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LIGHT AEROPLANE ENGINE DEVELOPMENT.

By Lieut.-Col. L. F. R. Fell.

(Paper read at a joint meeting of the Royal Aeronautical Society
and of the Institution of Automobile Engineers,
February 19, 1925.)

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LIGHT AEROPLANE ENGINE DEVELOPMENT.*

By Lieut.-Col. L. F. R. Fell.

It has frequently been stated and written that in order to popularize light aircraft the first essential is the production of a reliable engine capable of being easily maintained and having a long life, at the same time selling at a low figure. In the first part of this lecture it is desired to point out the difficulties in the way of realizing this ideal before remarking on the claims of the various types for adoption.

Difficulties in the way of the Production of Light Aircraft Engines

In the first place the public, and even aircraft designers, have been misled as to the type of engine that is required by statements made in the nontechnical and semitechnical Press to the effect that it is possible to fly an aeroplane satisfactorily with a motorcycle engine. At this stage it is desired to state quite definitely that this is impossible, as figures, which will be given later, clearly indicate.

The method of rating on capacity, instead of on a HP. basis - the normal manner for aircraft engines - has also caused consid-

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erable misapprehension and called forth the statement that a complete motor car with an engine of 1100 c.c. capacity can be purchased at the same price as a light aircraft engine of similar capacity. It is the case with most prime movers, and especially so with internal combustion engines, that it is the normal HP. that an engine can maintain indefinitely which has to be paid for, and when the light aircraft engine as we know it today is examined in this light, it will be found that it is not a particularly expensive prime mover. A car, or a motor cycle, driven as hard as British roads will allow, does not exceed an average HP. greater than about 1 HP. per 100 c.c. Very few road vehicles are put to as severe duty as is indicated by this figure, and the £175 variety does not withstand such treatment for very long. As is shown in the following Table I, the average HP. taken from the various engines used in the Lympne competition was 34, or about three times the normal for a motor car engine of similar size. In fact, the output from these competition engines compared very favorably with the best Brooklands efforts of engines of the same capacity.

Table I.

Engine	R.P.M.	B.H.P.	Aircraft	Remarks
Cherub	3200	32.6	Beardmore	Direct drive (cruising)
"	3600	34.0	"	High speed trial
"	4000	36.0	Avis	Geared
"	3600	34.0	"	Direct drive.
"	4010	36.2	Pixie	Geared (two parts)
"	3000	31.0	Brownie	Direct drive (cruising)
"	3200	32.6	"	" " (high speed)
"	3000	31.0	Cranwell	" " (cruising)
"	3200	32.6	"	" " (high speed)
Blackburne	3600	36.0	Sparrow	" " (cruising)
"	3800	38.0	"	" " (high speed)
"	3800	38.0	Pixie	" " (cruising)
"	4000	40.0	"	" " (high speed)
Anzani	3000	31.0	Hawker	" " (cruising)
"	3600	35.0	"	" " (high speed)
A.B.C.	3200	32.0	"	" " (cruising)
"	3600	34.5	"	" " (high speed)

It will be readily understood, therefore, that the engine for light aircraft must be a machine far superior to anything that runs on the open road and, in consequence, more costly in direct proportion to its power output. The requirements of the satisfactory light aircraft engine are precisely the same as for large aircraft types, viz.:

(A) Reliability.

(B) Light weight in working order.

(A) can only be obtained as the result of careful design and laborious and expensive testing on the bench. (B) is actually more difficult to attain in a light aircraft engine than it is in one of 500 HP. for the following reason. Though it is true that a slightly higher HP. per unit of cylinder volume is permissible with the small engine, certain parts - such as cylinders - have to be made thicker and consequently heavier than is dictated by stressing, in order to obtain the necessary rigidity. In an engine of about 500 HP. this condition does not arise. The use of a higher HP. per unit of cylinder volume is, of course, strictly limited by propeller speed unless gearing is to be introduced. The latter is undesirable as, besides putting up the cost of the engine, it has been proved in engines of all sizes that the reliability is materially decreased and vibration is introduced unless the engine is multi-cylindered or fitted with a flywheel, with consequent increase of weight.

