EVENING SESSION

General Discussion

DR H ROXBEE COX, D I C F R Ae S , F I Ae S

President of the Royal Aeronautical Society

in the Chair

J K Williams (Air Registration Board) *Member* He emphasised Mr CLAIR'S point which was not fully appreciated by everybody, about the introduction of safety factors in order to reduce insurance rates

The helicopter had definitely arrived as a successful flying machine, but the eventual helicopter passenger, the " man-in-the-street,' still regarded the helicopter as a spectacular piece of ingenuity, capable of performing incredible tricks in the air, but not yet as a means of transport In the next few years helicopter designers must concentrate on safety and on improving the efficiency of the design with regard to the percentage payload available, instead of increasing the complexity of the design in order to achieve spectacular records He did not wish to belittle the splendid accomplishment of the Fairey Gyrodyne in attaining the speed record, but he felt sure that Dr BENNETT would be the first to admit that the attainment of that record was only incidental to the completion of a successful design

From the safety point of view there were five major problems to be studied and overcome They were —

1 The helicopter at present was far too complex with too many moving parts Simplification was needed to reduce the risk of failure of a component part which might be vital to the whole They must make certain, by means of additional safety factors and check laboratory tests, that within the specified life, the parts, including gears, bearings and rotor blades, remained airworthy

2 They had little knowledge of the loads which helicopters actually experienced during manoeuvres in flight The various types should be extensively flight tested with strain gauges to obtain a more accurate estimate of criteria for design purposes so that, not only could they be reasonably assured that the helicopter was safe for normal manoeuvres, but also that the structure was as efficient as possible, without introducing undue failure hazards

   One of the most important problems was the possibility of the fatigue failure of a main rotor blade in flight A great deal of reasearch was necessary to establish adequate design safety factors and the technique of the laboratory fatigue tests An excellent treatise on that subject had been written by Mr GARRAWAY in his Cierva Memorial Prize Essay

3 The single-engined helicopter was a far safer flying machine than a single-engined aeroplane in the event of engine failure but, as Captain LIPTROT had pointed out, a danger zone, for engine failure for single-engined helicopters did exist It could be eliminated by making the helicopter twin or multi-engined, or so designing the rotors that the pilot could use their kinetic energy to reduce the vertical velocity (before touch-down), or by the provision of a long travel under-carriage

   He agreed with Wing Commander BRIE that all future helicopters in operation on scheduled routes should be twin or multi-engined types, the basic performance requirement being that the helicopter could maintain height on one engine under adverse conditions

4 A reduction in the disc loading was needed There they were faced with the paradoxical problem of reducing the disc loading and at the same time increasing the percentage payload to make the helicopter a competitive means of transport

5 A successful technique for the complete blind flying of helicopters must be devised, with the attendant problems of the development of instruments and ground aids, reduction of pilot fatigue to the minimum, and overcoming the inherent instability of helicopters in their present stage of development He believed that the B E A Helicopter Unit would solve that problem successfully before long

If these safety aspects could be successfully incorporated during the next few years, what were the future fields of operation for the helicopter ? The whole trend of development depended on that Surely thay would not be satisfied with the limited fields envisaged at the moment, such as crop-dusting and spraying, Post Office work and shuttle services between the Scottish islands Could they look forward to helicopters superseding fixed-wing aircraft on some of the major internal airlines in this country during the next ten years or so ? If not, he felt that helicopter development would be seriously retarded

Dr A P Thurston *Member* What was the correct pronunciation for the machines under discussion , he had heard them called " helicopters," " heelicopters," " haylicopters," and Group Captain LIPTROT had even called them " witches cauldrons of fluctuating forces ' , years ago Sir HIRAM MAXIM had called them " hell-icopters "

He sympathised with those who complained that money was not available for the development of this most important branch of aeronautics, but much development could be effected at little cost by means of models For many years he had experimented with models, some of which did not conform at all with practice, and it seemed to him that with them many problems would be solved concerning the fluctuating forces which set up vibrations, and so on He exhibited one of his models, which was stabilised like an ordinary aeroplane , it was dated 1939 It flew best when *not* pivoted at the root of the blade and he showed the optimum point of pivot At times he had been in peril, by reason of the speed of the models in the air, which was unbelievable Such blades spaced themselves when flown in multiple He had used all types and shapes of blades *stabilised* and had determined by experiment the best point to pivot the blade Models could be controlled remotely by means of a Bowden cable with a centre wire , differential control, pitch control and any other form of control of blade or engine could thereby be achieved

A H Yates (College of Aeronautics) *Member* What was being done to narrow the range of danger heights between which, if engine failure occurred in a single-engined helicopter, a crash appeared to be inevitable ? If an engine failed at a height below 30 ft the landing could be cushioned by increasing the blade pitch If an engine failed at a height above 300 ft there was sufficient height for the auto-rotation of the rotor to be achieved but at less than 300 ft there was not that opportunity It was desirable that, as soon as torque failed, the blades automatically set themselves to autorotating pitch, without time lag

The pilot of a fixed-wing aircraft had to be on the extreme *qui vive* for only a few seconds after take-off, and had not to watch the controls so carefully when a comfortable height was achieved, but the helicopter pilot had always to be alert and was at a disadvantage in that respect

Helicopter meetings seemed to attract people of such diverse interests that he wondered if the time had come when the specialists should separate There were references to laminar flow, the Fourier series, and so on, and these subjects would not interest the " crop sprayers " Those interested in aerodynamics could very well spend the whole day discussing the aero-dynamic features of the aircraft, and they might gain, perhaps if the meetings were a little more specialised

F/Lt J R Anderson, *Member* At a joint meeting of both rotary-wing and fixed-wing experts, it seemed appropriate to mention the combination of the two types of aircraft So far the only reference to the type had been a mention of convertible aircraft by Mr FITZWILLIAMS The combination was now a practical proposition because of developments in gas turbines and in other technical spheres

