot.

The method employed of locking nuts is the other point I mentioned. For this purpose I divide the bolts up under two heads, namely:—

- (1) Those used for construction, which seldom or never require removing.
- (2) Those which require removing to make adjustments or for cleaning.

For No. 1, as a general rule, I prefer to use Castle nuts with spring washers under, and for No. 2 ordinary nuts and spring washers. A Castle nut, in my opinion, should never be used without a spring washer, as it requires such care in tightening so as to fit the cotter, if it is to be done without either straining the bolt or leaving it too loose.

An example of the indiscriminate use of nuts came before my notice some months ago in an engine which, originally of American design, was being brought up to English practice so as to be placed on the market here. The only way of describing it is by saying that it looked just as if a bucketful of odd sizes of bolts and nuts had been poured on to it, and that they had been fitted where they fell. To take any part off required about five spanners and a screwdriver. This state of affairs, I am pleased to say, has now been remedied.

In the consideration of the position of nuts and bolts it is general practice to arrange them through a boss; this in nine cases out of ten projects outside the case or whatever part it belongs to. It is also common to find gear cases and engine cases shaped so as to fit close to the gears inside. When a case is so arranged it may be very nice designing, but it always appears to me that if it were smoother and flatter outside, the bosses being arranged as much as possible inside, the weight would not be very much, if at all, increased; it

would be much more easily cleaned, and it would simplify the patternmaking, and in all probability cheapen the moulding, and, perhaps, make the holding of the piece in its jig for machinery much easier. The most important point about having cases smooth outside is so that, in the event of anything requiring to be done inside, the outside may be made absolutely clean before it is dismantled. Under these circumstances, grit will not find its way into the interior when the parts are in the hand of the repairer.

The repairer's lot is not altogether a happy one, as he is supposed to know all about a car which he may never have seen before, have a new part in stock to replace a broken one, and charge less for doing the work than the new part is generally worth. It is well to consider him somewhat, for when a car does get into his hands which is easy for him to handle, he can help a great deal; at the same time, one must remember he can do the reverse.

We now come to detail design, and will consider the engine first.

If this is of the vertical type, many difficulties exist which may not appear at first sight. To comply with our axiom it should be possible to withdraw a piston without disturbing any other part. To do this necessitates a very large hole in the side of the crank case, or else it must be done from underneath, which is generally very inconvenient. If it is arranged to be taken out at the side, to make it really convenient, the engine must be fitted very high up in the frame—so high, in fact, that the fly-wheel and other parts will more or less interfere with the carriage body. Of course, if there is a hand hole in the crank case sufficiently large to take down the big end easily, it is possible to remove a piston by dismounting a cylinder. This method, however, is crude and unpractical in most engines by reason of the number of joints to be broken, and it does not at all fall in with the axiom with which we started. On a horizontal engine it is possible to make the whole of the top side of the crank case to come off without impairing its strength, and then the whole of the crank shaft, connecting-rods, and pistons are in view, and each part can be easily dismounted separately.

As to the cylinders themselves, there seems to be at the present time a great wave in favour of casting them all together. This may be good from a constructive point of view, but it is not so from the point of view of accessibility and repair. It has one advantage in its favour, and that is, it enables the whole of the valve stems and springs to be encased. The question is whether this is necessary. As long as we encase the engine in a nice bonnet and undershield,

and then pump air laden with dust and mud through the radiator and over the engine it will be necessary. Should we not rather seal the engine up and pump air from the radiator around and out at the back of the car? This would tend to keep the exterior of the engine cleaner, and allow of a large amount of casing at present fitted on the engines being dispensed with and fitted instead as a casing for the grit-laden air to pass through. Reverting to the cylinders, in the whole of my experience I have never had to replace a cylinder because it was worn out; but still, I advocate casting them separate on account of accessibility, and so as to be certain of all casting strains and unevenness of expansion being eliminated. If my memory serves me rightly, I know of five cylinders being replaced, but all through accidental damage and in different cars. This, with four cylinders cast in one, would have necessitated twenty new cylinders and the proportionate extra expense to the owners of the cars.

To my mind, a cylinder should be easily detached without removing even an inlet, water, or exhaust pipe, but only breaking the joints.

The valves on most engines nowadays are easily removable, but it should not be necessary, in removing them, to have to take off the spring. This should be arranged to be supported whilst the valve is withdrawn and ground in. At the same time, a valve spring itself should be easily replaceable in case of breakage.

Another part which is usually rather difficult to get at is the gudgeon pin. In most cases this is fixed by two taper-pointed screws. As these require very carefully locking with nuts, and are very close up to the side of the piston, they are practically only removable with special tools. At the same time, they have the disadvantage of causing the piston to oval when hot, as the expansion of the piston and gudgeon pins are slightly at variance. To obviate this, as long ago as 1899 I fixed the gudgeon pin in the small end of the connecting-rod by a taper pin, driven through on the side away from the big end. This has been found by experience to be very easily fitted and dismantled, and has never given trouble; it allows for perfect lubrication and free expansion, as well as accessibility. To make it easier to fit and remove, it is better made of three diameters, the smallest and largest fitting in the piston and the intermediate in the connecting-rod. To fit the taper pin in its place, and also to extract it, there are holes made in the piston

opposite the ends of the pin. It is drawn in through one and out through the other.

During some repairs to a car recently, a quite impossible design of gudgeon pin, from the point of view of accessibility, came under my notice. In this case the pin was solid with the connecting-rod, and the bearings in which it moved were eyebolts in the piston end fixed by nuts in the combustion space. Taking off the nuts wrung the neck of the bolts, and so necessitated new eyebolts. It was necessary also to bring up the pin in place or else fit new connecting-rods and eyebolts.

The ignition distributor or commutator should be arranged so as to be easily taken apart and cleaned. This I have managed by making the rotating centre spindle and contact cam withdraw out of its bearing, leaving the whole interior free for cleaning; the end of the spindle is driven by a dog clutch so that it can only be fitted in its right position.

