$C_T = \frac{T}{\rho A V_T^2}$ = thrust coefficient
V = Aircraft flight path speed, ft per sec
V_T = Rotor rotational tip speed, ft per sec
α_f = Fuselage datum incidence, degrees
α_{sh} = Rotor shaft incidence, degrees = $\alpha_f + 1\ 5^\circ$
θ_0 — Mechanical Collective Pitch (Pitch lever input) degrees
μ = Tip speed ratio

Discussion

The **Chairman** invited Mr Austin to open the discussion

Mr R G Austin (*Bristol Aircraft Limited*) (*Member*), who thanked the author for his paper, said that the addition of fixed wings to the rotary wing aircraft was of undeniable advantage and a lot of work obviously had yet to be done before a complete understanding was reached of the aerodynamic effects involved The wing, however, only delayed the onset of compressibility and retreating blade stall troubles Could the author say whether information was available as to how close they had got to the compressibility " barrier " and the retreating blade stall " barrier " ? That is Tip Mach No and retreating blade incidence

The Rotodyne, like all aircraft, was an aerodynamic compromise and the advancing blade compressibility limit was no doubt of significance in that in order to achieve a compromise between the aerodynamic efficiency of the rotor blade and the thermodynamic efficiency of the tip jet system, a rather thick aerofoil section was used At the high μ values when the Rotodyne was operating at high speeds, in common with any other form of rotor plane, the area of the retreating blade that was actually doing any work was quite small , and the stall lift coefficient that was achieved on the section must be very little different whether one used a rotor in the autogyro or helicopter state Information therefore obtained from one type in this respect is applicable to the other The only difference between the two types was that the helicopter might have the advantage on the advancing blade compressibility limitation due to thinner tip sections, whereas the Rotodyne type of machine had possibly a small advantage with the retreating blade stall Hence the actual forward speed available in both types was similar

He was rather puzzled about the use of airscrews for forward propulsion because (apart from the added weight of the hardware involved), one imagined that their power transmission efficiency was of the order possibly of about 80 per cent , whereas using the power by a shaft drive directly to a rotor system was probably of the order of 95 per cent efficient

Mr McKenzie, in reply, said that he did not know whether he spoke a different language, but he found it difficult to put together Mr AUSTIN's questions Mr Austin was probably uneasy in his mind about the whole business of the retreating blade stall, and one tended to agree with him in his uneasiness

In the particular problem with the Rotodyne, the tip speed of the rotor in autorotation was being reduced to such relatively low value that it was possible to accept high forward speeds of the order of 200 knots without getting into a significant compressibility on the tip of the advancing blade

On the question of retreating blade stall, again in the ultimate autorotational configuration of the Rotodyne one was not dependent on the rotor for providing a large proportion of lift In the ultimate solution, therefore, one was removed completely from the questions raised by Mr AUSTIN Exactly what he was trying to convey in his question, however, remained obscure—or was he talking about a helicopter configuration ?

Mr Austin said that summing up to his way of thinking, the limitations imposed on the rotor by compressibility effects on the advancing blade and the stall of the retreating blade, was independent of the direction in which the rotor was tilting

https://doi.org/10.1017/S275344720000473X Published online by Cambridge University Press

Could the author give some information on the advancing and retreating blade angles on the Rotodyne in forward flight at 170 or more knots? He felt quite sure that this figure was achievable by a helicopter rotor

A rotory wing aircraft that achieved its forward thrust by means of tilting the main rotor rather than by providing auxiliary thrust devices was the more efficient Even though auxiliary fixed wings were used on both types, the result would be a much more efficient aircraft in that one was using a thrust device with a much higher Froude efficiency than the other's small diameter propeller

Mr McKenzie replied that speaking from memory, the type of tip incidences that would be obtained on the advancing blade with this type of problem in auto-rotation were round about zero and, obviously, there was a large proportion of the lift inward This was fundamentally different to helicopter study

Mr Austin No It is the same sort of order as far as the advancing tip is concerned