With convertible aircraft the landing and take-off difficulties of the fixed-wing aircraft could be overcome to a great extent and, for a given engine power, the convertible could show less than half the drag area, which meant higher speed For heights below 8,000 feet, it meant that the convertible type could be operated at speeds which fixed-wing aircraft could not touch, and thus could fill the gap between the helicopter at the lower heights and the fixed-wing aircraft at high altitudes

There were none of the vibration difficulties found in the helicopter because of the periodic forces on the blades, since the axes of the various airscrew systems were not at approximately right angles to the air flow

They lagged behind with helicopters through insufficient support, and one speaker had suggested this was because of their low military value The convertible type had high military potentialities and its development was of importance—possibly vital—to the defence of the country It was to be hoped that those responsible would not bury their heads in the sands of complacency The papers presented to the meeting had clearly explained the limitations of the helicopter, and he hoped that support, both financial and in other directions, would be forthcoming from the departments concerned

Wing Commander L P Gibson *Member* It had been said that fixed-wing aircraft pilots with thousands of hours of flying had " given up the ghost " after trying to fly the helicopter and that, in trying to fly the helicopter, it was as though one were trying to balance a billiard ball on a pin He felt that this was a slight exaggeration and the view that helicopters were difficult to fly had arisen largely, perhaps, because of the attitude of those who could fly them already , they formed something like a " magic circle " or " closed shop " It reminded him of the old flying boat days and their " Union " There were two cases recently in which pilots had learned to fly the helicopter after only 1½ hours dual

The lack of real facilities for learning to fly helicopters in Great Britain was perhaps the difficulty at the moment People came along for a ride and their first flight was just a novelty , they did not really learn anything from this

He suggested that there should be established somewhere in this country a familiarisation course—not a course which would cost something like £300, but one which would include, say, five hours flying He recalled that when jets were introduced there was established in the Service a week's course, which included five hours flying , the whole idea being to dispel the " black magic " which had then surrounded the jet

If helicopters were to be developed so that everybody could use them and could take-off from, and land in, their gardens, they must rid themselves of that " black magic " idea The difficulties of flying the helicopter must not be exaggerated

Squadron-Leader F J Cable (Airborne Forces Experimental Establishment) *Founder Member* A middle course should be adopted on the flying of helicopters They should not suggest that only a race of supermen could fly them and we must not go to the other extreme and say that they were easy to fly

As to the stage at which a pilot should first be allowed to fly solo, it was one thing to get into a machine and fly it around the aerodrome, when everything was working well, and put it back on to the ground without damage, but it was another matter to operate and look after it regularly and to meet the cost of repairing the damage

Difficulties, or the idea that the flying of helicopters was difficult, had arisen in the early days largely because of the mental approach and the necessity to appreciate the co-ordination of the controls

There was no difficulty about the engine-off landing problem and that bubble should be exploded At A F E E , Beaulieu, they had made 500 or so engine-off landings successfully from various heights during the past few months The Sikorsky R4 was in the nature of being an experimental machine Tests had been made with it, with more or less success, and presumably test results with later machines would be better than those obtained with the R4 When operating the R4 at 2,700 lb (the full weight was 2,800 lb) in still air conditions they had cleared a 100 ft screen and had come to rest within 125 yards That was not a stunt, but had been done often , he had been responsible for more than a hundred of those landings To those who were interested from the insurance point of view, he could say that helicopters could be landed in one piece, depending largely, of course, on the circumstances and the skill of the pilots

The helicopter could not be used fully until blind flying was a practical proposition At the moment it was possible, but he would not like to say that it was practicable In his opinion the first requirement before blind flying could be made practicable was stability The helicopter was not free of troubles in that respect, but the problems were not insurmountable Given a stable aircraft and the development of one or two instruments, blind flying would be practicable

W M Evans (Air Registration Board) Speakers so far had avoided mention of the power plant, but from recent discussions with helicopter designers it appeared that there was a feeling that a case could be made for a modified method of rating helicopter engines The helicopter designers felt that they needed a power for hovering (which was say, 90 per cent of the maximum power of the engine), a power higher than that for emergency conditions and there might be some third rating, such as a power limited by b m e p and r p m , at which weak mixture strengths could be safely used

He had tried to obtain some collective idea, if such existed, as to how helicopters, particularly the new designs that were coming along, could be operated, and he had found it extremely difficult It might be that, as with most new designs, the designers were more optimistic than other people, or alternatively, they feared their optimism It seemed that, not only would helicopters take a far greater percentage of the maximum power of the engine for longer periods, in relation to the total period of flight, than would fixed-wing aircraft, but that the engine r m p would tend to be narrowed down to within a tight band just below the maximum r p m permissible for extended periods

That meant that engines were going to have an exceedingly hard time in helicopters Did the Lecturers think there was any possibility of the efficiency of the helicopter being improved to such an extent that it would no longer be necessary, a few years hence, to take these relatively large percentages of engine power from the engines ?

J Brocard (Chief Engineer, Breguet Company, France) He expressed his thanks for the invitation extended to the French engineers to attend the meeting, and the pleasure it afforded them to attend

The first Breguet helicopter had been built in 1905 , in later years M Breguet did further work in that field and in 1935 had secured the altitude record Before the 1939–45 War a third machine had been built, which he believed was the only machine having two rotors, contra rotating, an arrangement which gave very good efficiency The new machine was powered by a 240 h p motor and the diameter of the rotor was five metres (about 16 ft)

Group Captain G V Howard *Companion* He was interested in the use of helicopters for anti-pest spraying and dusting work and had made enquiries as long ago as December 1946 about insurance rates , he was quoted variously 12 per cent , 10 per cent and finally 7½ per cent Because of the lack of helicopters from British sources, it had not been possible to proceed with the scheme at that time, but having been promised a Sikorsky S51 helicopter for delivery in February 1949, he had approached the insurance companies again in July 1948 and had learned to his horror that the rates had increased from 15 per cent to 20 per cent It was explained to him that the large increase was caused by the high incidence of accidents to crop spray and dusting helicopters in the United States On making enquiries, he discovered that the accidents had occurred chiefly to tail rotors—not because of any mechanical defects in the rotor system, but on account of the rotors striking trees and hedges His informant volunteered the information that the helicopter operators liked to get the chemical well into the corners of the fields and generally got as close as possible to the boundary obstacles before turning In effect, the accidents were caused principally by careless or rash flying and he suggested that this factor should be made clear to the various British Underwriters interested in the insurance of helicopters engaged in crop culture

