DISCUSSION

Mr R A Shaw (*A D /A R , Ministry of Supply*) (*Member*), who pointed out that his department had a slight monetary connection with the project, said that the meeting had heard a description of one of the world's most remarkable aircraft To hear Dr HISLOP describing it in all modesty was most remarkable There was not sufficient time during the lecture, however, for him to enlarge upon some of the refinements of engineering that had gone into the aircraft

One's own belief was that the Rotodyne was one of the most remarkable aircraft in the world The fact that it happened to be pretty well a civil transport ready for use, apart from the ordinary clearances that would still have to be attended to for the next few years, had rather taken the world by surprise It would be of interest to hear the views of some of the operators

The Author had spoken of the potential of the aircraft in supplying a traffic need for Western Europe and places much more remote and desolate, but he had, perhaps, left something unsaid It was not enough merely for people to conceive and build such an aircraft as the Rotodyne If it was to be used, the rest of the world must move forward at a similar pace The ground organisation and everything that went with the V T O system must come along in time Time must not be wasted

Everybody would agree that the Rotodyne was the most remarkable helicopter, apart from the niceties of definition It was justified in being called the first V T O airliner Taking into account the possible wind speeds, it could probably complete a scheduled timetable about twice as fast as ordinary helicopters, and it was certainly in the class of transport aircraft that were still operating conventionally

It was interesting to recognise that the Rotodyne exposed the main problems of V T O L aircraft Fairey's had tackled these problems and found solutions The problem was mainly the full integration of the power plant with the airframe and a control system suitable for landing, take off, transition and forward flight, and to do it economically , and, further, to find sufficient power for vertical take-off and landing in a system which did not need so much power for cruising This had been done very ingeniously by the use of compressed air and superheat

If the concept could in any way be criticised, it was that some of the possibilities which the use of compressed air in an aircraft presented to the designer had been left untried Were the designers satisfied, for example, that they had chosen the best pressure ratio of this air ? If they wanted to achieve higher speeds, they might well have used a higher pressure and thinner aerofoils

It would be helpful to hear the comments of the operators and of organisations such as the A R B

Mr B S Shenstone (*B E A*) (*Member*), recalled that it was in the days when the Author was with the Corporation that B E A had had a hand in the origin of the requirement behind the Rotodyne It must have been something of a shock to Dr HISLOP to find not only that he had had a part in drawing up the specification, but that he had to go away and produce it It was rather like seconding the Chief of the Air Staff to Handley-Page

The aircraft had many points which appealed to the engineering side of B E A , chiefly because there was not too much machinery The preference was to have pipes rather than shafts, for fairly obvious reasons The difficulty from an engineering viewpoint was to think clearly One was fascinated by such ingenious solutions as the Author had described, but it was also necessary to think about what to do with the aircraft and how much it cost It might not be thought that these were engineering matters, but in an airline engineers were deeply involved in costs in one way or another

If the machine was to operate from city centre to city centre, the noise level must be fairly well acceptable The difficulty concerning noise was that it was difficult to conceive what was happening merely by recording a reduction of so many decibels One could only say, as the Americans had said, " I am from Missouri," which in this case meant that hearing was believing

It was, of course, difficult to produce the right level of noise quickly It was very easy to produce the wrong level of noise quickly, which was what Fairey's had done, but they would have to be given a certain amount of time to produce the right level The difficulty was that nobody had seriously defined the right level of noise

As far as B E A was concerned, it was understood to be the level with which the Chairman was satisfied!