The cam shaft should be made to come away sideways; when made to withdraw from one end it often necessitates the taking down of some other part. It is better to my mind if arranged so as to be inspected by simply taking off a cover.

Carburetter.—This part of the anatomy of a petrol engine has received an enormous amount of attention in the last few years, but I am sorry to see that the tendency has always been to add parts, and not to eliminate them. Some of the later types may or may not be more efficient than their predecessors, but they certainly are not more accessible.

It is impossible in most of them to ascertain if the petrol stands at the correct height in the float-box, for the simple reason that the float valve has its gear on or is guided by the cover. Why should it not be made independent of the cover? Similar contrivances for other purposes have been in use for years, and are always made accessible, yet a carburetter, which depends on the accuracy of this adjustment, in a great measure is incapable of correct adjustment. The design which I now use has the float on one end of a lever, the other end of which presses on a horizontally arranged needle valve. In this way the needle valve and its seat can be withdrawn together by undoing the petrol pipe union, and the petrol level can be observed and checked with the top of the float-box off. The float, too, can be easily removed.

The jet in many carburetters is so arranged as to necessitate the removal of quite a number of pieces to clean it out; in others it is

extracted with a tube spanner. In doing so, it generally falls out of the spanner and drops inside, giving rise to much waste of time and many words. As a jet never gets stopped up except at a most inconvenient time, it is as well to provide for its easy removal. This I have done by cutting a groove around the hexagon end of the jet and fitting a spring on the spanner which engages in this groove and so prevents its dropping.

There is a great tendency to place the pump and magneto by the side of the engine; in this position they cover up space which should be left open for the inspection of the big end brasses and valve gear. The correct position to gain the maximum of accessibility seems to be to arrange them in front of the engine, and drive them by a shaft at right angles to the engine crank shaft, in a vertical engine. A horizontal engine can have the magneto alongside one cylinder, or in front of the cylinders, and no pump need be fitted.

In many cases the exhaust pipes will be found on a car wrapped up with asbestos; instead, they should be carried out of the way. This is another point where a horizontal engine scores, as they are quite out of the way underneath.

It is essential to have an under-shield completely enclosing the engine; it should be quite tight-fitting, and if it is necessary to have a hand hole in it, the hole should be large enough to work through, and a good three-eighths bead carried around it. The shield should be oil-tight and fitted with a sump, into which all dirty oil will drain, and which can be easily removed and cleaned out.

I prefer to make the under-shield in the form of separate trays, each oil-tight and easily removable, and sprung into place and fastened. Any tray may then be taken off. As a further protection to the engine, I have carried the frame down to below the step, and carried it and the wings into the frame, to which I have joined them. The step is also joined to the back end of the front wing and the front end of the rear wing. With this arrangement there is absolutely no space through which mud can be thrown by the wheels on to the engine, carriage body, or steps.

As it is not much use having parts accessible if the tools required to do any adjustment are not at hand, it is as well to consider the arrangement of these. If arranged in a deep box with trays, the tool one wants is certain to be in the lowest tray; therefore it is better to fit them in shallow trays, and make each tool have its allotted place. The step is the most convenient place for these,

and, by having our outfit reduced in size by reason of the small number of sizes of nuts, a duplicate set of spanners can be carried, one set in each step. Anything can be adjusted from the side nearest to it without loss of time. This is, perhaps, an unnecessary refinement, but a very convenient one.

Before we finally leave the engine, there is one other part I must mention, and that is the adjustment usually fitted on the coil trembler.

This, as a rule, is a screw with a milled head passing through a bridge piece, and a hexagon lock nut to fix it after adjustment.

This nut nearly always requires a special thin spanner, as the space between the milled head and the bridge is not sufficient for one of ordinary thickness, and it has the further disadvantage that the locking of the nut by pulling the screw up into the threads disturbs the adjustment. A much more accessible way of doing this is by splitting the bridge vertically throughout its length, and fitting a screw through, coupling the two halves, and so clamping the adjusting screw. In this way a much finer adjustment can be made.

I am sorry to say the time has been very limited which I have been able to give to the preparation of this paper, and as a consequence it has not had a sufficient period to mature, and the remaining parts of the chassis will receive but scant mention.

We now come to the clutch and gear box. In the majority of cars at the Show at Olympia these two parts seemed to have received the greatest amount of attention to make them individually accessible. Whether they were so collectively with the carriage body mounted seemed to be, to a very large extent, left to the tender mercies of the carriage builder.

Given that the carriage body is not in the way, there is very little to note with regard to either of these parts, as they can be made so easily dismantled.

We now come to the back axle, and the more I go into this the more there is to say. So many different types are in use, and each must be considered separately, that I think it better only to mention a few points to be considered.

The chief features which have to be retained in view are these: Either wheel should be easily removable. The differential should be accessible. It should be possible to correct the adjustment of the drive, be it bevel, chain, or worm, and the brakes should be easily adjusted, and their adjustment should not require altering to

remove a wheel. From the point of view of cleanliness, if chain drive is used, the chains should be encased if outside, or else the under shield should be so prolonged and shaped to protect them.

As regards the steering, this is usually arranged so that the various connecting-rods are outside the under shield, and the joint ends protected with leather covers. I prefer making all the connections inside as much as possible, and have designed the joints so that they are dust-proof. One further point should be considered, and that is cleanliness, from an outsider's point of view. It is not well to leave drippings of oil about wherever one goes, nor is it nice to raise clouds of dust. The shape and construction of the under shield should receive great care, so as to prevent either of these forms of nuisance.

I have to thank all those firms who so readily responded to my queries, and rendered me assistance and information.