Mr McKenzie, replying to the question on propellers, said that the reason for the choice of propellors was primarily because he was concerned with a high forward speed solution where not much rotor lift was carried When relying for rotor propulsion in that type of condition, one would have to tilt the rotor extremely far nose down This would aggravate the compressibility characteristics and eventually an unsteady state would be reached at which the aircraft could not be balanced out by tilting it in a reduced rotor lift state None of this problem arose on the Rotodyne since the propulsion system was completely independent of the rotor lift

Dr Stewart (*R A E, Bedford*) (*Member*), said that at the beginning of the lecture, the author had pointed out the compromises that had to be obtained to get a balanced design and then took the aircraft off as a helicopter He then took his audience through the transition into the high-speed cruising flight but, unfortunately, he left them there and one had to assume that the rest of the flight was merely a reversal of each of these steps In a balanced design, the implications of the approach to land should have had a very important influence on the design compromise Dr Stewart did not wish to argue the requirements for or the desirability of certain types of landing approaches, but merely to ask the author for his views on their technical feasibility

From helicopter flight experience and looking at the Rotodyne planform with its large tail plane, serious doubts could be cast on the possibility of very steep descents For machines of this type, it would seem that descents of the order of 10—20 degrees were more likely This would then mean that for a realistic rate of descent, one would get approach speeds in the region of 30—40 knots At this condition, was it not possible that the Rotodyne could be flown in this approach in its actual autogyro regime? The extrapolation of the graphs which the author has shown down to low speed made it appear quite possible

That led to the immediate question of whether it was really necessary to do the transition as high as 100 knots Could not the helicopter be brought right down as an autogyro to the low speed end of the autogyro range and do the transition at this lower speed? One of the immediate bonuses to be derived from this was getting rid of the noise problem during the approach as the jets would be brought in only at the last stage in landing and noise would be created only within the actual confines of the landing area

The same argument might be applied also to take-off Why should it be necessary to accelerate with all the noise from tip jets up to 100 knots, if the transition could be done at 30—40 knots, a speed which could be reached in comparatively small areas? So that, by looking again at the landing case and fitting these possibilities into the design compromise, there might be even greater possibilities for the Rotodyne than Mr McKenzie had tonight made out

Mr McKenzie replied that it seemed to depend largely on what one was prepared to do in the way of systems and in the way of putting in wide tolerances It was possible to talk of a wide speed range provided one was talking about an aircraft that was relatively fixed from other considerations When dealing, however, with an operational machine which was involved in quite large ranges of weight and quite large possible ranges of altitude, one was already talking of a relatively large range of forward speed for this condition

There was a large number of problems behind this which, admittedly, the lecture had not covered Some of them were in the regime of pilot control i e, how many things must the pilot be capable of doing at one time faced with the operational complexities of an aeroplane as opposed to a pure research aeroplane ?

Concerning operating down to anything as low as 30 knots, certainly one could design a research aircraft to do this for a particular point, but such an aircraft would be almost impossible to control from the piloting viewpoint over a wide range of heights, altitudes, centre of gravity loadings and everything else that one was faced with in a transport operational machine There were implicitly problems of operational safety behind this and the question of what happened when an engine failed at very low speed

The figure of 100 knots which had been talked about was not given as a sheer magic figure but was talked about in terms of directional safety of the aircraft in the event of an engine failing with a high amount of power on the propeller Equally, if a large r p m variation was permitted on the rotor, the answer to the question was "Possibly" The type of problem that one was then dealing with included very wide variation of r p m, a large number of controlled variables, a large number of operational variables and a large number of airworthiness problems In talking about his own particular configuration, he was talking about a solution limited by these operational problems and not necessarily about a research vehicle

Admittedly, it would be relatively useful to do it at a low speed Dr STEWART had, however, overemphasised the problems associated with using tip propulsion to speeds of the order of 100 knots The time was comparatively short Safety was very much increased, both going out and coming back Approaches had been done in the order of 20 degrees There did not appear to be any major problem on the aircraft as it stood at the moment Having reviewed all the operational complications it seemed that this was a reasonable solution which was capable of being safeguarded