Another aspect was how and where the aircraft would be operated From the engineering point of view at least, B E A felt certain responsibilities in this direction Having nursed the project in its early stages, it would be an alarming state of affairs to find, to one's surprise, that it was unusable This would probably surprise Fairey's more than it would surprise B E A It was not only rotary wing aircraft that the Corporation found difficulty in fitting into its pattern, and B E A had to change its mind more often than one might consider likely This was not to say that there were any depressed feelings about the Rotodyne, because, as far as could be seen, it was certainly the most economical rotary wing aircraft in the world and it was the only one that was big enough to carry sufficient B E A passengers to make any difference to traffic

There were, however, a number of questions still to be solved, and Mr SHENSTONE felt that he was hardly the person to solve them tonight

Professor J A J Bennett congratulated the Author not only on presenting a superb paper, but on having so successfully brought to fruition a decade of engineering development It was in January, 1949, that Professor BENNETT had had the privilege of flying to Bermuda to discuss the preliminary design of the Rotodyne with Sir Richard Fairey and he remembered Sir Richard's amazement that the aircraft had features so closely approaching those of a conventional aeroplane He was almost afraid that Sir Richard would say " If you admit that fixed wings are an improvement, why not discard the rotor entirely and make it a really good aeroplane!"

Sir Richard had not taken that view Looking back, however, over the history of rotary wing aircraft since Cierva began his development of the Autogiro, one felt there was a real danger that such a view might well impede not only the progress of the Rotodyne but also the progress of other forms of rotorcraft

Those who had read the current issue of *World Helicopter* would have seen Major-General Parham's comments on the delightful handling characteristics of the C 19 Autogiro This aircraft, with a simple fixed-pitch rotor system, was controlled by ailerons attached to small fixed wings and by elevators and a rudder at the tail It was not put into production, however, because its control surfaces became ineffective below about 25 m p h It had been decided to wait until direct control, obtained by tilting the rotor tip-path plane, was developed

Writing from Spain in January, 1931, Cierva had forecast that, with the successful development of the C 30 Autogiro, 1931 would prove to be the year in which the Autogiro would be put into general use Although about 100 C 30's were built, the production of Autogiros was again retarded because direct take-off was just around the corner It was not until 1939 that the problems of jump take-off allowed Autogiros with this new feature to be produced, and a batch of C 40's were supplied to the Royal Air Force

It was true that the war interfered with further activities in that field, but quite apart from this interference jump take-off was overshadowed by yet another new feature, *viz* , hoverability, which had clearly become practicable as had been demonstrated by the Focke and the Weir helicopters at that time

It had been said that Cierva never believed in the idea of driving the rotor in flight This must not, however, be interpreted to mean that his objective was not a rotorcraft capable of hovering The Rotodyne would have met his specification, and so also would helicopters with jet-powered blades It was the torque-driven rotor that Cierva disliked, and everybody knew what a penalty had had to be paid for rotor torque in the so-called " pure " helicopter

Rotor torque required that if one control were moved, most of the other controls had to make compensatory movements This applied whether there was one rotor or two Tonight, however, there was no need to elaborate on the advantages of a torque-less rotor

The question now arose, after that long sequence of events would lifting propellers, mounted on tiltable wings, or lifting ducted fans or rotors or even jet lift, with short duration hoverability be preferable to a rotor of large diameter? Would this latest form of Autogiro suffer the same fate as its predecessors by being overshadowed by things to come, or was the project the practical compromise between the conventional aeroplane and the helicopter that had been awaited since the invention of the Autogiro?

Professor BENNETT's view was that just as there was still a place in aviation for the propeller as well as for the propulsive jet, so the rotor would retain its place as a lifting system even when jet lift rendered obsolete the very long runways now required for high-speed aircraft

Mr A McClements (*Bristol Aircraft Limited*) (*Founder Member*), congratulated the Fairey Company, Dr Hislop and his team, his predecessors, Prof Bennett and Captain Forsyth, on the work which had culminated in the Rotodyne—a very notable achievement With one exception, he did not wish to raise any special points about the Rotodyne itself since the lecturer had dealt very adequately with the subject

Clearly the lecturer found it necessary to compare the Rotodyne with existing forms of rotating wing aircraft and he had accordingly done so, using the mechanically driven helicopter as a yardstick In so doing, Mr MCCLEMENTS felt that the author had been somewhat harsh in relation to the maintenance and reliability features of the mechanically driven helicopter, and the percentage disposable load which it is capable of achieving

