# SOME CONTROVERSIAL POINTS IN AIRCRAFT DETAIL DESIGN.

**Paper read by Mr. F. T. Hill, A.F.R.Ae.S., Wh.Ex., Member, before the Institution at the Engineers' Club, W.1, on 12th April, 1923, Mr. W. O. Manning in the Chair.**

MR. HILL said :—

In presenting this paper for discussion I have to thank the Council for their permission to introduce matter which is frankly controversial instead of informative, as is usual in meetings of this description. One of the acknowledged functions of our Institution is to encourage the free exchange of the views of its members by means of discussion, and it is the author's personal opinion that the design side of the aeronautical industry stands very much in need of more opportunities for this at its present stage of development.

Consider the general process of the design of any engineering product. It falls broadly into three phases. First, the conception of the idea, which is usually commercial, i.e., a demand for some new piece of apparatus has arisen and the directors of a certain concern decide to cater for it. Second, the general design of the article is settled by the chiefs of the various departments concerned. These will be chiefly from broad theoretical principles and will decide the general outline and main dimensions only. Third, these particulars will be passed on to the engineering staff for development of the details whose quota to the work will be mainly practical and is the result of an engineering instinct, generally referred to as "Experience."

One of the aircraft designer's principal troubles at present is undoubtedly the lack of this experience. The opportunities of using his own products and discovering their weaknesses, although improving, are still hopelessly inadequate. The reports upon them by users during the late war were in many cases unreliable and were often never acted upon. It is not the concern of this paper either to discuss these or even impute that any blame is attached to either side because of these shortcomings. With the end of the war and the removal of the necessity for strict secrecy the opportunities

https://doi.org/10.1017/S2976690700000309 Published online by Cambridge University Press

for conference between designers and users have increased considerably in individual cases, but there is still a lack of the machinery for thoroughly broadcasting the aircraft operator's experiences among the designers.

Broadly it should be one of our Institution's principal functions to become the disseminator of this kind of information, and it is hoped that this paper will, in its limited scope, provoke sufficient discussion to help in this respect. The author endeavours to adopt a strictly impersonal attitude in this paper, merely giving results of his observations upon the inconsistencies in the design of certain details, which appeal to him as tending towards being adopted as standardised practice, apparently for no better reason than that they served their respective purposes moderately well during the war period.

## Construction of Body or Fuselage.

Before and during the earlier years of the war practically all the bodies were of the " Girder " type of construction, built up of usually four horizontal longerons at the corners of a rectangle, the girder being completed by vertical and horizontal struts dividing them up into a number of bays which were cross-braced into triangulated structures with wire bracing. The whole girder was then covered with light wood or fabric chiefly to reduce its head resistance and afford some measure of protection to its occupants. Later in the war the " Monocoque " type was developed in which the main frame consists of a number of bulkheads shaped to the required outline of the body. These formers were held in their correct relative position partly by a number of horizontals equivalent to longerons, and partly by the plywood covering wrapped over the outer surface of the whole construction. There were also a few types midway between these two which had the longerons and struts of the girder type but replaced the wire bracing by the outer plywood covering of the monocoque type. Since the war most of our leading designers seem to have selected one of these types as their standard and have stuck to them except in such cases as a machine built to an Air Ministry specification with the type of body laid down. It appears to the author that each of these types have their own particular advantages which make them superior to the others for a machine for certain duties but inferior for other kinds of machines.

The good points of the girder type can be roughly summarised as follows. Lightness, as each individual part can be designed to suit its local loading. It facilitates quantity production as it consists of a number of small parts mainly of simple shape which can be both manufactured and assembled by semi-skilled labour with suitable jigs. The attachment of the aerodynamical surfaces, undercarriage, etc., is easy, as the forms of both the body itself and its constituent parts are mostly rectangular.

The bad points are that it requires considerable skilled attention for maintenance owing to the fact that the stretching of the wires and the settling down of the numerous small metal fittings allows a gradual deformation of the whole girder if the slack is not taken up periodically. The large number of small parts in its construction necessitates the stocking of a large number of spares if any possible breakdown is to be rapidly dealt with. The cross-bracing in the internal bays divides the whole body up into a number of compartments the capacity of each being very limited, while that in the external bays interferes with the placing of doors, etc. The outer surface is built upon an elaborate and very fragile fairing which is bound to be damaged with careless or inexperienced handling.