Mr. Martineau then illustrated, by means of diagrams, one or two points mentioned in his paper. No. 1: The back axle of the Iris car, showing a very accessible type of differential gear. No. 2: The Iris back axle, showing a very good and neat design and one that was easily accessible. Nos. 3 and 4: The engine of the same car, very clean in design and easily accessible, but with cylinders cast in two pairs. Nos. 5 and 6: The Iris gear-box, which was very accessible. Nos. 7, 8 and 9: The same car with side-chains. In this car the brake gear did not require adjusting, or rather dis-adjusting, to remove either sprocket or rear wheels. No. 10: The engine with exhaust pipes wrapped up in asbestos; these should be carried out of the way. No. 11: The engine on the inlet side. No. 12: The rear live axle which required splitting to inspect, and therefore had to be taken off the car. No. 13: The same put together, illustrating a bad arrangement of ribs and bosses which would collect dirt. No. 14: The Pilgrim engine with separate cylinders, flat faces, and single bolts to inlet pipes, allowing of easy removal. No. 15: A rear view of the same engine with cover removed, giving access to the big ends and making pistons easily removable. No. 16: The Pilgrim chassis, underside view, showing an arrangement by which the frame was carried down and into the steps and wings, so as to preclude the possibility of mud and dirt being thrown on the body or steps, and also the under-trays (separately removable) and the smooth surface offered to the draught under the car, thus preventing air waves being formed and so causing no dust.

THE DISCUSSION.

Mr. F. W. LANCHESTER: I should like firstly to express my very great appreciation of much that Mr. Martineau has said. He has called attention to so many points in automobile design, and has covered the ground indicated by the title of his paper so fully, that the only thing left to do in commenting upon it is to play the part of "devil's advocate," and point out a few ways in which the giving of accessibility is undesirable.

The proposition is one that sounds curious, but I have one or two typical cases in my mind. In the early days of the motor car, some ten years ago, a problem in accessibility presented itself to me in connection with a "hit and miss" governor mechanism. In such mechanism the hardened steel "catch plate" is liable to wear, and requires occasionally to be removed for grinding or replacement, and I therefore designed it as a part separate from the valve stem which it was required to operate. In practice this arrangement gave trouble; the quick detachment joint between the two parts always constituted a source of weakness, and the part required replacement half-a-dozen times on account of the joint for every once for legitimate reasons. I eventually sacrificed accessibility, and made the valve and catch plate in one piece and had no further trouble. Incidentally, a moral may be drawn that I have found of great utility: *Never make a thing in two pieces if you can reasonably make it in one.*

In the evolution of a new combination of mechanism, such as the automobile vehicle, it appears to me that there is a stage of development when accessibility is a matter of first importance, but that after a time, at a later stage, accessibility takes a minor place. It may be said that all mechanism is a matter of compromise in design. There are certain factors, one pulling against the other, that the designer has to consider; frequently the best he can do is to endeavour to strike a happy medium, giving accessibility at some points and sacrificing it at others. In the early stages accessibility requires to have every consideration; in the later stages it frequently has to take a back seat. I could quote a number of cases in support of this view. The *watch* is a case in point; without doubt in the early days, when the monks had to put their own watches right whenever they broke down, accessibility was a matter of great importance. Nowadays the works of a watch are all enclosed so that they are altogether inaccessible except to skilled

repairers. The ordinary man is helpless ; if his watch goes wrong, and it is a cheap watch, he throws it over the nearest hedge ; if it is a valuable one he sends it to an expert repairer. It seems to me that the watch has reached the stage where accessibility is not a point to be considered, and similarly the final stage in any other mechanism is that at which accessibility is a matter of little or no importance. The *rifle*, owing to the exigencies of service, is a notable exception.

In regard to the merits of the horizontal *versus* the vertical engine, I fully agree with Mr. Martineau that the horizontal engine has great advantages from the point of view of accessibility, but unfortunately the designer has nothing to do with the type of engine (*i.e.*, horizontal or vertical) used in a car. The public pays the piper and the designer has to dance the tune, and for the time being the public insist on a vertical engine. This is one branch of engineering where the voice of the public is paramount.

I must confess that in listening to Mr. Martineau's paper, if I had no previous knowledge of the subject, I should have found it difficult to avoid the impression that a motor car is something which is always being taken to pieces and put together again—a sort of demonstration model for lecturing purposes, in fact. It is, without doubt, advantageous to make a car so that it can be taken to pieces with the greatest possible facility, but I think this sort of thing can be carried to excess. In the hands of the public a breakdown is a breakdown, whether it be a piston rod that doubles up, or a cylinder that splits, or merely a “shorting” of the ignition circuit at some unusual point ; the car comes to a standstill, the people go on (or back) by rail, and the car is left at the garage or sent to the maker to be repaired. It appears to me that there is a lesson to be learned here : it is better to make a car that will only break down *once* even if its parts are quite ungetatable, than one that will break down *twice*, however easy it may be to get at the defective part.

In conclusion, as an illustration of the unimportance of accessibility in well-established mechanisms, I may say that I thank Providence that *my own carcase* was designed with a complete disregard to Mr. Martineau's axiom.

MR. R. W. A. BREWER : This is rather an early stage in the discussion to make the remark I wish to make. I am neither a designer nor a maker. If I were, I should not attempt such a daring departure in design as has been attempted by the author of this