Mr J M Harrison (*Westland Aircraft Limited*), said that after listening to Mr McKenzie's interesting talk, he imagined that he had detected more than a hint that the design team must be more closely integrated on a machine of this type than in the case of a more conventional aircraft It was quite possible that he was stimulated by his own experience, which suggested that this was true of all VTOL and STOL type aircraft, the fundamental reason being that propulsion was closely tied up with sustenation In addition, particularly on rotary wing aircraft, dynamic problems associated with blade motion cut right across several specialities

An example of the sort of thing he had in mind was the author's early reference to a compromise in blade design On the one hand, the propulsion experts demanded a huge duct to feed the drive units, at which the aerodynamicist threw up his hands in horror thinking of the thickness/chord ratio and/or solidity

He would like to probe a little deeper into the rotor design philosophy Why such a large rotor diameter ? There must have been some clash of interest here Assuming that the tip speed was limited to a maximum value—and 720 ft /sec seemed reasonable—the advantages from a performance view were fairly obvious A low disc loading was associated with low induced power, good for single engine case The effective horse power was, however, tied to tip speed, and an increase in blade length would cause an effective loss in centrifugal compression One would have thought, too, that the structural people would have something to say

A further aspect, which was dealt with at length by M Dorand and which one had no great desire to resuscitate, was the disposal of material across a chordwise section in an attempt to provide sufficient duct area and at the same time ensure flutter-free characteristics

When raising these points, one realised that tonight's lecture was but the latest in a series delivered by representatives of the Fairey Company which had dealt with the Rotodyne and that the author was to some extent restricted in his scope It was, perhaps, for this reason that he had made only a fleeting reference to the control system The flight and engine controls were essentially part of an integrated system in which the aerodynamicist had a vested interest One would have thought that the system and method of operation as described by Dr Hislop could be improved upon, or perhaps, with the larger version of the Rotodyne still to come, the time was not yet ripe to enlarge on this subject

The author had described the mechanics of longitudinal trim and load sharing between wing and rotor so lucidly that one paid him the compliment of not attempting to amplify his remarks Out of sheer curiosity, however, one must at this point refer to the lecture, delivered almost three years ago, by Dr ROBERTS, who had mentioned a singular speed at which the geometrical flapping angle, and the fuselage attitude, tended to infinity, at least according to estimates He further went on to say "The physical interpretation is very obscure and what happens in practice should be interesting" Well, how interesting was it, or were Figs 2—4 to be interpreted as not bearing out the predictions ?

The reference in the paper to wing rotor interference was rather scanty Was any more elaborate approach made other than by classic biplane theory ? One had in mind the comprehensive series of charts produced by Castles and his associates Examining a wing rotor combination in conjunction with a set of these charts would suggest that downwash was relatively insignificant over most of the speed range, both in helicopter and auto-rotative flight, especially the latter, and the effect on longitudinal stability almost negligible At the low speed end, where the wing was immersed in a wake of rapidly changing angle, were the trim changes with speed significant, or was the large downwash variation countered by a low dynamic pressure ? It was noted that Figs 2—4 did not extend to this region

The author had gone to a great deal of trouble to indicate where the main drag sources were Since it was becoming accepted, with the advent of gas turbine propulsion, that rotary wing aircraft, even helicopters, were no longer restricted to a speed of less than 100 knots, parasite drag assumed a greater importance than accorded hitherto It was certainly time to begin to move out of the era of improvised birdcage fuselages, hardily exposed engines and messy hub configurations The author's indications of their efforts to clean up the hub region of the Rotodyne and their unwillingness to rest on the laurels of the comparatively low basic airframe drag were encouraging and commendable

Dr H Roberts (*Chief Project Engineer, Fairey Aviation Limited*) (*Founder Member*), said that to cast his mind back to what he said three years ago, some analysis was done at that time based on such data as was available and which showed the peculiar occurrence which had been referred to In practice, however, it had never been obtained It might sound strange to say "I do not think we got it" There had been occasions when one had had a certain amount of roughness which might indirectly have been something to do with it Possibly it was something else which happened As far as he knew, however, they had never got it, so the interesting part was not quite so interesting