The monocoque body has advantages and disadvantages arranged somewhat differently. Its principal advantage is that it can be built into any shape cross-section and gives any desired length without internal cross-bracing, making a much better cabin. Its superior construction makes it more water-tight, weather-proof and noise-proof, thus adding to the comfort of the passengers or the security from damage of the cargo. It has very few separate small parts which are vital and consequently require skilled attention. It is also stiffer as a beam and holds the tail surfaces more rigidly.

Against this must be considered the disadvantages that it requires elaborate jigs and much highly-skilled joiners' work in erection. The attachment of other parts is not always simple owing to its shape and the flexibility of its plywood skin. It is also somewhat heavier as it is usually necessary to make it too strong in the more lightly-loaded parts. Some designers meet this latter case by adopting a compromise, using a monocoque for the front portion of the body and a girder construction for the rear.

It is now necessary to consider the possible types of aircraft to which these bodies have to be applied. The broad distinction between the two is undoubtedly military and civil uses. The outstanding requirements of the former machines are speed and invulnerability to vital damage from hostile gunfire, while for the latter, safety, comfort, and low cost seem to be the most important features. It is hoped that users of the two distinct types will put forward their views as to the suitability of either body, in the discussion.

## Design of Longeron Fittings.

The case of the fitting connecting the end of a strut to the longeron and also forming a connection for the three bracing wires at this point is one upon which designers appear to hold diverse views. The Air Ministry Technical Department have stated at various times during the war that in a girder fuselage it is desirable that the longerons should not be drilled, nor have wood screws inserted, owing to the local weakening of the cross section, and also the liability of either of these to start splits in the wood. They also consider that a longeron should be easily removable in the event of damage, without dismantling the whole of the body. It is not at all

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easy to combine these two desiderata without making the fitting complicated and prohibitively heavy, and the opinions of those who have been in charge of repairs as to the relative usefulness of these two features would be valuable to the designer who is faced with the necessity of only being able to adopt one of them. The author's experience is that the removable longeron is an over-rated improvement. With military machines gunfire from an opponent is usually from behind the tail, in which the longerons do not form a very large percentage of the total target. Any spray of bullets hitting the machine would invariably damage numerous struts and bracing wires as well. In the case of civil machines, damage to a longeron local enough to necessitate the removal of itself only, is practically confined to persons climbing up on to it, and this can only happen when the fairing is taken off for any reason. Damage to longerons due to excessive bending of the fuselage, either by aerodynamical tail loads, or careless handling on the ground, invariably results in such extensive straining of parts that the whole girder has to be rebuilt.

### Size and Position of Doors in Fuselage.

This is a question upon which designers are badly in need of some definite ideas from the air transport companies. The present practice is generally to use as a door the space left between the top and bottom longeron and any two conveniently-placed adjacent vertical struts, or two bulkheads. The dimension of this opening, especially the width, is much to small for general transport of goods, if the spacing of the struts or bulkheads has been arranged for the most economical weight for strength as a basis, as is usually the case. A narrow door has a double disadvantage when dealing with goods in packing cases, which is not always realised by those inexperienced in the actual handling of articles for transport. It not only limits the width of case which will pass through the door, but when the interior of the cabin is comparatively narrow, as it is in an aeroplane body, it prevents the loading of long cases owing to the impossibility of turning them while passing them through the door. An actual occurence of this nature at the London Terminal Aerodrome, Croydon, is worth mentioning. The Daimler Hire Company wished to be able to transport a spare Napier Lion engine by air in the event of a serious engine breakdown in any of their machines. They found that it was impossible to load this remarkably compact engine into the cabin of their De Havilland machines without cutting a hole in the wall opposite to the door in order to allow the propeller end of the crankshaft to pass through it while it was turned round into the body space. Even then it should be noted this engine was not enclosed in a packing case. Had it been so protected, a condition in which most manufacturers would wish to transport their goods, it would have been quite impossible to get it into the fuselage at all.