In order to indicate the relatively high duty obtained from the engines at the Lympne competition, Table II has been prepared. From this table it will be seen that, in one case, the B.H.P. per cubic inch of cylinder volume was nearly 1.8 times that taken from the Napier "Lion," Series II, engines at maximum permissible R.P.M., i.e., the speed allowable for a few minutes' burst only.

Table II.

		B.H.P. per cubic inch cyl. vol.	B.H.P. per sq. in. piston area	R.P.M.	Total B.H.P. developed
A	Lion II	.343	1.76	2200	503
B	Condor III	.33	2.475	2300	705
C	Cherub	.33	1.23	2200	22.5
D	Blackburne	.357	1.36	2200	24
E	Cherub	.49	1.89	3200	32.6
F	"	.54	2.0	4010	36.2
G	Blackburne	.557	2.135	3600	37.5
H	"	.61	2.333	4000	41.0

In passing it is thought that it is of interest to point out that during the competition certain British engines were running at powers fully 50 percent in excess of their normal maker's rating. That unreliability was experienced is not therefore surprising. It must be remembered that just because an aeroplane engine is small it is no less likely to break down when run beyond its rating than is the engine of 400 HP. or 500 HP.

As has already been pointed out, a good power/weight ratio is more difficult of attainment on the light aircraft engine than it is on the larger engines, and even when run at the high ratings given in Table II, none of the engines can be considered as having a good power/weight ratio when compared with larger engines. Not one approached 2 lb. per B.H.P., and were mostly around 3 lb. per B.H.P. and over. In this connection the light aircraft engine is at a great disadvantage owing to the large proportion of the total weight absorbed by what may be termed auxiliaries, such as ignition gear, carburettors and oil pumps. Very little can be done to reduce the weights of these parts, and it has been roughly calculated that the percentage of the total weight taken up by auxiliaries is quite three times that of the engine of 500 HP.

As regards the carburettor, altitude control is found to be a necessity. In order to get good results from the engine the very finest workmanship is required on the control. Even on large engines, unless the highest degree of refinement in manufacture is put into the construction of the carburettor, and altitude control in particular, trouble is experienced. The light aircraft engine will obviously be more sensitive still to any air leakage.

As regards ignition, dual ignition is obviously as essential to reliability on the light aircraft engine as on all other aircraft engines. Merely to provide a magneto firing two sparking plugs is insufficient, for it must be borne in mind that the cylinders are working at as high a M.E.P. as is usually adopted on aircraft engines, and the sparking plugs and magneto are therefore just as liable to failure.

In order to ensure correct lubrication at high speeds without over-oiling and consequent high oil consumption, a positive dry base oil system is indispensable. With roller bearing big-ends, this oiling system is a particularly difficult problem, for contrary to the time-honored statement of the ball and roller bearing manufacturers, the roller bearing big-end run at the speeds and loads called for on the light aircraft engine requires considerably more oil "than is required to prevent rust." To supply this oil without over-oiling the cylinders calls for very great care in design and perfection of workmanship.

The design and manufacture of connecting rod big-ends for a radial engine is probably the most serious problem to be solved in this type of engine, and is the limiting factor in its development. Owing to the high speeds and outputs for light aircraft engines, the solution of this difficulty is no less serious in their case.

Finally, the light aircraft engine is a high efficiency engine, comparing so far as the motor vehicles are concerned with a track racing car engine only. The most thorough design, the finest materials, and the highest class of workmanship only can therefore be employed in its manufacture if success is to be achieved. It will readily be admitted that these requirements are incompatible with cheapness of production.

Suggestions and Remarks Regarding the Choice of a Type and Design Generally.

(a) Method of Rating.