Generally speakers had referred to the alleged difficulty of operating a helicopter and he would like to associate himself with the speaker who expressed the opinion that the pretence of some of the few original helicopter operators, to the effect that an exceptional type of person was required, was calculated to harm the helicopter industry and discourage would-be purchasers He had been permitted to take a short course on helicopter operation and mechanism, at an R A F Centre, while on his retirement leave and, judging by the description of a member of the staff concerning the complicated nature of operation, he formed the impression that at least four hands and two pairs of feet would be required In actual fact, he found that while it was true that the technique required was very different from that of flying a fixed-wing aircraft, there was no great difficulty about it and he formed the impression that the average individual would qualify for solo flying more quickly than in the case of fixed-wing aircraft, because of the impossibility of flying slowly in the latter

The creation of these mysteries by the experienced few was similar to the nonsense " Black Magic " of the earlier flying-boat pilots, who tried to make out that web feet were required to fly a boat successfully Every one now knew that the alleged difficulties were sheer invention and in actual fact the average landplane pilot experienced greater facility in operating a flying-boat, because of increased area for take-off and landing

SUMMING-UP

N E Rowe (British European Airways) *Member* He thought of the " General Problems of the Helicopter for Civil Use ' as being primarily passenger and freight carrying, although there were many other uses, a number of which had been mentioned

They had tended to think all the time of a machine with a single main rotor, something which had the stability characteristics of the machine they knew, having the difficulties in connection with a single power unit and power cutting which characterised it A good deal of the discussion was unduly coloured by their experience of the aeroplanes they had now, presumably because they had not experience of anything else, although there was a great deal of promise from the designers A challenge had been made by the operator and the technical expert, and that challenge was answered by the designers , in general he had concluded that many of the points brought out by the operator and technical expert were dealt with reasonably well by the designers The designers' figures were still rather unrealistic in that they were not backed by full measurements or prolonged experience , but on problems of stability and performance, engine-cut performance, and so on, it seemed that a good deal had been done, that those problems had been given real attention in design, and there seemed promise of getting what they wanted In particular, Mr SHAPIRO s claim that in his three-rotor machine he could attain stability over the whole speed range was extremely promising

For civil use safe, reliable, economic operation was wanted Safety, in the connotation of " civil use " which he had in mind, was perhaps best achieved by having multi-engines, a point made by Wing Commander BRIE, and he hoped they would get away from all the difficulties of engine cut and of landing with no power Machines must fly perfectly well on part power, and that was one of the things expected from the designer

In reliable operation were included all the points of maintenance, flying blind, good stability and control and operation in all sorts of weather Group Capt FENNESY had spoken of navigation, a matter which was of great importance in the whole set-up If navigation could not be effected precisely and automatically, they were in great difficulty

The problem of blind flying had not received the attention he had hoped The meeting had tended to talk about stability and control rather that the actual practice of blind flying, although all agreed that it was necessary In Great Britain it was essential for regular operation to be able to fly blind with complete precision of operation in terms of navigation, and complete safety in terms of control and stability and the pilot fatigue factor Mr FORD had mentioned the instrument layout, and the work that B E A had done emphasised the importance of good lay out for blind flying, so that the fatigue, which was inherent in the helicopter to-day, was reduced to the minimum

Wing Commander BRIE had made a very important point when he had urged that they must make the best use of what they knew already Exactly the same sort of plea was made by Sir HENRY TIZARD in his Presidential Address to the British Association in 1948 , he had said they would probably do more in advancing the general economics of life at this stage by making use of the knowledge they possessed now rather than by applying all their effort to the finding of new knowledge He commended that point to designers and all others concerned

The point made during the discussion concerning the provision of sites had not been taken up, although it was of great importance to operators It was said that if they had the best helicopters, but had not the sites to and from which to operate them, they could do nothing That was absolutely sound , there was need for real drive in connection with the provision of sites, so that they could get them as economically as possible and in the best position for economic and convenient use Another important point was that, since the helicopter was a short-stage vehicle, the number of sites in a given group system would be large, hence equipment, manning and so on of such places must be done on an economical scale

There had been a fair amount of discussion on vibration He had done a fair amount of riding in the S 51, and the B E A pilots had done a tremendous amount of work He would say that the vibration was rather high for comfort but not unduly so The point had been made by one of the designers that they should set down a standard of vibration which the operator would be prepared to accept , that was important because it would give the designers some idea of the limit on cruising speed imposed by passenger comfort Vibration was important, but he had felt that there was a tendency to over-emphasise it

He agreed on the point made that the total amount of effort being devoted to helicopter problems in Great Britain was too small and that they should have more training of technical men More technical knowledge was needed but without training they would not get it

Research with models was also important There was a technique in connection with fixed-wing machines which used a sequence of calculations and model tests and correlation with full scale , he believed it was true to say that, correlation between model and full scale having been established, they could advance much more confidently into new territory than they could without the model technique A similar technique was needed for helicopters As things were now, they had to build a full-scale machine and find out what it was like They should know a great deal more about it at the model stage , then they could advance with much more confidence and economy

CONCLUSION

DR H ROXBEE COX (*Chairman*)

The Chairman said he had been particularly glad to see the French engineers and also to see so many who were interested in the insurance side of the helicopter business at the meeting One of the diagrams in Wing Commander BRIE'S paper was important from the insurance point of view , it showed how easy it was to walk into moving parts of a grounded helicopter, thereby damaging oneself and the helicopter, so that the insurance charge would be quite appreciable unless the greatest care were exercised