The author is of the opinion that this question of loading goods would

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be very much simplified if aeroplane designers were to adopt the artifice of putting a trapdoor in the floor of the cabin and strengthening the roof above it sufficiently to allow of a light lifting-tackle being attached to it. Heavy or unwieldy goods could then be pushed beneath the body on a truck, raised through the trapdoor with a pulley attached to the roof, and swung into place. The benefits of purely vertical lifting, which can be carried out by mechanical means, over horizontal lifting, which has usually to be done by a gang of men when the vehicle being loaded has a roof over it preventing the use of any type of swinging crane, are well known to all persons experienced in the transport world. A precedent does exist for this method in the aeronautical world in the case of heavy bombers used by the R.A.F. towards the end of and since the war. Certain sizes of bombs were carried vertically in specially constructed bomb crates. These crates, already loaded, were wheeled under the fuselage and hauled up into position by means of a block and tackle attached to a specially strengthened rib in the upper plane centre section.

Designers could also take another leaf from the R.A.F.'s book in this matter. The Vickers " Vimy " Ambulance machine has a large door in the nose of the fuselage at such a height that a stretcher can be conveniently slid into it without tipping it to the inconvenience of the patient upon it. This idea should be useful in the case of large multi-engine machines where the engines are out on the planes and the nose of the fuselage is deep enough to leave a sufficient space under the floor of the pilot's cockpit. If the bottom edge of the trap door was approximately the same height from the ground as an average truck, goods could be pushed into it with a minimum of lifting, or possibly it would be worth while providing a loading platform sloping up to the required height, another device not altogether unknown in the ordinary transport world.

The Gloucester Aircraft Company have recently put forward a suggestion for a goods carrying aeroplane in which the rear half of the fuselage folds away sideways on hinges, as the Parnall Panther ship aeroplane folds for storing purposes. This gives the complete cross section at the rear end of the cabin as an entrance, and by dropping a suitably arranged tail board an exact equivalent of an ordinary pantechnicon is obtained. This is obviously the best solution of the door difficulty which has yet been offered, but it is not at all certain whether it would be practicable in actual use as the operation of closing the fuselage, connecting up and adjusting the controls, and presumably obtaining a clearance certificate from the official ground engineer would appear to be a fairly complicated one. The author is not in a position to know whether this aspect of the question was ever dealt with, and hopes that there will be some members of the audience who will be able to give the results of their experience in dealing with similar folding fuselages in the R.A.F. If this operation can be reduced by automatic catches, etc., to something which is little more than slamming the door and giving the signal to start, this type should be the most useful one of the future.

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Petrol Systems.

So much has been both written and spoken with reference to the merits of rival fuel systems that it is unnecessary to go into details again in this paper. It is felt that it is safe to summarise the opinion of the aircraft industry in general as follows. The pure gravity feed system is ideal because of its extreme simplicity. The whole of the fuel is contained in tanks which are so placed in the machine that they will be high enough above the carburettor to give the necessary pressure of petrol in all reasonable attitudes of flight. The air pressure system comes next in order of simplicity. In this system the major portion of the fuel is contained in a tank or tanks which can be placed below the level of the carburettor if necessary, and the petrol is raised as required by the action of a small air pressure which is maintained above the liquid in the tank, by means of a pump, either air or engine-driven. This system need not be much more complicated than the gravity system but it has the one inherent disadvantage that if any part of the tanks or piping becomes badly damaged and the air pressure is lost the whole is inoperative. The third type, the direct fuel pumping system, has been devised primarily to overcome this last objection, and designers have been compelled to bring this to an almost incredible complication in order to devise alternative methods of passing the petrol from the tanks to the carburettor in the event of damage to the different individual parts of the system. The complication of pipework, uncertainty of action of centrifugal pumps when working in a position such that they are not "drowned," number of non-return valves, release valves, etc., all of which add to the chances of something breaking down, and also to the weight and both first cost and maintenance charges, make it perfectly certain that the use of this system is only justified if the percentage possibility of damage and the consequent necessity for using one of the alternative paths for the petrol, is extremely high. Obviously, the machine in which this risk is greatest, is the military one whose duties are such that it will be exposed to enemy gunfire, and it is safe to assert that the greater proportion of such aeroplanes of to-day are so fitted. The point which needs to be debated in the discussion is which of the two simpler systems is the more suitable for civil transport machines. The simple gravity system is undoubtedly the best, but does the trend of design in modern machines indicate that the position of the main tank can usually be such that the requisite "head" of liquid will be available? For aerodynamical reasons it appears likely that the engine will still have to be placed fairly high relative to the main plane structure, and consequently the highest possible position available for the tank will never be much more than the minimum height above the carburettor required for the "head." If it becomes necessary for structural reasons to place the tank far behind the engine, this height may be considerably reduced or may even be negatived when the machine is climbing steeply, a condition under which the engine particularly requires a good and steady supply of fuel. A serious state of affairs might easily