The author had given a very good lecture Dr ROBERTS did not dare to ask him any questions, so what he would like to do was to put to Mr McKenzie one or two points that had given him a lot of trouble in trying to understand what was going on It was always taken for granted that as the speed went out, one wanted to off load from the wing and take the load on to the rotor

What was wanted was a high $\frac{\delta C_L}{\delta \alpha}$ If one accepted the need to reduce the wing incidence, the only way to get high wing load other than an increase in $\frac{\delta C_L}{\delta \alpha}$ was to tilt the aeroplane at a high incidence, which meant that there was another compromise to be made, because whatever was being carried inside the aeroplane must also be tilted at that incidence Considerations other than aerodynamics might well arise and convince one that although theoretically it might be worthwhile off-loading and having a low wing incidence, in practice other considerations prevailed

The other thing that worried him a little was that with a high $\frac{\delta C_L}{\delta \alpha}$ then obviously for a given load on the wing the alpha for the wing was decreased Since the rotor itself took up the constant tip path plane substantially, the mechanical angle of flapping was increased rather than decreased by this process This had caused headaches, and it was hoped that the author might be able to explain why it worked out the way it did and whether it bothered him too

Another worrying question was that of fins above the tailplane Fins underneath tended to be inefficient, for obvious reasons What was not so obvious was that one should consider redesigning the fuselage to improve this position Now, a particular shape was accepted Why not try something fancy on the fuselage so as to give a more efficient under-tailplane fin ? Again, there were good reasons for this, in which members might be interested if the author would like to explain them

Dr STEWART had made a point about the transitional speed This was a question of what the transition speed should be Transition speed, was, of course, dictated by several factors, and one of them was the response to engine cutting Quite obviously, as the transition speed was reduced, if an engine cut at low speed the possibility of controlling the aeroplane due to low aerodynamic forces then prevailing on the tail and on the aircraft got worse, and this would in the end be the prime consideration against too low a transition speed

Mr McKenzie, in reply, said he was sorry he did not warn Dr ROBERTS some few years ago that the infinity did not happen It all depended on which viewpoint one approached, what was defined as the variable and what was obtained at the bottom and at the top It did not happen in estimation, however, and it did not happen in practice

Concerning the lift curve slope, what the paper had sought to make clear was that when operating at a fixed r p m and a fixed collective pitch, the change in aircraft lift must be carried out entirely on the wing , and with an increase in lift curve slope there would be a reduction in wing incidence

What he had possibly not said explicitly was that what one was seeking to do was virtually to use a complete range of forward and backward flapping The range of forward and backward flapping was very similar to the incidence change occuring from the lift change on the aircraft as a whole Therefore, by increasing wing lift slope, the total range of the backward and forward flapping was reduced Flapping was not always merely backward in this context

On the question of fins and fuselage, there were reasons for not liking the box shape It was, however, very difficult to see how one could reasonably reduce the directional instability of the fuselage, which had to carry a certain volume and had to be a certain length, if the lower and the upper limits of the fin system were defined In this particular case, they were substantially defined by the ground and the rotor blade drooping Whether it was top fin or fin below the fuselage made little difference in principle to the fact that there were those two limits

It was stated in the paper that the lower fins were comparatively inefficient, and this was an experience which had been learned before in fixed wing aircraft, and why people went over to the single very high fin, where the height of the fin itself tended to become the dominant feature It becomes essentially a design choice of whether there was any point in putting on a longer undercarriage to put a fin beneath the fuselage or a larger pylon to put a fin above the fuselage

There was no magic solution in fancy shape of the fuselage The solution was to cut down the fuselage to the minimum, both in length and in cross-sectional area Beyond that, however, there was nothing novel and it was a straightforward design problem

Mr R A Shaw (*Ministry of Aviation*) (*Member*), said that something which would have been interesting tonight would be to hear a little more about the compromise which must have been struck in choosing the proportions of the Rotodyne when first designed Then, if the Company were frank, they would acknowledge that they were a bit surprised by their success ! They had done better than they had designed for Having achieved their present success, what changes in design and layout would they now choose ?