On the question of reliability and maintenance, the mechanically driven helicopter had developed whilst the Rotodyne had been developing and today very many such machines were achieving overhaul periods of 800 hours, and quite a lot were up to 1,200 hours This was quite a creditable achievement , it was not the end, and other forms of vertical take-off aircraft need not feel too ashamed of themselves if they are able to do as well On the other hand, it is not difficult to understand why operators complained about the mechanically driven machine because, in the main, it had been left to the user to provide the experience necessary to achieve such overhaul lives During the development of these aircraft there had been insufficient effort expended upon proving reliability and this was perhaps one of the main reasons why the mechanically driven machine was criticised The modern approach is to develop the aircraft extensively before it reaches the user If this practice is followed intelligently, he felt that many of the criticisms of mechanically driven helicopters will disappear

On the question of weight breakdown, Mr MCCLEMENTS took exception to the disposable load of about 27 per cent which the author offered as appropriate to the mechanically driven helicopter This was an old-fashioned figure and, when translated into a modern up-to-date turbine engined helicopter driven by a mechanical transmission, the figure was in fact about 40 per cent Such percentage disposable loads had already been achieved in helicopters in the 18/20,000 lb all-up weight bracket (*e g* , the Bristol 192) By scaling up to a machine the size of the Rotodyne the disposable load would not be less than the 35 per cent quoted for the Rotodyne by the lecturer , in fact, one would expect it to be higher than 35 per cent

Mr MCCLEMENTS made it clear that these remarks were not meant to detract from the qualities which the Rotodyne obviously possessed , rather, they were put forward constructively with the object of correcting a feature in the paper which he felt was somewhat misleading

The particular point about the Rotodyne which he wished to raise concerned the absence of any drag hinges in the rotor system Whilst it was understandable that in cruising flight flapping could be controlled and in-plane stresses kept low, there was still the manoeuvre case to be contended with when the rotor must flap, with resultant in-plane stresses No doubt this point had been examined during the development of the Rotodyne, and he enquired from the author if any embarrassingly high blade stresses had been found

Mr W Tye (*A R B*) (*Member*), said he looked forward to learning more about the Rotodyne because the whole approach of Fairey's and of Dr HISLOP sounded excellent and, from what the author had said, one felt sure that a tremendous amount of effort had gone into the basic safety concept

One particular fear that had been present for some time concerning future large helicopters was whether the kinds of failures which had been seen in a fairly innocuous form in the small helicopter might emerge in the large helicopter in a much more drastic form This fear had been particularly directed to the various mechanical rotating parts, shafts, gear boxes, and the like, which in earlier helicopters had shown a poor record compared with normal fixed structures It was, of course, extremely difficult to make a gear box as reliable as a piece of fixed structure

This state of affairs had not had particularly disastrous consequences, however, because the result of such failures had generally been that the helicopter had subsided

slowly and gently to the ground If, on the other hand, in the large helicopter of the future, a similar kind of failure stopped the rotor at one end of the aircraft and the rotor at the other end continued to rotate, the consequences would be serious This explained one's general feeling of concern lest the large helicopter of the future might be saddled with some very difficult problems in terms of getting the reliability of fixed-wing structure built into its various critical rotating portions

From what had been learned tonight from the author, one suspected that he had dodged a good many of those problems by the particular design concept of the Rotodyne One very much hoped so because, from the viewpoint of introducing the large helicopter into civil passenger use, the more that it was possible to 'design out' features that were difficult to prove completely by testing, the more quickly would the aircraft get into satisfactory service In other words, if it was possible to steer a way round the particular problem, rather than face up to what was admittedly the extremely costly business of proving reliability before a helicopter entered service, so much the better

On the question of proving reliability, the A R B was no doubt seen by the helicopter enthusiast as being a fairly stodgy sort of body! However, the enthusiast must accept that what he was trying to do was to bring into service a vehicle that was still to some extent on the frontiers of new knowledge, alongside aeroplanes with fixed wings from which experience had been gained for the last fifty years When buying his ticket the passenger expected to have exactly the same safety in both cases Thus, the helicopter designer had set himself a fairly tough problem to solve