As already indicated, the writer is of the opinion that the method of rating by capacity is definitely undesirable. The choice of the cylinder capacity should be left to the designer and should only be settled by him after selection of the type of engine which he wishes to build. As is the case with all other aircraft engines, for any given HP. the multi-cylinder high speed engine will have a smaller capacity than an engine employing a few larger cylinders, both designs being of similar weight and giving equally good reliability. It is safe to say that had the 1100 c.c. rating not been a necessary condition for the engines to fulfill in the Lympne competition, two-cylinder engines would have been produced with larger bore cylinders running at lower speeds, and having very much greater reliability at a negligible increase of weight. The adoption of the capacity rating in general and of the 1100 c.c. in particular was fully justified at the time. It was considered that motor car and motor cycle engine manufacturers were used to this method of rating and, in most cases, had designed their engines to fall into certain clearly defined categories. It was hoped, therefore, that more entries would be encouraged from the motor trade if it was made possible for them to introduce their standard models for light aircraft purposes. Having established the capacity basis, and in order to make the competition of the greatest value to aeronautics, it was obviously desirable that the smallest engine that could possibly do the work should be specified. This was assumed to be the 1100 c.c. As the motor manufacturers have not been able to see their way to enter their standard models, in view of the heavy duty called for, the reason for retaining a method of rating foreign to aircraft practice no longer exists.

In the writer's opinion, the normal ground level HP. and propeller speed capable of fulfilling the duties of the various classes of light aeroplanes should first be determined and laid down, and the engine builder thereafter be given a free hand to produce an engine of the best power/weight ratio he can at the horsepowers and speeds given with no other restriction than that his engine must be capable of passing the Air Ministry's standard test of reliability as given in Part "B" of Air Publication 840.

(b) Air versus Water-Cooling.

It is somewhat astonishing, in view of the competition between water and air-cooling on large aero engines, that the protagonists of water-cooling should have left the field clear for air-cooling.

It has already been proved that the air-cooled engine is not necessarily lighter or cheaper than the water-cooled and, on the other hand, that the water-cooled engine can be produced to give considerably less head resistance than the air-cooled. This latter feature is clearly indicated in Fig. 1, which is a comparison between a flat twin air-cooled, a three-cylinder radial air-cooled, and a four-cylinder in line inverted water-cooled with a special form of radiator, all the engines being of equal capacity. These types will be referred to in detail later.

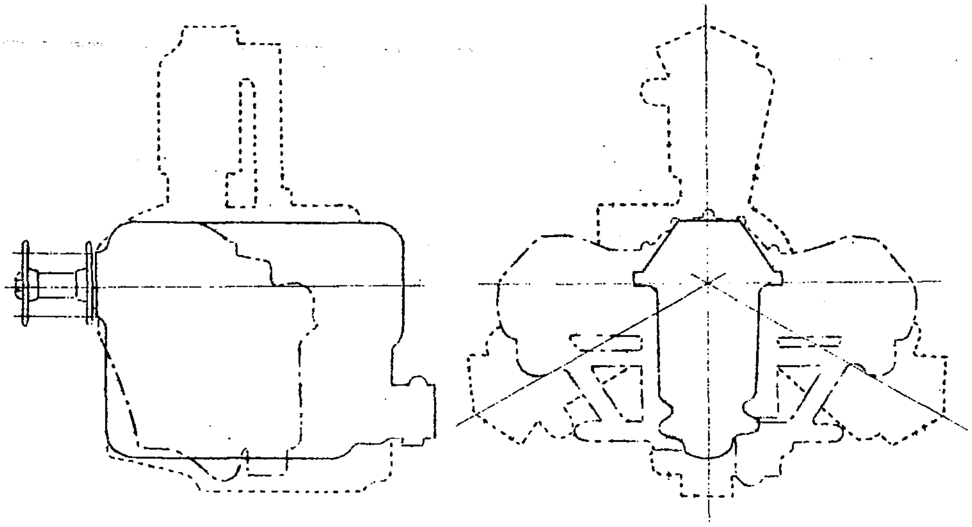

Fig. 1

As regards reliability, from the motor car manufacturers' point of view, there can be no doubt that the water-cooled engine is supposed to be superior to the air-cooled.