paper. There are a great many points which one might discuss ; and I may say, in the first place, that I consider *too much* accessibility is a somewhat dangerous thing in a motor car. My chief reason for saying this is that the majority of men who have motor cars, or who have to look after motor cars, are not fit or capable, or sufficiently well-trained, to make any adjustment, except, perhaps, the most ordinary ones. In following up these remarks, I must say that the horizontal type of engine, as suggested by the author, I thought was already dead, though it has been more accessible in every detail than the vertical type of engine. I must say that I regard the ordinary adjustments which are required in a motor car engine, such as may be made by the man in charge of it, are certainly difficult to make when that engine is underneath a body, or in any other way covered up by wood-work or any other material. As to lifting the body to expose parts which very seldom require looking at, I do not think that is at all necessary. A friend of mine bought a car, and showed me how easily accessible his gear-box was, but during the whole of the time he had it he never once required to look into it ; but certain parts which did require attention, such as the exhaust valve and the carburetter, were absolutely inaccessible, and other parts were most difficult to get at. We ought to be able to remove any one part of an engine without disturbing others. A good deal has been said about removing pistons, gears, and camshafts. Now, a piston or a cylinder, if properly designed, need only be looked at about once a year. Any extra work involved in getting at these parts is no great matter, though it ought to be reduced to a minimum. There is no necessity to have a great hole in the crank chamber ; nobody but an expert would dream of drawing a piston out through the crank chamber or adjusting a big end through the crank chamber. I should take the thing apart. It is not advisable to have these adjustments done in a small and confined space, and it is not a good thing to put these easy adjustments within the reach of the ordinary motor-car man, who is, at the best of times, not a skilled mechanic. All these repairs should be done by a competent man, for the sake of the motor car and for the sake of the user. There was a remark in the paper about the body of the car and the length of wheel base. I should not, if I were designing a car, settle upon the length of wheel base by certain conditions which obtain in Devonshire lanes. Very few cars are used in Devonshire lanes, and anybody who wants to buy a car for pleasure or sport wants a car which will give him the maximum of

comfort, and which, never in its lifetime perhaps, would be driven in a narrow Devonshire lane. If it should be so driven it must take its chance. But I should design a car for good wide main roads, and take advantage of what opportunities are left to the designer to get accessibility in a long chassis, and as much accessibility as is required in the bonnet. The length of the tonneau at the back part of the car was specified by the author as 108 inches. It seems to me that inches are rather small dimensions when talking of the length of a car. That is a dimension I should certainly leave to be determined by the people who are to occupy the car. The length must be sufficient to provide convenient accommodation for the occupants in inclement weather. I do not like the exact length being specified in this hard-and-fast way, as though the length had been standardized. I am glad to see that the standardization of nuts and bolts has been mentioned. I think it is a suitable subject for this Institution to take in hand. In the old days a number of nuts and bolts for other kinds of machinery were standardized. I do not know why the author takes a dislike to moving spanners. I like to carry a set of moving spanners. I do not like the remark as to gudgeon-pins. I think it is tying one down to small limits to do as the author suggests. In a great number of engines which have come under my notice I have found that it is quite usual to have the gudgeon-pin free and unfixed in any way. If the pin is pushed through from the side of the piston, and an arrangement made whereby the pin cannot be rubbed against the sides of the cylinder, it allows plenty of room for expansion, and it is not moving about and does not wear. It is easy to draw, and I see no objection to doing it; it does away with all those side pins, split pins, and so on, which have been mentioned. As regards camshafts, I have never had the necessity to draw a camshaft. I find them wear well, and that in about half an hour one can remove a camshaft and put it back again.

Mr. H. AUSTIN: Taking one or two points in the paper, I cannot agree with the last speaker, Mr. Brewer, in regard to not building a car for a certain portion of the country or for a certain use, but I think Mr. Brewer missed one very important point. Cars to-day are not only required for country use but for towns. At the present time very great attention is being paid to building town carriages. The town carriage, for the reason that we cannot alter the shape and dimensions of the streets, must conform to certain limits. We must comply with the conditions as they exist in towns

and build a car suitable for town use. For this purpose it must be short in its wheel base. There is no question that a long wheel base would be better for straight open country roads, but the question of wheel base is absolutely settled for us by existing conditions; there is no use arguing about it. If one attempts to build a public service vehicle the bye-laws lay down certain limits which one has to comply with, so that in speaking about the building of a car it is not well to limit one's ideas to a particular locality. It must be understood that within certain limits there are various conditions of comfort to be complied with. The town carriage is likely to be a more important vehicle in the future, and the length of wheel base will be probably one of the first things that the designer has to contend with. I am quite sure, and I may be pardoned for saying it, that I sympathise with the author on the question of horizontal engines. Attempts have been made to put a vertical engine in a short wheel base and then to place a man on the top of the engine, but this is worse than putting a horizontal engine under the chassis. There are many better horizontal engines being built and used, and which have proved their value, than any vertical engines that have ever been put under the driver. I do not know anyone who has been so well satisfied with a vertical engine in that position as with the horizontal engine under the body. I am not upholding the horizontal engine unduly, but there are certain conditions which must be taken account of in design. Certain main features must be complied with, and the remainder have to be brought in as well as possible. Speaking of the question of accessibility, I notice a rather peculiar remark by the author of the paper. He mentions, referring to the accessibility of cylinders, that he has never had to replace a cylinder by reason of its having been worn out, but he knew of five cylinders having been replaced in consequence of accident. I suppose that they were on the James & Browne car. What I wish to say on this point is that if in his experience, which has been considerable, he has only known of five cylinders having to be replaced from breakages or causes other than wear, and has never had to replace one because it was worn out, does not this rather prove that the question of being able to dismantle one of the cylinders separately is not a very important one? I mean to say there are very practical advantages in making the whole of the cylinders in one or two pieces, but there is no very serious obstacle in the way of their being so cast on the score of replacements. Mr. Brewer made a rather strange remark which is

totally at variance with my experience; that is, as to leaving the gudgeon-pin loose. My experience is that anything which is left loose wears out more quickly than anything which rotates. If one left the gudgeon-pin loose one would want a new piston very quickly. In regard to the question of shields on gears and engines, there is one rather serious difficulty that a designer has to contend with. It is, generally speaking, almost, from an engineer's point of view, a mistake to design a car so that the fan draws the dust and dirt from the road and throws it on the engine or on any working parts. In most designs this cannot be avoided. In one particular car, however, the Renault, the engine is put in front of the radiator and the air is drawn through the radiator without being drawn over the engine. The engine has got to be kept cool somehow, and it seems to me difficult to so design the car or the engine and place the engine in the car relatively to the radiator, and yet keep the engine cool without drawing dust around it. There is one other point touched on by the author, and that is the question of accessibility of the rear axle. I should like to mention one or two features in connection with that as illustrating how accessibility can be carried too far. I consider that any live axle on a car should be made as light as possible. Any weight on the other side of the springs is always a dead weight, and in making the Iris gear box, which was illustrated on one of the slides, get-at-able, the design was made rather weak. It would have been very much stronger if it had been made less accessible and more attention had been paid to the strength and weight of it.