It was necessarily a fairly costly matter to try to prove the safety of this relatively new and, in some respects, untried kind of vehicle to make certain that one was offering the same level of safety as the fairly straightforward fixed-wing aeroplane about which so much was known On the question of proving, Mr TYE knew that many of his technical colleagues in the industry would indeed like to do a great deal more than the financial purse would permit them to do He very much hoped that, when such a magnificent effort as the Rotodyne was presented, the ship would not be spoiled for a ha'porth of tar, the ha'porth of tar being the odd million pounds or so which would be needed to develop basically excellent prototypes into fully fledged airline vehicles

Mr Peter Masefield (*Bristol Aircraft Ltd*) (*Member*), said they had all heard a most impressive statement of the development of a very impressive piece of "non-agricultural" machinery

It was rather remarkable that most of those who had spoken had at one time or another, or so they had claimed, something to do with the development of the Rotodyne And most of them had been Scotsmen He was not himself a Scotsman, but some time ago, in the very early days, he had at least had something to do with the Author on drawing up the original specification

Looking around the Institution of Civil Engineers, one could not help feeling that it was a very suitable place in which to discuss the project described in the paper On the walls were names such as Watt and Brunel When one listened to the Fairey Rotodyne in the air, one could not help feeling that those originators of the steam engine would have been delighted to hear the familiar sounds as of a thousand beautiful steam engines puffing away at their best It was a delightful noise

People in the centre of cities should be grateful to both Napier's and Fairey's for the way they had gone about the task of combining the old and the new in such pleasant proportions

Having listened to the Author, many of those who were associated with other forms of rotating machine might feel that it was a wonderful thing to do away with shafts and gears Behind the façade, however, were there any problems of valves, tubes, pipes and things about which the meeting had not heard in detail? It would be interesting to know Would the Author say whether he had had problems in that direction? At least, they might be gentler ones than others had had in gearing

Another impressive feature was how well the rig tests worked These rigs, by means of which it was possible to learn something about a machine on the ground, were a major development in getting complicated pieces of machine to work before going into the air This represented a tremendous advance in the science of developing aeroplanes, helicopters and affairs of that kind, and one hoped that more and more of these rig tests would be seen in the future

Like everybody else, Fairey's obviously had the problem of how to get the money to develop a project If only this country had an approach such as the Americans brought to bear—who were delighted to place evaluation orders for a dozen machines to get them going—it would be possible to see the development much more swiftly of what could be very important new lines of British thinking The Americans were doing these things better, perhaps, because they had more money

Before the British operators all had Faireys at the bottom of their gardens, Fairey's must find some fairy Godmother in the shape, one hoped, of the Chancellor of the Exchequer, with a wand—and in the coming festive season a fairy Godmother would be especially appropriate—so that some money would come into the Fairey coffers

Everyone in the rotating wing business wished Fairey's the best of luck and wished also that the Godmother might be appearing around the corner—without, of course, giving any less gifts to other people who were obviously just as worthy

Mr T L Ciastula (*Saunders-Roe Ltd*) (*Member*), said that for a helicopter designer it was extremely important that one is rational when comparing the transmission-driven helicopter with the pressure jet system The comparison made by the Author related to transmission helicopters powered by piston engines When the first turbine powered transmission helicopters begin to come into the field, this comparison will perhaps be quite different In fact, the transmission helicopter is really only beginning and it is a pity that it was ever necessary to power transmission helicopters by piston engines

Whilst these comparisons were perfectly justified, it is well to remember that turbine powered helicopters are just starting Piston engines in transmission driven helicopters have produced very serious problems connected with engine vibrations which feed into the control system and require very extensive investigation, followed by fatigue testing All these problems will be very much easier with the application of turbines