Owing to the cylinder block construction of the water-cooled, great rigidity and, consequently, less vibration is obtained from the water-cooled engine. As will be indicated later, it is a simpler matter to make a multi-cylindered water-cooled engine than it is to make an air-cooled multi-cylindered engine. Higher speeds of rotation are, therefore, more easily obtained with the former than with the latter. This, of course, allows of an engine of smaller capacity for a given duty than can be obtained from an air-cooled engine of normal type.

In the writer's opinion, these advantages are quite sufficiently great to warrant serious consideration of the water-cooled type for light aircraft. Further, there are quite a large number of water-cooled engines in use on the track capable of performances equal to the requirements for light aircraft; these engines would only require developing in a lighter form, probably by the substitution of light alloys for cast iron, in order to make them suitable.

(c) Supercharging.

It is considered that the application of a supercharger to the light aircraft engine is a problem well worthy of investigation by designers, in order to make the maximum use of the cylinder capacity without resorting to excessive speeds. By supercharging, the writer only wishes to suggest the use of this device as it is used on the track, that is to say, for the purpose of obtaining an output greater than normal from a given capacity and not as it is known in aircraft, i.e., with a view to maintaining ground level power at altitude.

As an instance of what has already been done on motor cars in this connection, the following figures relating to the Sunbeam 1500 c.c. racing cars are of interest:

Bore and stroke 67 mm x 105.5 mm

Volume 1487 c.c.

1922	engine	developed	50	B.H.P.	at	4000	R.P.M.
1923	"	"	60	"	"	4000	"
1924	"	"	72	"	"	4500	"

	Engines		
	1922	1923	1924
B.H.P. per 100 c.c.	3.33	4.0	4.66

For purposes of comparison with light aircraft engines in use at Lympne these figures have been converted to a 1100 c.c. basis; they then read:

1922	engine	36.63	B.H.P.	at 4000	R.P.M.
1923	"	44	"	4000	"
1924	"	51.26	"	4500	"

The 1922-3 engines were fitted with four valves per cylinder, whereas the 1924 type was fitted with two valves per cylinder, but was supercharged by means of a Root's blower driven direct off the crankshafts. In 1922 the fuel used was 50 per cent. benzol and 50 per cent. aviation spirit, whereas, in order to get the increased performance in 1923, alcohol was necessary. Owing to the use of the supercharger, however, it was possible to return in 1924 to the aviation spirit only in spite of increased HP.

It is thought that only the geared type of supercharger of any of the well-known types - such as the centrifugal, eccentric vane or Root's blower - should be considered for light aircraft engines, as the additional complication, expense and weight of the exhaust driven turbo-compressor type would not be justified in view of the comparatively light duty required from the supercharger.

(d) Relative Merits of Different Types.

"V" Twin.

In the writer's opinion, this type of engine has no particular merits for aircraft propulsion. Should it be used, however, it is essential that it should be constructed as what is known in the Air Ministry as an inverted engine, that is to say, with the cylinders below the crankcase in order to get the exhaust away conveniently and also that it may not interfere with the pilot's view. The ordinary wet sump motor cycle engine is obviously unsuitable for this reason, even were these engines up to the duty. The main reason for the popularity of the "V" twin is that it can be conveniently accommodated in the normal form of diamond frame almost universally adopted in motor cycle practice. The balance of engines of this type is poor and the firing interval is, of course, uneven, both of which facts militate against its successful use in light aircraft owing to the difficulties in securing satisfactory mounting and eliminating harmful vibration on the machine structure, the instruments and the pilot himself.

180° Flat Twin.