Mr. A. CRAIG: I think the subject of the paper which Mr. Martineau has put before us is one of the most important which can engage our attention. The opening speaker's remarks, as is sometimes the case when he opens a discussion, do not always convey his exact views on the subject. I think even Mr. Lanchester would admit that, other things being equal, accessibility is an advantage. The second speaker took up an attitude which I do not think you, as engineers, would support. I certainly would not take the same view. I have expressed the opinion that, other things being equal, accessibility is a great advantage. The suggestion that we should make those parts inaccessible which are beyond the powers of the ordinary motor-car man to attend to, so that people should not interfere with the adjustments, is ridiculous. There are lots of other things that can be got at, the tampering with which would spoil the car. One important advantage of inacces-

sibility is that most repair dealers are paid for stripping the car down and putting it together again, and not for doing the actual job, thus causing some cars to be given up. A repair which ought sometimes to cost only a sovereign costs £10, simply because the car has to be taken to pieces in order to get at the part required to be repaired, and then the pieces have to be put together again. That should not be the case, nor would it be if some little attention were given to design. Mr. Martineau recommends that we should adopt horizontal engines in order to get accessibility. That is not necessary. My experience is, and half-a-dozen leading designers would agree with me, that we can make as good a horizontal engine as a vertical one, so far as power and transmission are concerned, but the fact is we have to design for public requirements. Design is governed by public taste, and is governed also in this country largely by Continental designers. If we may judge from the Exhibition at Paris, we are safe in saying that the French have not much to show us. In a vertical engine, if you take care to leave one side of the crank chamber exposed, you can get at the bearings—all of them which should be got at. In spite of what the second speaker said, we can make it so that the brasses can be taken down and put in again. If we cannot take down a pair of brasses and put them together again with some degree of certainty we are poor mechanics. A piston does not need drawing very often. After hearing the discussion to-night, one would be left with the notion that there is no such thing as a commercial vehicle. We have been talking about pleasure cars, where the conditions are not so exacting as in connection with industrial vehicles. In motor 'bus work they have to take the piston out, take the big ends down, and strip other parts almost daily. Big ends are taken down on the slightest provocation, and if they had to strip the engine down to get at the big end it would be a tremendous job. The commercial side of the motor car movement will compel us to make things accessible, otherwise we shall be left behind by the Continental people. They are making great talking points of accessibility. If we realise the importance of the question in time, and do what we can, we have a chance of going a step in advance of foreign countries in design in this country. I trust that the remarks of some previous speakers will not be taken as an indication that the opinion of this meeting is that we are in favour of boxing things up so that they cannot be got at. Such an impression would be very harmful to the trade. Mr. Martineau deserves

more than credit for his pluck in his advocacy of the horizontal engine. If the time comes when there is a change in fashion, and we have to make horizontal engines again, there will not be much wrong with it.

Mr. H. STURMEY : I am so entirely in accord with the reader of the paper that I can do very little in the way of discussion except to back him up. With regard to what was said by the second speaker, that we should not design cars for use in Devonshire lanes, I think Mr. Austin answered that very well by pointing out that we have often to design cars for use in towns and town streets, where the corners are quite as bad as, nay, worse than, anything in Devonshire. A car designed for negotiating the corners of Devonshire lanes will necessarily be able to negotiate the traffic and corners of narrow streets in towns and cities. I think it would be a mistake to have a vehicle which is built only with a view to its use on broad country roads, as suggested by one of the speakers. While there are persons who desire to keep cars solely for that purpose, still the designer who has to design a car does not know that the car will be used solely under such conditions. He will be better advised to give his attention to designing a machine which will be as nearly as he can possibly make it suitable for all purposes rather than for one purpose only. The man who drives his car on broad straight country roads has also to take that car into towns some time or other. He does not keep his car only on country roads, and even if it is only a matter of getting it into his coach-house, sometimes he will find a long wheel base very awkward. In my own experience I have on more than one occasion found that a customer who has taken delivery of a car complains that it has too long a wheel base, thus making it almost impossible for him to manœuvre it into the narrow entrance to his coach-house. Not long since a customer ordered a car with an 8 ft. 6 in. wheel base and drove it to Yorkshire. A fortnight afterwards he wrote asking me to take it back and let him have a car with a smaller wheel base, because he had to go through a narrow roadway and take a right angle turn, then turn sharply again to get into his coach-house. Every time he took his car out he either carried away his mudguards, or did some other damage, and had no end of trouble in manœuvring the car with its long wheel base, so that on the whole it was a great deal more trouble than it was worth. When we come to long wheel bases of 12 ft., which I believe some of the touring cars have, it becomes impossible to use them in many cir-