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develop here in the case of a machine landing and overshooting the mark, when the only way to avoid crashing into the aerodrome boundary is to switch on the engine and climb rapidly over it. Another disadvantage is that the tank in this position is in the worst possible position for causing a fire in the event of a crash, as it is directly over the engine, and if damaged will allow petrol to spray directly on to it. This point can be avoided by placing the fuel in two tanks, one out on either plane, but further trouble is then introduced by the length of piping setting up friction and consequent virtual loss of head, and also the inevitable extra complication of pipework, not the least of which is the necessity for two flexible joints owing to the fact that the tanks are situated on the slightly moving plane structure while the engine is on the rigid body.

None of these difficulties present themselves with the air pressure system, and it is the author's opinion that its chances of failing owing to its one weakness, its vulnerability in the event of mechanical damage, is largely imaginary in the case of a civil machine built with a reasonably robust structure and handled by an experienced staff. The author is confident that this system would not be so popular in the motor-car world if the proportion of failures was unduly high.

### Types of "Oleo" Gears for Undercarriages.

There is no part of the modern aeroplane which has suffered more through a tacit suggestion that it had attained its ideal in design, than the undercarriage. During the latter stages of the war the R.A.F. did undoubtedly make efforts to standardise this component, choosing the simple V strut with rubber cord or rings for shock absorbing as their type, but the author can speak from personal knowledge of the fact that this was because of the advantage to be obtained from the point of view of supply and storage of spare parts, rather than because they felt that the last word had been said in undercarriage design. The best of the simple "V" types with rubber shock absorbers, are, however, still particularly suitable for military work where their simple and clean lines give a minimum of head resistance combined with a reasonably safe landing device in the hands of skilful pilots. Civil aeronautical practice at the present time seems to be adopting the same form of undercarriage, but supplementing the shock-absorbing parts by the addition of some adaptation of the well-known oil dashpot method of damping vibrations and absorbing the impulse of a blow. Essentially this consists of an oil-filled cylinder and piston which are attached to the fuselage and the axle legs respectively. In the most simple case this piston contains a number of "leak" holes which allow the oil to be gradually displaced to the other side of the piston under the pressure due to downward momentum of the fuselage continuing after the axle has been arrested in its downward path by striking the ground. When the momentum is expended the oil is returned via the same holes by the action of a coiled spring or rubber rings

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which have been stretched during the action just described and now contract to their original dimensions, bringing the piston back to its normal position. This device is too slow in action for a bad landing in which there is a tendency to bounce and several designers have added complications to their gears to increase its speed of action and reduce its harshness. Amongst these are, using an auxiliary valve which opens at a certain increase of pressure and assists the flow of oil through the piston, passing a tapered needle through a hole in the piston so arranged that the annular space between the needle and the hole increases in area as the piston moves further from the normal and thus giving the same result as the auxiliary valve but with a graduated effect, and fitting a return valve arranged to open automatically when the impulse is absorbed and assist in the return of the oil ready for the next blow. These additional complications have proved to be necessary in order to give rapidity of action to this gear, without which the machine will develop a " roll " if it happens to land on one wheel first. The necessity for all these additional working parts, each with their extra chance of failure, also extra weight and cost, forms a very serious disadvantage to this type of gear, and it is hoped that the discussion will bring out some of the users' experiences upon the efficiency of it.