One of Mr SHAPIRO'S diagrams, seemed to show that, if the number of rotors were increased on one of the multi-rotor machines, the ratio of disposable load to all-up weight tended to become asymptotic That was puzzling There was a clear difference between gaining further disc area by increasing the number of rotors and achieving the same result by increasing the area of each disc It seemed to him that the former was more expensive in structure weight than the latter, and he would like to know why he appeared to be wrong on that point

CONTRIBUTIONS

B H Arkell (The Fairey Aviation Co Ltd) *Founder Member Written contribution* Opinions had been voiced from many quarters during the discussion on the controversial subject of whether or not the helicopter was difficult to fly

It was generally agreed that in steady forward flight, apart from stability problems, there was not a great deal of difference between the rotary and fixed-wing aircraft, and it was on the question of hovering that the controversy arises An examination in detail of the characteristics during this condition of flight might throw some light on the subject

In the fixed-wing technique, discounting aerobatic manoeuvres, the condition of flight calling for the maximum concentration from the pilot and the most accurate co-ordination of aileron, elevator, rudder, and power controls, was the hold-off and touch-down to landing, occupying a period of perhaps a few seconds

If the fixed-wing pilot considered the amount of concentration and co-ordination of control he needed to employ during this short hold-off period in order to ensure that the aircraft touched down to a perfect three-point landing, he would have some idea of what was required to hold a helicopter hovering, in just exactly that position, over an extended period of time

Co-ordination of the controls in the helicopter was no more difficult than on the fixed-wing aircraft and became automatic with practice, but there would always remain the concentration, which was a source of mental fatigue This theory had been borne out in practice and agreed with the experience acquired in helicopter crop spraying, which was a particularly tiring form of flying

C M Britland (Royal Aircraft Establishment) *Written contribution* Apart from the specialised and irregular uses of helicopters, such as crop-dusting, and looking at the possibilities for regular airline transport, they might learn much from studying Masefield's recent " treatise " Masefield was convinced that helicopters as they knew them now were of little value for this purpose when the block distance exceeded 200 miles, both from the economic and effective speed points of view If they accepted his analysis they should either design helicopters specifically for such a short range or else overcome their fundamental handicap of low operating speed

The first alternative suggested to him that they should energetically develop the jet-propelled rotor principle, since it was at short-range that such a device had superiority over the present system Even with present knowledge the evidence suggested that they could build a jet helicopter which would hold its own economically with a reciprocating engine design over a stage length of about 150 miles, and they had not started to conduct serious research on jet-rotor problems yet, whereas the reciprocating engine was almost at the peak of its development Many people were confident that the jet type would come out on top eventually and greater urge should be given to its successful development, and they should not wait for the Americans to prove its practicability But perhaps it would be wise in the early stages to see how much noise would be acceptable over the peaceful English countryside !

The second alternative, of removing the handicap of low operating speed, could only be solved by the convertible aircraft in which, after take-off, the rotors were tilted through 90° to act as low-revving propellers while the aircraft was supported by small highly-loaded wings He realised the complexity of such a concept, but this must be weighed against its many advantages It could be the fastest form of inter-city transport for all distances up to 1,000 miles, except for the jet-propelled air liner at the longer ranges and it could combine the simple terminal requirements of the helicopter with the operational flexibility of a propeller-driven aircraft For the critical take-off and landing operations at night or in bad weather, a convertible had the inherent safety of the helicopter and should practically eliminate the stacking problem Such a machine, if proved practicable, would eventually outmode the present-day helicopter Would it not be worth while, therefore, to examine the possibilities in detail at this early stage ?

Major J L B H Cordes *Founder Member Written contribution*

1 *Captain Liptrot's paper*

Although he agreed with the major and technical part of this paper he would like to discuss further certain points on piloting—particularly from an aeroplane pilot's point of view Aeroplane pilots did not find helicopters difficult to fly because they were afraid of losing speed as it was only a matter of doing so at a different time of flight Every time an aeroplane landed it had to lose flying speed before it could touch down He thought it was the gradual change of behaviour of the controls, when merging forward flight to hovering, that the pilot found rather puzzling at first In forward flight the stick and pedals handled very much as they did in an aeroplane, but when hovering their functions altered considerable The pilot's first sensations were rather like those of " Alice " when her knitting needles turned into oars, and he became confused The actual loss of speed at this stage of instruction would not worry the pilot as he had already been taught to hover The pilot was not afraid of losing speed while hovering as he had none to lose, and in any case the controls were so different under hovering conditions that the pilot found he was learning something entirely new and aeroplane habits did not worry him

He had found that the comparison of the behaviour (not control) of an aeroplane to that of a helicopter was akin to a bicycle and that of a horse and there was no more difficulty in graduating from one to the other The bicycle depended on its forward

https://doi.org/10.1017/S2753447200000548 Published online by Cambridge University Press

speed for its equilibrium, and a change of heading for its change of direction, whereas a horse (a nice one) could remain stable irrespective of speed, and would move forwards, sideways and backwards, and could even be persuaded to stay still, although attempts at hovering should be discouraged The danger area too, to those on the ground, as with the helicopter, was in the vicinity of the tail

The claim had been made that, in comparison with the aeroplane, the helicopter could not be stalled Surely a wing, whether fixed or rotating, was stalled when the angle of attack was increased to such an extent as to induce a breakdown of the air flow over the top surface, resulting in a loss of lift? The action taken to prevent this with either type of aircraft was the same in effect, in the case of the aeroplane the angle of attack was reduced by putting the nose down, and in that of the helicopter by reducing the pitch of the blades There was this difference, however, if the increase in the angle of attack were persisted in, the aeroplane would stall, and if there were sufficient height, recovery would be made even from an incipient spin On the other hand, with the helicopter under the same conditions, even before the blades reached their full stall the mean lift was great enough to overcome the centrifugal force that kept the blades horizontal, leading to " over-coning " and the collapse of the rotor—from which condition there was no recovery, from whatever height, and the question of when the blades fully stalled was not even of academic interest to the occupants!