When one looked at the aircraft as an aircraft without its rotor, it appeared to be a very old-fashioned thing to be going along at 170 knots One had a strong feeling that a little refinement in the layout could put up the speed a little more For one thing, it could do with a bit more span and a more refined planform on the wing

It was still a very modern aircraft in concept , the design contrived to convert its power from the lifting system to the propulsive system To do this it used a lot of compressed air, and one only wondered if the compressed air had been used as comprehensively as it might have been A re-design, making the maximum use of compressed air might be still more efficient than the present Rotodyne When the present generation of Fairey technicians were old and grey, they would probably look back at the present machine as a very crude initial type of the Rotodyne principle For instance, there might conceivably be a place for something like a jet flap system on the aircraft with all its air to spare

It seemed perhaps a pity to have to resort to tip jet burning except as an emergency measure on an aircraft which had to operate close in to towns By using a more modern plant than the present concept—an all-jet power plant with, perhaps, a ducted fan for propulsion—it should be possible to get an integrated aircraft which did not rely on tip jet burning for lift except as an emergency in the event of an engine cut, and this would certainly not cause any complaint

Mr McKenzie, in reply, suggested that the answer to Mr SHAW might be that if the technicians were given the money, it would be possible to have some of these fancy things Certainly, the paper did not include Fairey's advanced ideas—they were not advanced in the terms that Mr SHAW might have been talking about, but the next stage of the Rotodyne There were a number of reasons why these ideas had not been given tonight, but the paper attempted to show more or less the method of approach to the ideas that went into the present design The points made by Mr SHAW about larger span had been replied to to some extent in the earlier argument on lift slope affecting the flapping relationship

He agreed with Mr SHAW that they were not satisfied with the shape and relative performance of the present prototype, not because they felt they could necessarily have done any better in the time, but because they wanted to go on from there and to make a machine of which they were completely proud in operational service and which was as economic as it could be for the job it had to do

On the question of using compressed air in advanced ways, Mr SHAW was right in saying that they might have grey hairs before they got round to it This, however was not because of bad will but, seriously, because it was a big job Great progress had been made in getting as far as they had gone on the first prototype They were going to get further Perhaps when several marks were in existence, they would always be keeping them up to scratch and always looking at means of improving them At the moment, however, there was no simple obvious advantage from these things in relation to the design problems that had been encountered

The question of tip jet burning and operating on air was not his own province Without tip jet burning, however, there would have been extremely big jet units, and probably very big blades, and he would have been concerned about the matter from this point of view

In relation to the propulsion and economics of the Rotodyne, the tip jet burning was the best solution yet seen Certainly it had noise problems, but these were being tackled in the development work At some time in the future there might be a case for jets, but it could not yet be seen in relation to the type of layout that was considered the right one from a number of different engineering viewpoints

Mr R C Webb (*Ministry of Aviation*) (*Member*), said he would like to follow Mr HARRISON in talking about the necessity for a reduction of drag in all the future generation of helicopters and rotorcraft It was obviously an essential feature

The Chairman said that the point he thought Mr AUSTIN was trying to raise was the question of the comparison of the Rotodyne with the classic helicopter without fixed wings If Mr Fitzwilliams had been present, possibly he might have been coaxed into the argument

Was there any real reason for using fixed wings ? As faster speeds were reached, both the advancing and retreating sides of the rotor contributed less and less lift, the single rotor arrangement thereupon becoming virtually a tandem rotor helicopter That being so, as the blade at azimuth angles of 90° and 270° was contributing very little lift anyway, need there be fixed wings at all ? One had expected this argument to come to a head, because the Russian helicopter designer, Mr M L Mil, announced a few months ago that he hoped to beat the Rotodyne record with his Mi-6 helicopter He had not done so, and his machine was now beginning to sprout fixed wings It would be interesting to know whether he really had investigated the problem and whether the helicopter without fixed wings might not achieve these high forward speeds

Mr Austin had referred to the question of the span of the fixed wings and wondered about the Rotodyne having such a large rotor and a small wing The point was whether, because of the high induced losses in forward flight, it should have a small rotor and a large wing Was the Rotodyne the best compromise ?