cumstances. I think we should build cars which can be used under all ordinary circumstances. With regard to the horizontal engine and accessibility, nine people out of ten, when asked what the objections are to the horizontal engine, will say it is not get-at-able. I have had a little experience with horizontal engines, and I can tell you that when the body is designed to form one with the engine, or rather when the whole car is designed to go together, you can make the engine and machinery much more accessible with a horizontal engine than with a vertical one placed in a bonnet as is usually the case. With the ordinary engine under the bonnet, one end is usually jammed close up against the dash-board, and the other end close up against the radiator. There are a lot of parts screwed in between these portions very often, and you have in many cases to lean over a wide mudguard to get at them, whereas if you have a horizontal engine placed under the seat, which seat is hinged, then, by simply hinging over the seat, you expose the engine quite as clearly and readily as if you had a chassis only before you, and no body there at all. There is an objection to that, of course. I was showing a car with a horizontal engine built on these lines at a recent exhibition, and a critic was discussing it with me. He said: "It is no good at all; you have to disturb the passengers if you want to put anything right or make any adjustment." For minor adjustments he said the passengers did not like to be disturbed, but for large adjustments it would not matter, as the passengers would not remain seated in any case. Another man was listening—he looked like a handy man from a repair shop—and he said: "Excuse me, sir, what car do you use yourself?" The critic answered, so-and-so. "Where is the petrol tank?" asked the repair man. "Under the back seat," said the critic. Then, said the repair man: "Have you not got to disturb the passengers when you want to fill up with petrol?" I thought that was very apropos. Every car requires that, of course. The critic never thought of that, but when he came to do something different, not necessarily occupying more time, but different work, he began to find fault with it at once. On the question which has been raised with regard to casting cylinders in blocks as against casting them singly, I am entirely with Mr. Martineau on that point. I have been making engines for some years cast *en bloc*; they are very nice in many ways, but you do have to consider your customers, and when you get a breakage of any kind in a cylinder, or when a cylinder is cracked by frost, or a bearing gets adrift, and the thing goes

smash, or when damage is caused to one cylinder from any cause, the customer kicks very hard indeed at the great expense of having to rebuild the entire engine, and having to get three or four new cylinders instead of just a single one. I think also that in the workshop there is quite as much to be said in favour of the single casting as there is to be said in favour of block casting. When working on the unit system, if you are going to do anything more than make a single cylinder type of engine, it is very much better to have the cylinders cast separately than *en bloc*, and it lends itself much better to building engines with a larger number of cylinders, because you have simply one set of patterns for the one unit, and you simply get your reproductive machinery upon that, and make your engines with one, two, three, four, six or eight cylinders, as you wish.

Mr. L. A. LEGROS : To my mind accessibility can be divided into two sections. First, accessibility for examination ; and secondly, accessibility for dismounting the parts of the engine or car. Cleanliness, again, can be subdivided under two heads, internal and external. Accessibility is given in the Iris car mainly with the view of examining the interior of the engine as often as necessary, in order to see whether wear is starting or not, and whether everything is in the condition that one would like it to be in. That is a point which enables one to prevent anything becoming serious, and one to which a great deal of attention ought to be given. In regard to accessibility for dismounting the car, this is necessary, because in the case of cars which have been on the road for a long time you find that the time comes when the machinery has to be taken to pieces. Especially is this the case in heavy traction motors, where large mileage is required from the vehicles. In the ordinary touring car it is not so important a matter, because here nothing like the conditions are met with that are present on the motor omnibus, for example. In the case of the omnibus you have a vehicle which covers 25,000 miles in a year, whereas a touring car seldom exceeds 10,000 miles ; therefore it becomes necessary to provide for accessibility in commercial vehicles more than in pleasure vehicles. I think before long the makers of the ordinary touring cars will be compelled by the necessity put upon them by their customers' repair bills, to look into this matter of accessibility a great deal more than they have done in the past. We already see this in the abolition of the sandwich type of engines. The earliest engines were put together with the cranks and crank chamber simply

holding the brasses between them. That has been done away with, and the bearings are made adjustable in well designed modern engines.

With regard to cleanliness, I can accept what Mr. Martineau says about the Iris back axle; I am rather surprised, though, at Mr. Austin criticising it as weak. That axle has been extremely carefully calculated, and no material has been misplaced. In regard to what Mr. Lanchester says, if we were to take him at his word when he says you should never make a thing in two pieces if you can make it in one, there is no earthly reason why cylinders and crank chamber should not be made in one piece. One other point raised by Mr. Lanchester, was the comparison of a car with a watch. I wish we could build cars which would run like a watch. Some people think they ought to run as continuously as a watch, and that that is the right sort of thing to expect, especially in reliability trials. They do not, however, attain this ideal. Is not that due to the fact that we have not a responsible man in charge? As a result the touring car gets very poor attention.

I should be glad to know a little more in detail how Mr. Martineau manages to get the number of sizes of nuts on a motor car down to five. I do not see how he can get the number down so low. There are small electrical fittings, and things upon which nuts of odd sizes are found which run the number up, but the sizes I find most convenient are one-eighth, three-sixteenths and quarter inch tapped to B. A. threads; above that one has to use five-sixteenths, three-eighths, half, five-eighths and three-quarter inch. I have not found a way of getting rid of all the sizes I should like to see done away with, and try as I may I cannot get the number down so low as Mr. Martineau.

MR. E. LATHAM: May I be allowed to put in a plea for standardization? Mr. Martineau has mentioned that he has succeeded in reducing the number of nuts employed on a car to five. It has also been suggested that this Institution should take up the subject of standardization of nuts and spanners. If they do, they will not be quite the first in the field, because a body, of which I expect all of you have heard, the Engineering Standardisation Committee, have appointed a sectional committee to consider that question, only unfortunately it could not be considered from the point of view of one branch of the profession alone. It was considered from the points of view of marine engineering, locomotive work, and general engineering construction, all of which are very far away

