Discussion

Mr I M Davidson (*National Gas Turbine Establishment*), said that when he first heard about the paper he thought " Well, here is another paper on helicopters, and I know only one thing about helicopters, and that is that they are very complicated " After a few days a preprint of the paper arrived and he looked through the figures which had been shown on the screen and he thought " Goodness, it is even more complicated , I shall never understand this " until he saw Slide No 13

(*Slide No 13 was then shown*)

Then he realised that M Dorand had something really quite different and important Over the years a good many of those present, he was sure, had thought about the problem of applying the jet flap to the helicopter, and people had said to him " Why do you not think about this ?" That was an excellent suggestion, and, of course, they had all thought about it, but no one that he knew could think of a way of controlling the jet flap to give the variations in blade lift required

It would be remembered from an earlier slide that the flap which was used to deflect the jet was very small If one sought to deflect it mechanically, one could see the difficulties It had no torsional stiffness On the other hand, if one tried to vary the jet thrust one had to introduce considerable pressure losses into the blowing air, and since that was the means of propelling the blade one was completely ruining the propulsive efficiency and therefore the economics Therefore, it had seemed quite impossible to apply the principle However, what M Dorand had now shown was a solution to the problem of which no one else had thought

Perhaps he ought to explain in a little more detail than Mr Shapiro had done just how this invention worked It was a flexible rubber, fabric and metal arrangement, and in order to deflect it high pressure air or, he supposed, hydraulic fluid was pumped in and out of it so that it deflected like a Bourdon tube only in the opposite way The more pressure one put in, the more it curved, and therefore it was possible to change the jet direction very rapidly

He was sure that it was a very important principle, and he felt that all of those present would agree with him in wishing M Dorand the best of success with the engineering development of what could prove a very important invention which engineers in Great Britain had missed Now that they had the principle, he was very interested in looking at the end of M Dorand's Paper to the results In particular he was interested in the operating costs, but he was unable to comment on them himself and was looking forward to hearing some discussion on them However, one thing that did interest him was the question of the power plant If one looked forward to the day when flying machines of the type in question were used for normal everyday transport in large numbers, one saw that they must be very safe, at least as safe as fixed-wing aircraft

If one took a weight of helicopter of 10 tons and took the horsepower which M Dorand's results showed as necessary to drive it and then put in engines to produce that power, a fundamental problem arose The studies which he had made of the behaviour of engines when they failed suggested that one could not get the necessary safety with fewer than three engines, and that meant that, to get the horsepower which M Dorand's results showed with a machine weighing 10 tons, very small engines would be needed and it would not be economical to build and to operate the helicopter

On the other hand, M Dorand had mentioned a gas generator power of 30,000 h p to keep down the costs Even with one such engine, the helicopter would weigh 30-35 tons, and with three engines it would weigh 100 tons He wanted to ask M Dorand what he thought to be the best weight for his type of jet-flapped helicopter and what he thought about the number of engines which would be required to make it as safe as a present-day fixed-wing aircraft

M Dorand (in reply), answering Mr Davidson's first question said that they were not limited to intake deflection devices but were also carrying out experiments with mechanical deflection devices Comparative tests would be carried out in a wind tunnel under the same working conditions Also, a test of dynamic response would be carried out

His organisation had made a study, for the American Army, of crane helicopters lifting 20—30 tons Those helicopters had required an adiabatic gas power of

30,000 h p That dıd not permıt the use of three generators, because typıcal present-day generators, for ınstance the Conway type, produced 30,000 h p alone So the projects which were worked out were presented with hypothetical generators In the case of the projects where the rotor was mechanically driven and only 15 per cent of the power went into the jet flap, existing Pratt and Whitney engines had been assumed The power which had been considered was about 5,000 h p in the case of the mechanical transmission and about twice that in the case of the pneumatic transmission

The question of safety was one of engine failure It was possible to descend in autorotation even with all the engines stopped In the case of the mechanical rotor transmission where a certain amount of pitch control was retained, there was no question and no difficulty In the case of the cold flow, one still retained a certain amount of control through the centrifugal circulation inside the blade, and one still had control by means of the solid flap

In the case of jet driven helicopters with hot flow, it was necessary to use an auxiliary flow in order to control the jet flow, and there the jet flap control became ineffective when the engine failed In the case of engine failure, it was necessary with those designs to have an auxiliary control which was similar to an autogyro control, such as the possibility of inclining or tilting the rotor head The control process was as follows The rotor head was tilted while the jet flap control operated as though it were servo-controlled When the engine failed an auxiliary servo control was used in order to control the position of the rotor head Such a servo control installation could be quite simple because one did not expect it to have the time constant of a servo control for hovering flight Therefore, he believed that the problem of safety could be solved in all cases and that it was possible to reduce the number of engines At any rate, it was preferable to have three engines In that case, the order of magnitude of power was about 100,000 h p to design machines of reasonable size at present