The terminology used by the author when he referred to "zero mechanical flapping" was unusual, but it was clear what the author meant There were several reference axes that had to be defined There was firstly the axis at right angles to the flight path Secondly, there was the shaft axis which had a new significance in the Rotodyne, because it governed the angle of incidence of the fixed wing

Then there was the control axis or "axis of no-feathering" and the tip-path plane axis or "axis of no-flapping" The author had not mentioned these as such When he said that the mechanical flapping was zero, presumably he meant that the actual displacement about the hinge, as the blade rotated in azimuth, was substantially constant, i e that the superimposed cyclic feathering compensated for the alpha one term, i e the so-called "aerodynamic flapping"

Mr SHAW had spoken about the possibility of a cleaner fuselage Early wind-tunnel tests of a Rotodyne model indicated that the parasite drag, at 100 ft per second, with the undercarriage retracted was 135 lbs and 185 lbs with it extended If it were still as low as this, it would appear to be almost as low as, if not lower than, a small two-seater helicopter without any fairing, and therefore comparable with, say, the Fairey Ultra-Light

Mr McKenzie replied that the fuselage drag was certainly comparatively low He was not sure of the precise figure but he would put it at D100 of about 100 Certainly it was not quite as high as the figures which had just been given, and equally it was certainly not significantly different from that of the twin-seater Ultra-Light A large proportion of it was associated with the cockpit and the remainder could almost entirely be explained away by skin friction The squareness of the fuselage and the apparently bluff rear end did not seem to account for any significant proportion of the fuselage drag

What he was endeavouring to recommend was that on helicopters trying to do more than 100 knots, it was well worth getting the bits and pieces together in time very early on to study the mutual interference problems provided one had a fairly reasonable shaped basic airframe The chance of a significant drag reduction in basic drag was not great, but the majority of the drag came, in fact, from interference systems of one kind or another

The rotor diameter was certainly large, but the diameter was dictated by an economic solution of an engine failure during take-off and landing In that economic solution, attention had to be paid to weight and complexity It was not possible to say precisely where it came in in aerodynamic efficiency, but the overall criterion of the diameter of the rotor stemmed almost entirely from considerations of a compromise around the engine failure during take-off or landing

Mr Austin said that he wished to correct a misinterpretation of his question Rotary wing speeds were limited anyway by compressibility and retreating blade stall possibly to the order of 200 knots At that speed it was possible, provided that care was taken, to reduce drag by such means as retracting the undercarriage and provided that only moderate wing off loading was used, to the order of 50 per cent, to achieve the necessary forward thrust with fairly moderate rotor tilts

Up to that speed, there was no justification for additional forward thrust devices such as propellers, principally because the propeller system would be only about 80 per cent efficient It might be considered that energy was being fed inefficiently into the airstream and regained , instead of the energy being taken directly to the rotor

Now, if it were possible to overcome the limitations of compressibility and retreating blade stall, such that a machine might be flown to, say, 400 knots, then admittedly there would be a change Obviously, the parasitic drag could not be reduced to a reasonable level, and in that case additional forward thrust would be required whether by a propeller or a jet , possibly the jet at the higher speeds

He did not agree at the moment that additional thrust devices were necessary or even economic

Mr McKenzie replied that it was obviously a question of opinion One could say " If so, why not ?" This was the type of thing that possibly could be easily stated but which in its actual detail was much more complicated The propeller efficiency certainly was 85 per cent , but what was the transmission efficiency ?