2 *Safety*

(*a*) *Parachutes* It would be interesting to know what research had been, and was being, done to render the use of parachutes with a helicopter more feasible There were certain conditions that could be visualised arising in flight, such as partial collision with another aircraft, a blade hitting a large bird, blade or hub failure, or, with Service aircraft, effects of hostile gunfire, where the use of parachutes would save life Instructions to " jump clear in such a manner as to avoid the main rotor " were inadequate and, to his mind, a confession that a successful drill had not yet been evolved The helicopter was flown more often than not, below " parachute height " but on those occasions when it was flown high enough to justify the carriage of a parachute it would be nice to know that use could be made of it easily if anything sufficiently serious occurred

(*b*) *Reliability* He would like to add every possible ounce of weight to the argument for at least two engines for commercial helicopters He thought that one of the foremost and essential civil requirements of a helicopter was to be able to take short cuts with safety over built-up areas, rocky mountains, stormy seas or other unsuitable landing terrain For this purpose it must be able to cruise at full load without losing height, on half its total engine power It was also a requirement of the law pertaining to aircraft heavier-than-air He would prefer the configuration of three engines with one rotor to three rotors with one engine There was a practical comparison here with the aeroplane, where a tri-motored monoplane was obviously more reliable than a single-engined triplane

G H Cumberbatch Willins *Member Written contribution* The transition from slow or hovering flight under power to autorotation with the minimum possible loss of height, following a power unit or transmission failure, should be regarded as absolutely fundamental to safety of operation Had any tests been made to determine what proportion of the total height lost was needed for merely establishing " autogiro " flow pattern and a stable rate of rotation from the " helicopter " state of operation? It would appear that this was a fraction of the height loss that must be accepted as inevitable, but it should be possible, by means of lower disc loadings and longer travel undercarriages, to save in emergencies the whole of that part lost in building up forward speed for a safe landing

Mr Hafner had stressed the need for a definition of the permitted level of vibrations to keep within an agreed threshold of comfort This was important since prolonged subjection to certain types of vibration could be very injurious, and it would be advisable to take advantage of the latest medical research on the subject

The remarkable safety record of the Autogiro had been referred to several times during the course of the discussion It was interesting to recall that during their first ten years of development and establishment, Senor de la Cierva's Autogiros were flown in every part of the world by hundreds of pilots of all grades of experience, in schools, clubs, by private owners and on commercial operations without incurring a single fatal accident, a record that must be unique in the history of Aviation, and one that would bear comparison with any other form of transport

https://doi.org/10.1017/S2753447200000548 Published online by Cambridge University Press

THE AUTHORS' REPLIES TO THE DISCUSSION

Wing Commander Brie

The criticisms which he had made arose from a close association with, and experience of, so-called modern equipment If they looked back a little and delved into the nature of that equipment, no doubt they would get on to firmer ground In the first place the Sikorsky S 51 was of American origin Secondly it was a modified version of an aircraft conceived in 1942 for Service use, and soon after constructed in quantity under the stress of war conditions Thus, although considered modern in the sense that it still had no more recent competitor, it was in fact much out-of-date compared with a completely re-designed version incorporating those obvious refinements resulting from " know-how " which could now be produced It was remarkable that the S 51 was so good

On the other hand and despite the rapid advances made elsewhere in the rotary-wing art during the past ten years, it was only comparatively recently that in Great Britain the potentialities of the helicopter had received anything like sufficient official attention and support It was all very well blaming the war for this state of affairs, but in view of their pre-war achievements it ill behoved them to rely on such a flimsy excuse Now somewhat tardily they had seen the light, and there were heartening indications that an effort was being made to make up as speedily as possible some of the leeway lost

In this the B E A Helicopter Unit was making a valuable contribution The objective behind the acquisition of American equipment had been twofold Firstly to ascertain the operational characteristics of the helicopter whether, and in what manner, it could best be used to study the economics of scheduled services and to discover the problems, limitations, and difficulties Secondly they wanted their efforts to act as an incentive to the British Industry to produce something which could be used with satisfaction British European Airways now had over twelve months' experience in handling the Sikorsky S 51, and although current proposals for 10, 20, and even bigger passenger-carrying helicopters were attractive to contemplete, there were advantages to be gained by not trying to run before they could walk The British Helicopter Industry had yet to acquire that valuable background of design and constructional experience based on past achievement For the time being it would be something to shout about if only someone in Great Britain could demonstrate a prototype capable of performing no less efficiently than the S 51 On the other hand the operator could not acquire the desired standard of basic knowledge and experience unless he had the goods to handle So that his criticisms arose from the deficiencies which he and his colleagues in B E A had found in the equipment they were using He saw many opportunities in a meeting such as this of pulling themselves to pieces in fact he recalled a fairly recent article in the JOURNAL of the Institute of the Aeronautical Sciences showing how aeroplane interests got together and did exactly the same thing—but more so They had competent technicians, engineers, and pilots, but it was up to the Industry to produce something worthwhile before expecting that additional encouragement in the shape of orders which normally followed solid achievement

The point made by Group Captain Howard, who had asked why the British insurance companies should base their rates on what happened in America, was a good one In B E A , in the course of twelve months' operation, they had not had to replace even a split pin as the result of an accident That was a fact, and it was an achievement Perhaps they had a better appreciation of the limitations of what they were handling

He did not think it was easy to fly a helicopter He knew of no other aircraft which was so easy to fly as the C30 Autogiro When he took the first prototype to Martlesham Heath for its Certificate of Airworthiness tests he had sent off three pilots without giving them any dual instruction , but that could not be done with the helicopter During the evolution of the helicopter some very desirable Autogiro characteristics had been lost, and they had to retrace their steps a little

With regard to the provision of landing sites in city centres, a point raised by Air Commodore Primrose, they must be careful not to put the cart before the horse It was no use having the sites unless they had the aircraft But he believed that Westland Aircraft and others were doing their best to fill the gap