from the subject we are discussing to-night. The result was to effect a compromise. I am not certain whether it was a wise thing to do, but it was the only course open to the committee. They have practically standardized the Whitworth sizes. As you are aware, the Whitworth nut in many cases is too heavy, and although one single nut is a small thing, yet many nuts weight the engine considerably, and a car should have in its construction the nuts as light as is consistent with strength. A lighter nut than the Whitworth could very well be employed for motor car construction. This Institution should turn its attention to a light line of nuts of a strength sufficient for the purpose for which they are intended. A nut that would be suitable for a motor car would be one that is less cumbersome than the Whitworth nut. If this Institution would take up that subject, they would be doing a good service and would not be treading on the ground of the other committee. With regard to the number of sizes, these could be considerably reduced. The President of this evening, who figured most strongly on the committee to which I have referred, thought that certain sizes should be eliminated out of the standard list. He knocked out all those sizes which are hardly ever heard of, but unfortunately the committee printed those sizes in the list, placing an asterisk against them to signify that they should not be generally used. If this Institution could do something to carry the movement for standardization a step further by abolishing some of the sizes altogether and introducing lighter nuts, it would be a good thing. Castle nuts have also been touched upon, and have been standardized, the smaller sizes between quarter inch and one inch being most used. It is difficult to standardize where ordinary Whitworth nut sizes have to be employed on Castle nuts. We have Castle nuts of different kinds, some wider than others. There seems to be a considerable need for the lightening of these small accessories of an engine. There is a standard set of spanners, but not suitable for motor car work; for motor car work they can well be lightened. One other thing I would like to touch upon, and that is the pitch of the threads. Unless the pitch is correct the vibration to which the motor car is subjected tends to loosen the nuts. One reason for accessibility is because nuts are always dropping off owing to the vibration to which they are subjected. Nuts slacken back; even lock nuts sometimes slacken back. The committee, to meet that difficulty, should hold a conference to determine the standard to be adopted for

threads. A public report was issued by the committee to which I have referred nearly two years ago, but unfortunately it does not seem to be brought forcibly home to the motor car industry that there is this necessity for standard threads. The list of fine threads issued consists of threads of the Whitworth form, but possibly for motor car work they ought to be of finer pitch. If a conference could be held as I suggest, and this question of standardization discussed, a good deal could be done towards the solution of the points raised by Mr. Martineau; indeed, the difficulties he has raised would be overcome. What I wish to make clear is that the standard list to be adopted for motor cars should not be a compromise. The list that has been issued is one that has been adopted for other branches of the engineering profession without special reference to motor car construction. If this Institution can do anything in co-operation with the Standards Committee to bring about the issue of a list of standard sizes for nuts and bolts for motor car work, it would be an excellent thing.

MR. W. G. WILSON: I did not come here prepared to speak, but one point struck me in Mr. Martineau's paper, and that was in connection with the replacing of brasses. The author seemed to me to make rather light of that. On the whole I do not think a brass should be replaced in the light-hearted manner he spoke of; it ought to be put in and properly bedded down, and not be merely swung round. Another point is that it does not seem to me that there is any good reason for bosses being put inside a gear-case. We do not want to machine the whole surface merely for the sake of appearance, and putting the bosses on the outside of the case means that only the smallest amount of metal surface has to be machined so as to get a fair seating for the nuts. As regards presenting a smooth appearance outside a case, I think that can be overdone in the matter of putting nuts inside and pretending that they do not exist. There is rather a tendency that way. Anything which is liable to shake loose in the way of nuts or anything like that ought to be visible. I am speaking very much now for accessibility, and accessibility in both senses, although I may appear to be going contrary to what the author has advanced. By adopting the suggestion I put forth, accessibility would be gained both for the inspection of the parts and for replacement. I think that a very important point to avoid is the putting of small pins and nuts inside, where they are liable to shake

loose and not to be noticed in time to prevent damage being done. As regards gudgeon-pins, I agree with those who say that they ought to be fixed. A gudgeon-pin that is allowed to shake about is rather liable to give undue wear.

MR. T. C. PULLINGER: I think in regard to standardization, if we all adopted the metric system it would be a means of bringing about a universal system of measurement, and thus bring to existence a system of standardization. Accessibility in a motor car, I think, can be divided under two heads. There are certain things that we want to get at easily, and there are others that it is just as well if people cannot get at. There is a saying that "a little knowledge is a dangerous thing," and it is true here. When people try to get big ends and put them in as has been suggested they must not be surprised at meeting trouble. I think with the last speaker that big ends should be very carefully bedded in. If we limit our attempt to obtain accessibility to the getting of parts asunder without removing three or four other components, I think that would be sufficient for all ordinary purposes. As a matter of fact the principal parts of a car—the engine, clutch, gear box, &c.—can be got at without undoing others and adjusting them. The adjustment of the brakes, valves and carburetter should be very accessible. I do not agree with those previous speakers who say that we should get inside the crank case to adjust the connecting rod ends. Touching on the metric system, I think its adoption would be a good thing in the direction of standardization. I have not yet been able to get the number of nuts down to five; the most I can do is to get them down so as to be able to carry only four spanners. A bigger size than usual is required for wheel caps. I think practically you cannot get below six sizes. I do not see any difficulty in the way of taking up the metric system; I should suggest that this Institution take it up very strongly.

MR. A. J. McKINNEY: I think that accessibility is a *sine qua non*, a thing essentially desirable. I do not speak so much from a manufacturer's point of view as from that of the private user. I have had the misfortune of being a motorist for eleven years; I say "misfortune" because my friends are numerous, and I often incur a good deal of odium when taking them out simply on account of the inaccessibility of the car. I repeat that accessibility is the most essential thing in the qualities of a car. As regards a tipping body, the idea is an excellent one, as it helps towards this property. In regard to the carburetter there is a tendency to

add parts rather than to reduce their number. I suppose this cannot be helped; the time has not yet arrived for the standardization of the carburetter—it is, so to speak, a necessary evil. In a short time, no doubt, we shall get to the point when we shall have a thoroughly efficient carburetter—*i.e.*, probably one with fewer parts than at present. I have one or two other points that I wish to mention, but I think they had better be waived on account of the lateness of the hour.