Mr Austin really wanted to have his cake and to eat it Presumably, he was not going to run his rotor at very low tip speeds, yet he was still talking about getting the same compressibility characteristics as were obtained on such a configuration at 200 knots with the Rotodyne The tip speed was reduced considerably to deal with the problem In Mr AUSTIN's particular case, he had to reduce his tip speed, and unless the wing carried an immense amount of lift, somehow he would still be faced with a non-uniform loading system on the helicopter rotor If he reduced his lift to deal with this state, to deal with the lower tip speed required, he would be required to tilt far forward and in the process of getting to and from that state he would go into some rather weird behaviour of the wing He would require a very sophisticated control system to do the balancing of the aircraft allied with this large wing, which was dealt with separately and in, one hoped, a relatively logical sequence by divorcing the system as was done now on the Rotodyne

It was true that if helicopters were cleaned up, there was a considerable way they would go on top speed, but it was not likely to be 200 knots

Mr D T Grant (*Rolls Royce*) (*Member*), said that three or four years ago, it was more or less accepted that the helicopter could not cruise at much above 150 knots, but now a lot of helicopter people had thought of putting a wing on it and one was confronted with the fact that cruising speeds of 200 knots were quite possible Mr Austin of Bristol's, Sikorsky and the Russian helicopter designers, according to an article in "Aviation Week," claimed that a cruising speed of 200 knots was a distinct possibility If it were feasible, did it not, to some extent, reduce the advantage the Rotodyne held over the helicopter ?

There was an aeroplane flying in America which had the same principle as the Rotodyne, the McDonnell XV-1 This aircraft, however, had a third phase known as an aeroplane phase, in which it practically completely unloaded the rotor and flew on the wing It was claimed that in this phase speeds of 300 knots were possible If such a speed were possible by rotorcraft, the deflected slipstream and tilt wing, propeller driven, VTOL, aircraft became less attractive

At such speeds, it would be possible to consider a power plant considerably lighter and less complicated than that at present employed on the Rotodyne One had in mind a jet engine with a large by-pass ratio With such an engine, it could be envisaged that the compressor of the engine would be bled to feed air to the rotor for helicopter flight This could be either burnt with fuel at the rotor tips as in the case of the Rotodyne and McDonnell XV-1 or used to drive and control the rotor in the form of a jet flap as M Dorand had suggested Mr GRANT favoured the latter of these methods Did the author have any opinions on this ?

Mr McKenzie replied that in the case of the McDonnell story, there was no major difference in principle between what the Americans called their aeroplane configuration and what Faireys called their cruising configuration The prime state of the American machine was an exceptionally low tip speed, and a very high vibration region was passed when going down into it

The machine did not do anything like 300 knots It was a good machine for its time, but it was a pure research machine flying at one loading, one C G and one altitude for a comparatively short life The difference between that type of aircraft and the Rotodyne was that Fairey's type of machine was primarily the result of attempting to offer an operational aircraft The American machine was a pure research aircraft to attempt to understand the principles, and the principles that applied there were equally the principles applying in this country

What he had said immediately beforehand about helicopters and 200 knots should have covered the point, but apparently Mr GRANT believed the American papers Fairey's had done a particular speed They were not stretched to the limit of their design capacity or characteristics of the aircraft at that speed It was very different to talk of achieving 200 knots on the Rotodyne and to say that a conventional helicopter had a cruising speed of 150 knots

He did not know of any machine which had a speed anything like that with a reasonably low vibration level and a reasonable life It was against that complex that one should consider the question of relative speeds of helicopters Certainly, if they could get to 200 knots, Mr McKenzie thought he could go well beyond that figure, possibly to 300 knots

Mr Grant pointed out that he did not say that the McDonnell XV-1 would achieve that figure What he had said was that the Americans reckoned that such a configuration—not the present prototype—could achieve 300 knots

The Chairman, in closing the meeting, said that the Rotodyne just avoided some new problems In the case of the McDonnell aircraft, tip-speed ratios ranging between zero and infinity, were investigated, as it was possible to unload the rotor completely and decrease its angular speed At tip-speed ratios approaching 1 or even as low as 3/4, the flapping motion of the blade began to have negative damping during part of its oscillation and flapping instability became a problem at high tip-speed ratios, as was indicated by Glavert and Shone many years ago This was one of the problems that the Rotodyne had avoided Thus taking advantage of a completely unloaded rotor presented just as difficult problems as doing without fixed wings altogether and attempting compensation for the resulting vibration at high cruising speeds The Rotodyne was a compromise between the two extremes and avoided these major issues

A vote of thanks to Mr McKenzie for his excellent paper, proposed by the Chairman, was carried by acclamation and the meeting ended