What they wanted was not only a helicopter with acceptable flying and performance characteristics , they wanted also the advantages resulting from the healthy stimulus of competition He felt quite sure that then the economics of the problem would look after themselves

Captain Liptrot

He agreed that what he and Wing Commander BRIE has said in their papers was rather coloured by what they had at present They were using the equipment that was available, and from their experience of it they were trying to point the way and were trying to help others to appreciate what was being done in Great Britain in developing the helicopter The British designers and constructors were showing that they were giving good engineering in the British helicopter They were aiming at long life in the working parts, which meant low maintenance costs, and they were designing so that whole components could be taken out, repaired and replaced Such factors showed that the British-designed helicopter was a sound engineering job, and the designers and constructors at the meeting had answered most of the questions put to them in the papers

On the question of insurance rates in Great Britain, which appeared to be based on the accident rate in America, the accidents were not due to any intrinsic defects in the helicopter So far as he was aware, in the whole development of the helicopter only seven people had been killed That was a very low figure, and the helicopter was the only means of transport which in its early years of use had such a good record Also on the credit side was the fact that the helicopter, in the two or three years of its operation, had been instrumental in saving well over 100 people

They now had three helicopters of British design Helicopters could not take their proper place in aviation until somebody built them in numbers By giving the constructors the incentive to get a production line going, they could give enormous help to the development of the helicopter The mere fact of getting a production line running would put the machine on the market, and once it got on the market, increasing numbers would be sold When they reached that stage, down would come the price, and then it would become economical to the operator

Dr Bennett

Mr YATES had asked about the danger from engine failure at a height of less than 300 ft, he happened to be visiting the Sikorsky Company in America on an occasion when there was an engine failure in a helicopter while hovering at a height of about 50 ft, and at a time when it was thought that 50 ft was an unsafe height at which to hover It was demonstrated on that occasion that that height was perfectly safe, the pilot had landed the machine and nothing much happened to it, except that the nose wheel was slightly damaged There was no doubt that hovering at a greater height would be quite safe if the pilot took the proper action It was advisable, however, not to rely entirely on the skill of the pilot and to incorporate the Gyrodyne features of low pitch, low rotor power and load disc loading It was hoped eventually to ensure that a safe emergency landing could be made from any height by utilising the kinetic energy of the rotor before touch-down

Mr ROBERTS had referred to alleged inconsistency, in that the helicopter was required to have a high cruising speed for certain purposes, but not for others There was no inconsistency about that He thought that the Gyrodyne principle of independent propulsion would, in the future, enable considerably higher cruising speeds to be attained and that the development of blade tip jets would result in an improved slow-speed performance It was manifest that those features, far from being incompatible, could be combined, and, as development work was now at an advanced stage, it would not be long before rotary wing aircraft showed a marked improvement at both ends of the speed range

He agreed with Mr WILLIAMS that the present helicopter had too many moving parts Simplification was needed, not only from the safety point of view, but to reduce maintenance costs This was possible with the torqueless rotor which, with the absence of mechanical transmission, would enable rotary wing aircraft to be operated reliably and economically on scheduled airline services both in built-up areas and over water

In reply to Mr EVANS, helicopters which were required to hover for long periods should either have an adequate reserve of power or be confined to operations where an engine failure would not be dangerous Gas turbines, which might have to be incorporated in future helicopter designs simply for no other reason than that no suitable reciprocating engines would be available, offered certain advantages to the helicopter designer, one of which was that the helicopter could be designed to climb away vertically even if one engine failed

Mr Hafner

The references to blind flying equipment brought him back to his question concerning the need for standardisation of controls They could not get on with the design of helicopters if they did not know what was needed His Company had built a number of mock-ups during the past few years which had been changed considerably from time to time, mainly because of the uncertainty as to what was needed There was a definite need for an early agreement on standardisation

He sympathised with Mr TYE's feelings about present-day helicopter configurations, but they should remember they had only just started on this new venture There was consolation in the fact that in this instance at least they did not depend for safety on the maintenance of speeds of the order of 100 m p h The latter was something really worthy of rebellion He thought that the tandem rotor configuration contained a fair measure of features with soothing effects on engineer s instincts It was symmetrical, had a small frontal area and would look not unlike a streamlined railway coach that had decided to take the air

He felt that the real solution to the stability of the helicopter was essentially a simple one , he did not think the solution would be a gadget, but that there would be a sort of anti-climax There was obviously a need for stability in forward flight but when hovering, the pilot was concerned with accurate control and had to maintain his position with regard to a point on the ground and, therefore, would not miss very much stability in that condition of flight He felt that stability in forward flight would be obtained most easily by the conventional use of the tailplane He had pointed out that within a certain speed range the Bristol 171 could be flown with hands off the controls He hoped to be able to widen that speed range

As helicopter engineering was developing rapidly and becoming progressively complex, it was important to prepare for the education of the young people now, and to ensure that this education was thorough

The figures which Mr ROBERTS had read in the graph on tip speed ratio as 1, 2 and 3 were actuallv 0 1, 0 2 and 0 3 The factor ζ did not refer to the deflection of the induced flow before the disc, but to the curvature (or the distribution) of induced velocity at the disc ζ was defined in Ref 1

The technical developments of the helicopter and its ground equipment were interdependent Thus, for example, the size of a helicopter and certain of its design details (*i e* undercarriage) were probably controlled by the rotor stations employed and *vice versa*

He could not agree with Wing Commander BRIE that in the interest of safety in emergency landings it was particularly desirable to keep the rotor disc loading below 2 lb per ft ^{2}

It had been shown that the Bristol Type 171, notwithstanding the fact that its disc loading was over 2^1 lb per ft ^{2}, had excellent landing characteristics

Dr BENNETT had stated " helicopters which are rough in operation at high pitch in forward flight are usually quite smooth at the same forward speed in auto-rotation ' He was surprised to hear this because he was of the opinion that collective pitch (or λ) was not a major factor in rotor vibrations He could point out that the vibration level of the Bristol 171 was very low throughout the entire flight envelope It was independent of λ, *i e* flying the aircraft in a flat glide and in low rotor pitch (which corresponded to the Gyrodyne condition of flight) was no better or worse than flying level or climbing