To be rational in these comparisons, one would imagine that in the Rotodyne the control system must be more complex than in standard transmission driven helicopters This, of course, should be taken into account in such a comparison because the reliability of this more complex system is of vital importance It might well be that various duplications will be required, thus partially balancing out the fact that a pressure jet helicopter has no transmission as such For inter-city operations the reliability of this more complex control system will be vital In other words the shaft driven helicopter should not be condemned before it has even started, remembering that the application of turbine power will present a very much better picture

Mr A H Milward (*B E A*), who recalled the request for comments from operators, expressed surprise that nobody had commented on the cost per seat mile, which from the operator's point of view was a vital factor

There were two vital matters from the operator's viewpoint, one of which—noise—had been mentioned a great deal and which, as Mr SHENSTONE had said, nobody had yet been able to evaluate Noise, however, was of crucial importance, because unless the aircraft could operate into the city centres, the speed advantage which the Author had shown in his charts would disappear because the machine had to be quiet enough to operate a high frequency service into city centres This was something which had yet to be proved

Nobody had yet mentioned the question of cost per seat mile One thing which the recession now facing airlines had proved very clearly was that traffic was most susceptible to fares As all the other speakers had taken the opportunity tonight to indulge in advertising, Mr MILWARD saw no reason why he should not follow suit B E A had recently introduced a week-end fare on the main trunk internal routes which worked out at about 2⅝d per mile and there was a return fare to Glasgow of £8 The response to this in the first week had been overwhelming Each week-end so far, there had been 450 seats demanded but not supplied B E A was now faced with the need to put more aircraft on an operation which was supposed to be a marginal one If the Corporation did this, it would not be a marginal operation This showed that the traffic was available—if anyone ever doubted it—if the fares were reduced

He did not believe that there was an enormous amount of traffic that would pay very high fares to save that little bit of time between city centres There were, of course, exceptions on certain routes—possibly the Paris routes and certain inter-city routes on which business men would go by air to save time between, say, Birmingham

or Manchester and London This, however, was not bulk traffic The bulk traffic, as the introduction this year of the week-end fares had shown, was that which demanded the lowest possible rates

It was certainly no secret to say that B E A and most of the world airlines were turning more and more to cheap fares and becoming economy-class minded This was the obstacle which the Rotodyne had to meet, as did any other aircraft Mr MILWARD felt quite sure that the Author had thought about this and that the Rotodyne would be able to meet this demand

Mr Owen spoke briefly on the question of whether the safety aspects might be improved if the design incorporated two rotors instead of one

Dr Hislop, in reply, said that he would try to deal with the various points in groups The picture conjured up by Mr MILWARD of all the Scotsmen emigrating back to Glasgow on the strength of 2½d a mile was quite entertaining!

Mr MILWARD had raised the question of cost In presenting the paper, the AUTHOR had deliberately refrained for reasons of available time, from developing the pros and cons of the economics Fig 42, however, gave a graph of direct operating costs, showing the cost based on the present version of the Rotodyne with 48 seats, and a contemplated development, based on the existing cruising speed The paper did not show the effect of the further development in speed which was believed possible and which would bring down the direct cost to something of the order of probably 2 2d The difference between the direct cost and the total cost was a matter that lay in the hands of the operator If B E A could keep overheads down to the level that was appropriate, the Rotodyne would be a highly attractive vehicle

Mr TYE and others had referred to the financial problem, and hoped that development would not be restricted because of a " halfpenny worth of tar " He (the AUTHOR) could only say that he had never looked forward so eagerly to tarring and feathering! It would be very nice to be able to get the necessary finance to that implied level and to keep the project going to fruition

Mr SHAW had asked whether there were other possibilities of propelling the Rotodyne by using compressed air in an alternative manner to that already in use Of course there were other possibilities Time would be given to considering them, but in a development of this kind people must keep their eyes on the ball, otherwise they would be directed off the chosen field and the vehicle into which they were putting their money would not materialise What must be done was to choose the basic conception and to work as fast as possible to produce it The other developments which arose during the process could be weighed up sensibly and incorporated later if they were attractive