From the point of view of simplicity of design and production this engine is perhaps the best type. As in the case of the "V" twin, unless a very strong mounting is used the torque fluctuation of a two-cylinder engine is apt to result in damage to the machine structure. Also, it seems that there is a limit to the cylinder capacity which can be used in an engine of this design owing to difficulties experienced in balancing when the bore is more than 90 mm. Attempts so far with engines beyond this size have not been satisfactory. The carburetion of this type of engine is also a source of trouble and, in many cases, it has been necessary, in order to overcome this, to fit a separate carburettor to each cylinder. Owing to the comparatively large dimensions of the cylinders, this type of engine is not particularly suitable for running at high speeds and cannot, therefore, make the best use of its capacity. The fitting of a supercharger should, however, enable a reasonably well-balanced 1100 c.c. engine to be produced giving about 38/40 HP. at a speed of under 3000 R.P.M. From the point of view of air-cooling this design presents the least difficulties of any type in that, in addition to the fact that the cylinder head is well exposed to the slipstream, it is also easy to provide in the machine design for a clear exit for the air at the back of the cylinder. As regards lightness, it is considered that within certain limits of power, and provided the designer is given a free hand regarding the bore and stroke, it would be possible to produce an engine of this type with a power/weight ratio comparing favorably with any other.

180° Flat Four.

An experimental engine has been built in France having four cylinders in two blocks of two at 180°. It is understood that the results obtained have been quite satisfactory and that the engine is singularly free from vibration. No trouble appears to have been experienced with the cooling of the rear cylinder, though it would seem that cooling, and consequently, the output of the front and rear cylinders would most certainly be different. This form of engine has the following advantages over the ordinary flat twin:

1. The overall dimensions are reduced.
2. The frontal area is reduced.
3. Balance is improved.
4. Torque recoil on the machine structure is less.
5. If it is admitted that there is a limit to the capacity to which the flat twin can be built, it is obvious that the flat four can be designed up to double the capacity.

It is considered that this design is worthy of consideration by British designers.

Three-Cylinder Radial.

As is shown in Fig. 1, the frontal area of this type is very high compared with other types, and there does not seem to be any prospect of reducing this, as a larger crankcase than is required for the 180° twin is necessary in order to clear the triple connecting rod arrangement, and the resistance of the third cylinder would be only slightly less than that of one of the cylinders on the flat twin of equal capacity. On the score of weight this type comes out considerably heavier than the flat twin partly due to the fact that cylinder weight per B.H.P. increases as the size gets smaller, as already pointed out. There are certain difficulties in the construction of this type, chief of which is the big-end bearing. The balance of the three-cylinder radial is, however, superior to the flat twin, and, of course, the torque recoil on the machine is less, thereby rendering the mounting a simpler proposition. A neat induction system for a three-cylinder radial is not easy to arrange. It is obvious that the construction of the crankcase and connecting rods will be far more expensive than in the case of the flat twin. From the point of view of cooling it is not so easy to arrange satisfactory egress of the air behind the vertical cylinder, and the exhaust outlet from this cylinder is in an inconvenient position from the pilot's point of view.

Five-Cylinder Radial.

Owing to the method of rating on capacity, this type of engine was, practically speaking, ruled out of the Lympne Competition owing to the very small sizes of cylinders which it would have been necessary to employ to conform with the regulations. It is considered, however, that this type has much to recommend it. In a radial engine, in order to get light weight per HP., it is necessary to fit as many cylinders around the crankcase as possible. The crankcase to accommodate five cylinders is no larger in diameter or heavier than that required to accommodate three. The connecting-rod big-end difficulties are not seriously increased, and some form of induction manifold can be introduced conveniently. From the point of view of head resistance and power/weight ratio, this engine would be superior to both the flat twin and the three-cylinder radial. Larger capacity and, consequently, lower speed, is, therefore, permissible. In the writer's opinion, though somewhat expensive, this is a very promising type for light aircraft.

Swashplate Engine.