He had come to the conclusion that the important speed limiting factors of a rotor were —

Tip speed ratio
Basic lift coefficient
Mach number of the advancing blade tip
Coning angle

as could be seen from his paper

He thought the range of danger heights had now been reduced practically to nil He did not think the automatic reduction of pitch in a power failure was desirable, he thought it was dangerous, especially at high speed and near the ground There was no need for a hurried reduction of blade pitch in a power failure, except during hovering at night, when every pilot instinctively would be alert and ready for an emergency

The landing run of the Bristol 171 was practically nil, the forward speed was fully absorbed during the 10 seconds hovering prior to landing Those auto-rotative landings were very comfortable, and he joined with others who urged that they might now safely dismiss outmoded ideas on auto-rotative landings

In the design of the Bristol 171, great efforts were made to effect real simplification of components, not merely in order to make the aircraft cheaper to buy, but to reduce maintenance costs and to increase safety

With regard to the auto-rotative landing shown in the graph, the glide, with the engine idling, began at about 5,000 ft and at a height of 100 ft the engine was switched off, so that throughout the whole descent the rotor was not driven by the engine

He felt strongly that the helicopter might well supersede the fixed-wing aircraft for use on internal airlines He did not agree with Mr MASEFIELD's view that the helicopter would serve for journeys up to 200 miles only, beyond which the fixed-wing aircraft would take over, but thought that the helicopter would serve for journeys up to about 300 miles

Mr SHAPIRO had suggested that the tandem rotor arrangement was only marginally better than the side-by-side arrangement and, therefore, inferior to the three rotor configurations He, on the other hand, had found that the weight and drag of an out-rigger structure for side-by-side rotors were extremely high and, therefore, the tandem rotor configuration was by far the best one for large shaft-driven helicopters

Mr SHAPIRO did not think the benefit of tip speeds beyond 550 ft /sec was large That was true for the hovering rotor Many people, however, had pointed out the need for a high cruising speed and this could not be achieved without a high blade tip speed The best performance of the Bristol 171 was obtained at a tip speed of over 700 ft /sec and he thought this figure would increase as the art advanced

Mr Shapiro

Mr TYE was dissatisfied with the present state of knowledge on the subject of fatigue conditions in rotor blades Long ago, Autogiro blades were designed on the scantiest information but the genius of the early workers Glauert, Loch and Cierva provided a basis for practical design Studying subsequent investigations conducted by the R A E, he had been struck by the experimental confirmation of a brilliant approach Autogiros had been flying for thousands of hours without a single failure attributable to blade fatigue To-day analytical methods had been refined and measurements confirmed existing analysis even more closely

There was no cause for lamentations in this field and he thought they knew as much of blade fatigue loads as they needed considering how little they knew of the behaviour of structures under prescribed fatigue loads This shifted the emphasis to laboratory fatigue testing But even there they could learn more if they heeded Sir HENRY TIZARD's and Mr ROWE's advice on using existing knowledge Some designs were amateurish and it was not surprising that failures had created the impression of lack of knowledge Was this ignorance really necessary?

Mr FITZWILLIAMS wanted talented volunteers from the ranks of aircraft engineers and many speakers seemed to want to go even further and breed a special race of helicopter designers He disagreed let them have *engineers*, craftsmen of the bench, the board, the laboratory and the desk, thoroughly familiar with fundamentals Helicopter design was far too specialised an art to be taught at colleges, which should avoid specialisation *so far as possible* Engineering applications should mainly serve as examples which, to be truly instructive, must be good, time-tested examples He could not think of a worse example than the present-day helicopter

Specialisation in helicopter design required a co-ordination and maturity of knowledge which could only be achieved in practice and through practice, unless they wanted young men capable of indulging in large scale scheming but incapable of attending to detail

If specialisation were necessary let it be directed to types of activity rather than particular application There was a case for vibration engineers, gear engineers and the like He would like to create the profession of "stress physicist" and perhaps "fatigue engineer

Helicopter design was a field wherein it was essential to discourage idle speculation by constantly keeping in mind the supreme question how much? Opinions not expressible in quantitative terms were often worthless Not only did the helicopter share with all aircraft the three-dimensional limitation due to its weight sensitivity, but it filled an intermediate gap in communications threatened on both sides by surface transport and fixed-wing aircraft It must score in economics or be confined to a few specialised duties Economics were concerned with narrow margins of profit and loss

To illustrate what was meant by a quantitative approach, he would select a few topics from the Discussion

It was not very important whether helicopters were difficult to fly but how long they could be flown by the average pilot under given conditions such as low visibility or rough weather ? What was the fee for a course to reach acceptable standards ? What was the salary of a professional helicopter pilot ? Ships had been difficult to sail for thousands of years This fact never endangered the future of shipping, but they could not accept a dinghy requiring as much seamanship as an ocean liner Piloting must be related to the type of machine and its tasks

This brought them to the demand for stability The Air Horse had some stability but much more was wanted Broadly, he shared the stability enthusiasm of Mr SCOTT HALL and others, but felt that Mr FITZWILLIAMS had put the matter in a better perspective Some time ago he had come to the conclusion that it ought to be possible to make stability " to measure ' and suggested that this approach should be investigated The suggestion was taken up by Dr SISSINGH of the R A E and his work led to results summarised in his recent lecture to the Helicopter Association Those results, reinforced by information from the United States, threw the ball back to the operators If they specified stability and control in quantitative terms they should get them without undue weight, price, or delay

To specify those things quantitatively was not easy There were several kinds of stability, each capable of variation over the range of forward speeds, but intensive research should start at once An existing " unstable " helicopter should be equipped with instrument-controlled automatic devices capable of the widest variation in parameters When this information was available the mechanisms adopted to incorporate the required characteristics would vary in each case In the Air Horse with its power-assisted control it might well be that gyroscopic devices would fit in very well with its servo assisted rotor controls

He had already stated his view that " complication " and the " number of moving parts ' were rhetorical, rather than engineering, terms What was wanted was cheap maintenance The simplest thing of all was a sealed box !