The PRESIDENT (Colonel R. E. Crompton): Time is so short I must sum up, though in regard to this the character of the discussion has been so eminently practical and has brought forth such a number of excellent points that there is not much need for summing up. One point brought forward is, and on this most speakers are agreed, that the time is past when designers are to be overruled by the uneducated opinion of the buyer. What has the buyer to say in the matter? He really wants a car which will be most comfortable to ride in, which will cost the least money, and be the least expensive to maintain. It is not for him to name the conditions of design, his conditions are those which set forth his requirements, and the other conditions are accessibility and low cost of maintenance; it is not for him to prescribe the means whereby these features are to be attained—whether you are to use a vertical or a horizontal engine, and so forth. It is for the designer to decide that, and one of the uses of this Institution is that it affords engineering opinion an opportunity of discussing these matters. Engineering opinion must therefore be stronger than it has been in the past. It is perfectly monstrous that the uneducated customer should dictate to the designer. As regards one or two points on which I have special knowledge, I may say that I am one of those who took an active part in the work of the Standardization Committee, and one of the matters taken up has been the standardization of nuts, bolts, key-ways, and things of that kind. The industry which we represent is a peculiar one; it has come to a stage when the division of labour is carried to such an extent that it has never been carried before, so that it is necessary to make the component parts of a motor car in different places and not all in one shop. These parts are brought together and erected so as to form a complete vehicle. It is that fact, which is a good thing and not a bad one, that has led to the multiplication of small pieces, such as nuts

and bolts and spanners. The man who purchases a magneto from one or other of the makers of these instruments, and other parts from other people, finds on these articles varying sizes of nuts and bolts according to the fancy of the makers. This feature is really a bad one, especially if it is allowed to go on, and will lead to complications and unnecessary trouble both to the makers of motor cars and to the users. Cars can be turned out in the cheapest and best manner when they are simplified according to a correct standardization of the minor parts such as nuts, bolts, &c. Some of the component parts of a car are made in one country, some in another, Germany, France or England, therefore we get odd sizes of screws, &c., and the object of the Standardization Committee is to find out what sizes are best for general use in automobile engineering. At the time we commenced our work there was no organised representation of the automobile engineering world. From what we see now the outlook is that we shall have a properly organised engineering opinion in regard to our industry, then we can send our demands in to the Engineering Standardization Committee. Some of the members of this Institution will be made members of that Committee, and the work will be undertaken.

Mr. MARTINEAU, in replying on the points raised in the discussion, said: The general tone adopted by the various speakers seems to have been in favour of accessibility, and the various points raised by those who have differed from me seem to show that they are rather divided amongst themselves. Mr. Lanchester, for instance, wishes apparently to have things made in as few parts as possible. In this matter I absolutely agree with him; but there is no reason why you should not have things accessible and yet have them made in few parts. If you can design one piece which will do the work of two, by all means design it so, but at the same time have it so designed that you can take it out and replace it easily when required; that is an important point. With regard to what Mr. Brewer said, the main point to consider with regard to this is that it was from a technical or mechanical point of view, as well as from the private user's point of view, that the whole of the points with regard to accessibility were suggested. It is not only very important from the owner's standpoint that he should be able to get at the various parts of his car in order to make small adjustments easily without disturbing other parts; but it is equally important that when the car is returned to the maker for repair at any time the maker

should be able to get at the pieces easily so far as removing any damaged part is concerned, and put a new piece in the car without having to disturb all the other parts of the mechanism. This will be best, not only for himself, but for his customer. From the repairer's point of view even, it is desirable that the repair bills should not be too heavy, otherwise it may mean that the customer will be so disgusted with motoring as to give it up entirely. We, as designers, want to consider the buyer's purse as well as mere mechanism, so as to retain his custom, otherwise it is not worth being here to discuss these matters. That is my way of looking at it. With regard to the point that has been mentioned about wheel bases, Mr. Austin answered this question when he said that you have to make a car for every use and not merely for one particular purpose. The reason why I instanced the roads of Devonshire was to show that we ought to make cars that will be able to tackle anything. The roads of Devonshire are probably the worst roads in England, and if a car can take these roads all right it will do almost anything anywhere else. With regard to Mr. Austin's idea on the subject of keeping the engine cool, I have come to the conclusion that it is possible to keep the engine cool without leaving the engine itself open; the temperature at which the cylinders can be worked can be much higher than is usually the case when designed as I have suggested, not only so, but the engine can be worked with advantage. I am able to work my engine ten degrees higher than would be the case under ordinary circumstances. Another speaker referred to the question of wheel base. This question of wheel base also affects another point, and that is, if you increase the wheel base, you increase the weight of the car as a whole, and on a pleasure car this means an increase in the cost of tyre upkeep. That is a point which ought to be considered. With regard to the sizes of nuts, Mr. Legros asked me for further information on that point. The sizes that I use are 1 B.A. nut and $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in. and $\frac{7}{8}$ in. Whitworth nuts. There is another one really, but as there is not one amongst those I have mentioned big enough, the way I get out of the difficulty is by casting a nut on the face of the part where it is required. With regard to the standardization of sizes of nuts, the use of $\frac{1}{16}$ in. and $\frac{1}{8}$ in. nuts are not so difficult to deal with, the trouble I have experienced is with the medium sizes between these two. There is the petrol tank, the nut on the top of which I use a little bit smaller than usual so that I do not need

a separate spanner for it. The sizes of hexagon adopted by me for the whole car were as follows :—

Size 1	.....	·375	across flats.		
„ 2	.....	·525	„	„	
„ 3	.....	·710	„	„	
„ 4	.....	·920	„	„	
„ 5	.....	1·300	„	„	

With regard to putting brasses in, I quite agree with what Mr. Wilson said, that they ought to be put in very carefully, but what I wish to provide against is a temporary breakdown. If you have the misfortune to get a breakdown and have to put a new brass in, which is lined with white metal, it is very convenient to be able to get one in temporarily so as to get you home without having to take the whole thing to pieces. That applies particularly to public service vehicles and heavy vehicles for commercial work. It is a great convenience to be able to effect a temporary repair in order to take the vehicle home for permanent repair. I must thank you all very much for the way in which you have received my paper.