On the question of compression ratio, a compromise between the internal and external aerodynamics of the blade involved a compromise between a low compression ratio with a thick blade, and a thin blade but a high compression ratio with lower rotor propulsive efficiency Compression ratios varying between 3½ and 6 to 1 had been considered, but the optimum was not far off four, the present figure

The points concerning noise which Mr SHENSTONE had raised would have to be demonstrated This was something for which time and effort were required As shown in the slides, the basic lines to follow up had been determined and the team were working on the engineering development which was involved He was confident that it would be possible to get to the level that would satisfy the man from Missouri —or, in this case, the man from Keyline House

The question raised by Prof BENNETT of whether the rotor would ever be overhauled by other VTOL devices was receiving much attention There were a number of very interesting VTOL aircraft Some had been flown and others were approaching flight conditions The big advantage of the rotor which could not be overlooked was that it was the most economical form of vertical take-off and undoubtedly the safest It had within its basic characteristics the ability to provide lift, even when its source of power was cut off, a feature which was particularly attractive when dealing with any civil application

The AUTHOR did not share the view of Mr MCCLEMENTS that his comparisons had been very hard on mechanical drives from the point of view of reliability and maintenance The attitude expressed later by Mr Tye showed the caution, to say the least, with which regulatory authorities approached the problem of providing a certificate of airworthiness on a large transport with a mechanically driven rotor

This was an answer in itself It was true that the use of turbine engines would ease the problem somewhat in improving reliability The engine and the rotor must, however, be developed, and because one interacted mechanically on the other vibrationwise, the complete assembly must be thoroughly developed

If there were a number of power transmission shafts between rotors, whether these were the main and tail rotor combination, a twin tandem, or a multi rotor configuration, the whole system of shafting must be developed for different combinations of power There was a formidable task to be done in demonstrating the necessary standard of reliability

One of the great advantages claimed for the Rotodyne was that the link between the engine and the rotor was entirely static and could be subjected to straightforward fatigue tests It was not subject to vibratory loads in the same way as a rotating piece of machinery

Mr McClements had made the point that on a large modern turbine version of a shaft-driven helicopter, it would be possible to reach a disposable load of 35 per cent , and this was no doubt true The data shown in Fig 7 was the average for large piston engined mechanically driven helicopters as published Turbine engines would show a 3—4 per cent improvement in disposable load in hovering By taking the very latest engine for an aircraft of the size of the Rotodyne and using it in a military version, one could show that the disposable load might be well over 40 per cent There was plenty of scope for arguing on the subject of weight analysis One must go through each item carefully and make sure that there was a common basis of comparison

In the Rotodyne the drag hinge had been omitted as unnecessary, since the fluctuating lag plane loads could be absorbed in the inner spar without recourse to the drag hinge

The design of the head included the high stresses due to manoeuvres, and these were quite acceptable , the situation was that the basic design of the head and blade in this rotor and control system was essentially that of the cruising or fatigue case

The reply to Mr MASEFIELD was that everybody had problems, but the AUTHOR had nothing lurking in the back of his mind of the magnitude of the gear transmission In fact, one of the few problems was the one connected with the only mechanical drive of the head, *i e* , that down to the auxiliary gear box This was the only problem of any magnitude in the head which so far had been encountered, but happily, it had now been sorted out

It had been suggested by the last speaker that the safety aspects would be improved by having a multiplicity of rotors instead of a single rotor A great deal had been written about this, usually trying to prove that the multi rotor systen was as safe as a single rotor system Dr HISLOP did not propose to enter into this argument tonight beyond saying that the single rotor was, in his view, the optimum since the probability of failure of such a major component was minimised by reducing the number of such components

Sir Arnold Hall, in proposing a vote of thanks to the Author, said the meeting had had an excellent paper on a remarkable machine, delivered by a most able and attractive personality There were many present who had known George Hislop for many years In introducing him, Professor Bennett had omitted to mention that he was also a mountaineer, and a very good one

The vote of thanks was accorded by acclamation and the meeting then ended

https://doi.org/10.1017/S275344720000442X Published online by Cambridge University Press