Safety was measured by the insurance rate which, presumably, was related to the accident rate

Here a quantitative approach required the intervention of statistics, and guessing was inadvisable Some speakers were worried about structural and functional safety but he could not see much evidence to support such an anxiety

It appeared that insurance rates soared because of a number of accidents entirely due to carelessness In such circumstances, the appeal to the designer should be to make pilots errors unlikely The Air Horse went a long way in this direction because of configuration, size, and undercarriage design Insurance interests would find the elimination of the ' danger height " and the absence of a tail rotor of particular interest With the exception of a twin-engined installation, most future tasks were steps towards elimination of pilot's error through automatic devices

Mr WILLIAMS seemed to think that reduced disc loading enhanced safety and reduced the payload Neither, he thought, was true in general Reduced disc loading led to more powerful control, higher maximum lift and generally more chance for good or ill, depending on the skill of the pilot The effect of disc loading on payload was complex and had been discussed in his paper

He thought that in a machine destined for public transport, such as the twin-engined Air Horse, the engine would be used much in the same way as in fixed-wing transports Other machines would have some more severe and some less severe, duties than transports and small machines would be as unpredictable as small aircraft On the whole, in adequately powered helicopters, the engine was no more heavily loaded than in equivalent aircraft

Moreover, there was not so much difference between helicopters and fixed-wing aircraft in installed power per passenger as Mr DAVENPORT thought Where duties were comparable, such as in medium transports, both required about 100 h p per passenger Wide discrepancies existed when duties were ill-defined, such as in personal aircraft Fuel consumption in m p g per passenger, therefore, was inversely proportional to cruising speed in transport aeroplanes and the ratio might be 8 6 or 9 6 in favour of fixed-wing aircraft When delays, caused by traffic control, were included the helicopter scored for short journeys

The necessity for an undercarriage had been questioned He thought it was like questioning the necessity for doors in a house which were only used for getting in and out and had no function in the process of dwelling The helicopter was no

https://doi.org/10.1017/S2753447200000548 Published online by Cambridge University Press

different from the fixed-wing aircraft in this respect but, because of its shorter range, the undercarriage was used much more often in a given number of flying hours It was take-off and landing which distinguished the helicopter and the underc rriage was an essential part of it

The difference between a fixed-wing and a helicopter undercarriage was primarily in the take-off run and, therefore, mainly affected the wheels In their experience wheels could be much smaller in a helicopter because fixed-wing wheels were designed around their brakes In the Air Horse the wheels weighed one per cent of all-up weight It would be difficult to improve on that with any device, conventional or otherwise But the structure must include a tripod with a broad base for ground stability and that was where much weight was generally spent The wisdom of meeting emergency conditions by means of undercarriage shock absorption had been discussed in his paper Even if they considered normal operation only, both fixed-wing aircraft and helicopters *could* be landed very gently , whether they would land gently, when traffic schedules had to be maintained, only statistics would tell He doubted it

Some questions asked and criticisms advanced would vanish automatically when sizes increased He suspected that this applied also to Mr ROWE s comment that designers' figures were unrealistic Weight always went up in flight development to operational standard but increase was greatest in items of equipment and, therefore, proportionately smaller in larger machines

It had been suggested that more attention should be given to model research From his experience and the general rules governing model research, he had been led to believe, paradoxically, that the reason for the relatively small use made of model research in helicopter development was not that they knew too little, but too much Model research would always be confined to enquiries into *isolated* problems This was fundamental and was due to the laws of similarity which could only be met in one respect at a time There were few urgent isolated problems in helicopters about which they knew too little for *design purposes* at this stage of refinement Where such problems were encountered, as in the three rotor configuration in forward flight, model tests were made and proved relatively straight forward and instructive To-day's problems in helicopter design were composite problems Models could hardly be expected to answer such questions as how to specify required stability, what were pilots' reactions to control characteristics, or how to achieve smooth rotors In such matters model results could be definitely misleading and many a designer had been tempted to vow never to use models again Nevertheless, model methods could be fruitful and more research would require more model work

Dr ROXBEE COX had asked why the disposal weight percentage continued to grow when the number of rotors went up Let them first agree that this was a speculation to which the graph given in his paper was not a reliable guide All such graphs, more often than not, lost their validity when pushed to the extreme His speculation on the graph was that the percentage of disposal load approached a constant It stood to reason that in a hypothetical machine with 37 rotors (Jules Verne's number), each rotor was of the same value structurally and both additional lift and additional structure were independent of the number of rotors

Increasing the disc area by increasing the size of each rotor was quite a different matter and the percentage disposable load was bound to decline In his paper he had elaborated the structural reasons for this decline There were other, independent, reasons, such as the coning angle

Major CORDES doubted the ability of rotors to reach maximum lift without collapsing through overconing In the Air Horse all the blades must be stalled before a coning angle of 16° was reached, which he would agree was not " overconing "

Perhaps the best comment on the jet helicopters suggested by Mr BRITLAND was give them the jets and they would finish the job He thought that in fixed-wing aircraft the merits of jet propulsion for civil use were often over-boosted because they were comparing hypothetical, and therefore somewhat ideal machines with real aircraft already operating (not merely flying) In helicopters both torque and jet-driven machines were *operationally* hypothetical and comparison did not look so good for the jet-driven rotor, which was only attractive in a narrow range of duties

The *convertible* machine on the other hand was, as Mr ANDERSON asserted, a great attraction From the civil angle it might be premature but it was not too early to start development on a *compound* machine deriving some lift from wings It was one of the major attractions of the Air Horse that it was eminently suitable for such development It might be just a little too early to disclose more at this juncture, but the helicopter was going ahead and those interested should not compare 1945 helicopters with 1955 fixed-wing machines