An engine in which the axes of the cylinders lie parallel to the axis of the driving shaft has always been a form of engine particularly attractive to aircraft designers. So far the mechanical difficulties involved in the transmission from the pistons to the driving shaft have been too great to permit of the adoption of this type. It is hoped, however, in the not far distant future these difficulties will be overcome. For the small engine, however, it is thought that such a design, incorporating an ordinary ball thrust race, as the wobble, or swashplate, could be quite satisfactorily designed; be capable of high speeds, giving low head resistance and reliability; and be comparatively cheap and easy to produce.

Four-Cylinder-in-Line.

It is curious that, though this type of engine is by far the most extensively used in motor-car practice, it has not come into prominence for light aircraft. As an air-cooled engine, it is probable that owing to faulty cooling of the rear cylinders it would not be possible to obtain the high duty called for, unless some elaborate system of air scooping was fitted which would greatly increase the head resistance. Further, in its air-cooled form, the engine must be somewhat long owing to the necessity of arranging for the passage of air between the cylinders. An air-cooled engine, also, is dependent entirely for its rigidity on the crankcase, which is not wholly satisfactory. The other advantages of the four-cylinder engine are so well-known that it is unnecessary for me to deal with them here. In its water-cooled form, however, this type has much to recommend it both from a production and installation standpoint. As will be seen on reference to Fig. 1, it presents the smallest head resistance of any type. The outline of the engine shown in Fig. 1 is intended to be what is known in the Air Ministry as an inverted engine, i.e., with the cylinders below the crankcase. It will doubtless be argued that a water-cooled engine is too complicated, when the radiator and water piping, etc., are taken into consideration. Further, that the additional weight due to these parts and the water would put this engine on a worse footing than air-cooled engines. In point of fact there is very little difference between the weight of a water- and an air-cooled engine, for the weight of water and radiator is largely offset by the increased cylinder and piston weights of the air-cooled engine, and, also, to the lower speed at which it is necessary to run the latter owing to the fact that it is almost of necessity of the radial type, thereby introducing connecting-rod and crankshaft difficulties, which render the type unsuitable for running at high speed.

In the case of the light aircraft, it is considered that the advantage of the water-cooled engine would be even greater than with the large engine, owing to the fact that it would be possible to build in the radiators to the sides of the water jackets, thereby largely eliminating water piping. In the design diagrammatically indicated on the sketch it was intended that the radiators should be formed by two nests of "Brown" tubes, each a block of approximately 3-inch diameter and running the whole length of the crankcase on each side of the cylinder liners located at the highest point on the water space. From the point of view of weight, it is considered that, constructed with an aluminum cylinder block with steel liners, and otherwise conforming to standard high performance motor-car lines, a rigid and, consequently, sweet running engine could be produced at a weight certainly not exceeding that of the 180° twin.

Straight Six and Straight Eight Engines.

As we now have the luxury and special model car, so we may expect in the future to see similar classes of light aeroplanes, and, for the latter, doubtless both the straight six or the straight eight will have strong supporters. The advantages claimed for the four-cylinder-in-line engine, with the exception of simplicity and first cost, apply to an even greater extent in the case of engines with the larger number of cylinders in line. As an instance of what can be done, the writer has recently been given the opportunity of considering a proposal for a 1500 c.c. eight-cylinder-in-line design to give 70 B.H.P. continuously at a speed of 5000 R.P.M. Owing to the good balance and slight torque fluctuation of these multi-cylinder straight-line engines, the machine designer's problem is greatly simplified, and engines of these sizes could quite easily be designed to be self-supporting from a flange mounting, thereby eliminating the necessity for the introduction of engine bearer weight, which presents somewhat of a difficulty in the case of the larger engines of these types.

(e) Most Suitable Types for Various Duties.

To sum up, the writer is of the opinion that it is not possible to exalt any one type of engine as eminently suitable for universal adoption on light aircraft of all types and for all duties. Light aircraft requirements will, it is thought, vary widely in the future, and the engine builders must be prepared to meet all these requirements. The writer's suggestions as the most suitable types of engines for the various requirements as they can be foreseen today are as follows:

Single-seater,	180° Twin Air-cooled.
Two-seater,	Five-cylinder Radial Air-cooled, or Four-cylinder-in-line Water-cooled.
Luxury of Speed Machine,	Six or Eight-cylinder-in-line, Water-cooled.