This additional complication, and the prospect of even further devices being required on the larger machines of the future, has recently given rise to a school of thought which has endeavoured to solve the problem of shock-absorbing by a somewhat different method, and has apparently at the same time set up as their axiom the simplification of the whole gear and the reduction of the number of working parts. This new type is due to Messrs. De Havilland, and its essential difference is that it does not attempt to return the oil to the normal side of the piston until the machine has risen into the air again, when the weight of the axle and wheels returns the oil through the standard leak holes. Thus the oil dashpot is practically inoperative after the first heavy shock upon landing, the rest of the bounces and any taxying shocks being taken entirely by the auxiliary rubber absorber. As this now becomes a more important part of the gear the designers have paid more attention to it and instead of the usual rubber cord or rings connecting the two relatively moving parts they use a number of rubber buffer pads placed in a cylinder connected to the same spindle as the oleo cylinder. These pads being in compression only, and also totally inclosed in the cylinder, protected from the deteriorating effects of light and atmosphere, will be immune from most of the weaknesses which have made rubber so unsuitable for use in any constantly stressed parts of the undercarriage construction.

This simplification has, in the author's opinion, given the question of the " Oleo " undercarriage gears a decidedly more hopeful outlook, as it does not involve any additional complication as weights and sizes increase. This type will undoubtedly supersede the earlier ones if its shock-absorbing qualities are sufficient, and if the rubber pads do not harden too rapidly under the heavy compressive loads placed upon them. Nothing but experience will settle this and it is hoped that there may be some members of the audience who will be able to speak upon the merits or otherwise of this gear in use.

Attempts are also being made to solve this problem of the secondary springing by using compressed air cylinders instead of rubber. The author has had no experience of these, but suggests that the necessarily high air pressure required will call for a very robust construction of the cylinder if troubles with leaky joints, etc., are to be avoided. It also appears that it will be necessary to carry some form of air compressor for use in the not unlikely event of the air pressure being lost whilst in flight. Possibly the discussion will bring forward some further views upon this subject.

## Design of Engine Cowling.

Many questions upon the desirability of, and the form which engine cowling should take, occur if the subject is considered carefully. The addition of cowling over an engine practically dates from the realisation by designers that the head resistance of a body can be materially reduced if it is smooth and clean lined, even if it is not possible to produce the ideal "streamline" form. The avoidance of protuberances and the gradual transition from one cross-section to another along the body, often calls for a form of cowling which is difficult to produce in large pieces if it is to be easily removable for access to the engine, but at the same time to be capable of being rigidly fixed against the tremendous wind pressures to which it will be subjected during flight. War-time designs in general seemed to favour the permanent fixing of the cowling and the provision of small doors wherever access to any particular item on the engine was required. This simplified the question of attachments, and the small doors had the double advantage that they could be so hinged that the rush of air would tend to keep them closed should their fastenings open during flight, and being small, were likely to cause only a proportionately small amount of damage to other parts if they came adrift while the machine was in the air. On the other hand, the process of unfastening them was a slow and tedious one and it was always difficult to give proper attention to the object inside through the restricted door opening.

The modern tendency seems to be an entire reversal of this policy. Several of the latest civil transport machines have their engine cowling arranged in two pieces, hinged at the top and bottom, so that they can be opened and folded away in an exactly similar fashion to a motor-car bonnet. The good and bad points of this method are exactly as in the previous type but reversed. The engine is much more accessible, but the method of attachment is more difficult and its reliability less. The ideal cowling probably is a compromise between the two which can only be selected by a user who has had experience of both types, used under all possible variations of conditions. This point in the discussion should bring out some invaluable information from engineers who have had aircraft operating experience.

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THE NECESSITY FOR FOLDING WINGS.

The R.A.F. specifications for their machines lay down definite regulations that all designs of over a certain wing span must have folding wings. This is probably justified in the case of war machines which may have to operate under all kinds of unexpected conditions and be stored in unsuitable and makeshift accommodation in the event of an emergency, but this rule seems to have created an impression that folding wings are a necessary complement of all large machines, a law that is by no means definitely established.