(f) Installation.

From an examination of the machines in the Lympne Competition, it is considered that the same attention is not given to the problem of satisfactorily installing the engine as is usually the case on aircraft of greater power. For instance, engine mountings in some cases gave the impression of having been designed at the time the engine was installed in the machine, having too many parts in the form of tubes connected by forked joints and bolts, or, in some cases, the ends of tubes just flattened out and bolted to the engine and fuselage. As already pointed out, a two-cylinder engine calls for great care in mounting, and, in this respect, the engine designer might have rendered considerably more assistance to the machine designer by supplying satisfactory bearers as part of the engine. This is now becoming standard practice for engines of over 400 HP., and the engine designer's systems of engine supports are only arrived at after a considerable amount of discussion with the machine designer. The argument against the engine designer producing the engine mounting himself is that in some quarters it is held that this hampers machine design. In practice, however, this difficulty has not become apparent. The great advantage of the engine builder producing the mounting is that he can test his engine installed in the same way as it will have to run when fitted into the machine.

As regards cowling, it is preferable that this should also be carried out by the engine builder, as, if this is so, adequate provision for attachment will be provided on the engine itself, and, in consequence, one very serious source of trouble with machines in service would be avoided. The difficulty of introducing this, however, is far more serious than in the case of the engine mounting owing to the different body shapes of the various machines.

If light aircraft are to become popular, the importance of as rigid fire prevention as on larger aircraft must be realized. Fireproof bulkheads must be constructed with the same care and have no unbushed holes made for control rods, etc. Here, again, the engine designer can be of great assistance, as, if he makes provision on his engine for it to be bolted up to a flat plate, such as is formed by the fireproof bulkhead, and conveniently arranges his controls, the machine designer will have no difficulty in making a really sound fireproof job.

Engine builders have always been somewhat sensitive about the engine controls supplied by the aircraft designer, and these will require to be an especially good job on the light aircraft, where such fine control will be necessary especially on the altitude control. In this connection, it is pointed out that the Bowden engine control has been prohibited for years on Service aircraft, and there is no reason, therefore, why it should be considered good enough for light aeroplanes.

The importance of accessibility to the engine and its auxiliaries generally cannot be over-estimated, and, if the engine designer provides his own engine bearer, he has no excuse if his engine lacks merit in this respect when installed in the aeroplane.

Conclusion.

In the writer's opinion, as is the case with all other aircraft, the successful development of light aircraft for any purpose whatever depends on the engine designer. The competitions so far have indicated that the light aircraft engine builder's problem is a far more serious one than was anticipated. In this lecture the writer has indicated why this is so, and that it is only by the very best work of those most highly skilled in high efficiency internal combustion engine design that an engine sufficiently powerful, and, at the same time, durable, can be produced. The light aircraft engine must always be more expensive than any other engine of similar capacity, for the simple reason that, in addition to the fact that it will always be called upon to give the maximum duty obtainable from its capacity, as is the case with the racing motor car engine, it has the further disadvantage of having to be produced at minimum weight. It will no doubt be stated that the maximum possible rating will not be used, and that reliability shall be accepted in lieu. It has been the writer's experience, however, during the last ten years, if there is anything left in the way of power inside an engine, the aircraft designer will have it out, and he sees no reason why this is less likely to be the case with the light aircraft engine. It is absolutely essential that an aero engine be designed to withstand indefinitely the maximum duty which it is possible to obtain by running full throttle under the best possible settings for carburettor and ignition for maximum power.

Finally, the writer would like to say that in this lecture he does not pretend to have covered in any way the whole ground, nor would this be possible in the course of one lecture. He hopes, however, that, as a result of his remarks and the suggestions which are contained therein, a good discussion will ensue.