Consider the case of a company operating an air transport line over a definite route. They will certainly have suitable storage sheds wherever their particular time-table calls for them, and with proper organisation these sheds need not be wide enough to accommodate the machines lined up wing tip to wing tip. It is acknowledged that when machines are "staggered" in a shed the problem of removing one from the middle of the space is a serious one, but with proper organisation this necessity should not often occur. If the shed is so placed on the aerodrome that it can be fed from either end, and if the machines are wheeled in on suitable trolleys so that they can be moved easily with a minimum amount of labour this problem is not so serious even when it does occur. It is the author's opinion that the difference between the time taken to remove a machine stored under these conditions without folding wings, and one which, having its wings folded back, could be stored side by side with its fellows and simply dragged straight out, would not represent such a great loss as the continued running of machines which were unnecessarily heavy owing to the added complication to their wing structure. The other possible advantage claimed for folding wings is that in the event of a forced landing, it is easier to peg the machine down during rough weather as the wings being back to back neutralise each other's lifting effect. This is certainly true, but it is questionable whether there would be sufficient crew available in the machine to fold the wings, especially if they had been thrown out of alignment by a bad landing, a state of affairs which it is not unreasonable to expect when a forced landing takes place. It should be remembered that the case being submitted is that of the really large machine in which the wing structure would be exceedingly cumbersome. The case of the medium-sized machine, in which it is agreed that the folding can be reduced to a one-man operation, does not occur, as no modern civil machines are so fitted.

The chief losses in efficiency due to folding wings are caused by increase of weight, additional head resistance, complicated aileron control, troubles with pitot tubing and electrical wiring connections, slight reduction of plane area, etc., and it is highly debatable whether this is compensated for by the facilities for handling on the ground that this type of wing gives.

REMOVABLE ENGINE MOUNTING.

Towards the end of the war the desirability of having the engine portion of the body so designed that it could be removed from the rest of the structure quickly, when the engine needed a repair which could not conveniently be carried out with it "in situ," was clearly demonstrated, and several designers have incorporated this idea in their modern machines. The arrangement usually consists of an engine portion of the fuselage made as a complete structure, and attachment bolts, generally four in number, provided at the front ends of the longerons of the main body. Sometimes this front portion is entirely detachable, while in some cases two of the bolts on one side are hinges, which allow the engine to swing outwards. The former is the most popular at present as it lends itself more particularly to horizontal engines. In theory this idea is excellent as it allows of a quick interchange of engines without putting the whole machine out of service, while it also increases the accessibility of the different parts of the engine, and it was necessary when it was originally called for.

Since the war, however, there has been a marked improvement in the co-operation between aero-engine and aeroplane designers with the result that the more modern aero-engine is much cleaner in design and has its fittings which need attention placed with a view to their being easily reached for adjustment when the engine is installed in the average shaped fuselage of to-day. The consequence is that many jobs which previously needed a complete removal of the engine, can now be carried out in a few minutes with it still in place. In addition engines have improved in reliability and temporary repairs are less frequently called for, and altogether the necessity for the detachable engine mounting seems to have disappeared. It is general experience at the London Terminal Aerodrome, Croydon, that these mountings are seldom used. When engines have to be removed for an extensive overhaul and are likely to be out of use for some time it is better to disconnect them from the engine bearers in the ordinary way and mount them on special beds in the workshop. The detachable mounting is not a convenient shape for using in the shops, and when supported on a special truck, is too high and needs trestles to bring the mechanics up to the required level to work upon it. It also generally calls for extra joints in the piping, engine control rods, etc., all of which appear to render it undesirable now that the original necessity for it has passed.

In conclusion the author would again like to emphasise the fact that this paper has been specially laid out to provoke discussion upon certain points which appear to be in danger of becoming standardised in aeronautical design, rather than to impart any new information, and it is hoped that the discussion will be as wide and as frank as possible. The points raised are entirely impersonal, in fact names of designers have been deliberately avoided, and if any of the audience see criticisms of any products of their own particular school of thought it is hoped that they will accept them in the spirit in which they are offered. It is furthest from the author's intention that he should be regarded as posing either as an expert or a pedant upon aeronautical design.