Mr G F Langdon (*Ministry of Aviation, A & A E E , Boscombe Down*), said that one of the most interesting sections of the Paper, at any rate to him, concerned the experimental results This represented something which had actually been done It was something concrete, as opposed to many of the Papers which had been offered, which were purely theoretical If he understood them correctly, the results had shown that if one wished to drive a rotor by blowing gas, one should blow it as a thin stream rather than as a solid jet, and also that at high speeds it was better to use the jet flap for control

M Dorand (in reply), said that about 15 years before the appearance of the jet flap conception tests were carried out with a 10 metre diameter rotor at Lyons where a free piston generator was used and the rotor was driven by a jet device near the tip It had already been found then that it was better to allow the jet to issue in the shape of a thin layer rather than that of a round tube

Mr Langdon said that it seemed to him to be another example of the jet flap being known under another name rather earlier

He had one question to put on the results Mr Wilkinson, of Boscombe Down, had conducted some simple experiments on a very small scale He was rather shy about mentioning them after having seen M Dorand's impressive apparatus Although Mr Wilkinson found that there was an increase in lift co-efficient if a jet driven rotor was powered by a jet in the form of a thin sheet the increase in C_L was less than he would have expected from experiments on the same jet flapped aerofoil in straight flight

He had been unable to decide from the figures in the Paper whether that result was borne out by the large-scale experiments with which the Paper dealt

M Dorand (in reply), said that he would let Mr LANGDON have the figures and the results of the tests which he had carried out The tests were carried out with the support of the French Air Ministry and they were carried out over a large range of variables The rotor was rotated by means of an electric motor, and the whole range of jet flows was measured very precisely He was prepared to communicate the test results to Mr Langdon's establishment

Mr Langdon said that his organisation would be very interested to have the results

In the Paper there was a reference to Class I B which he understood referred to a helicopter with hollow blades in which the natural centrifugal pumping action of the rotor was used to produce a jet flap at the tips of the blades

M Dorand said that that was so

Mr Langdon said that that seemed to him to be something of very great interest if there was a worthwhile gain to be obtained and it was something which could be done simply He would be interested to know what percentage gain one could get Obviously, one had to work to pump air through the rotor, and that would increase the effective profile drag coefficient of the blades Was the increase in lift coefficient worth the increase in power which must be supplied to the rotor ?

M Dorand said that that depended on the design of the blades If they were blades with circulation channels of large cross-section, then it was worth while

Mr Langdon said that perhaps he could make his question a little more particular He asked M DORAND to suppose that he was Mr Sikorsky building a blade like Mr Sikorsky did, a fairly thick one, and that he was going to turn it comparatively slowly Suppose he took an S 58 blade Would it be worth while putting an air channel in it ? That was a particular case

M Dorand said that while hovering one obviously lost In forward flight one could obtain control of the boundary layer and render any flap control more effective He felt that that could be determined by a project which could be seriously considered rather than by an example like that

Mr Langdon said that it seemed to him that it was a possibility of getting a little bonus, which was always welcome

When one considered the case of M DORAND's Class I, which was still controlled by means of cyclic pitch, the outer part of the blade, which had the jet flap on, would presumably have a very different centre of pressure to the inner part He imagined that the centre of pressure would be much further back

M Dorand agreed that it would be further back

Mr Langdon asked whether that was likely to cause much difficulty in the design of blade There they had something unusual, and it was obviously going to set up some sort of torsional effect

M Dorand said that he took it that the question in which Mr LANGDON was interested was that of the displacement of the centre of pressure There were two centres One was the ordinary centre of pressure, which was at 25 per cent, and the other, which was the centre due to the effect of the jet, would be at about 40 per cent of the chord The zero incident moment varied with the setting of the flap In the case of a pure jet flap, the change in zero incident moment altered very little with the setting of the flap In the case of a solid flap with tangential blowing, the second centre was at about 45 per cent, but the zero incident moment increased quite sharply It could reach, say, 0 3 at a jet flap setting of 60° The conclusion was that between the pure jet flap and the combination flap it was possible to choose a variation as desired It was a good thing that one had an element of the aerodynamic moment which could increase so sharply, because it was that in conjunction with the square of the speed that created a component of torsional moment which, of course, varied round a disc, and that could counteract the torsional moment otherwise obtained due to the change of the flap setting Even in helicopters which retained some slight degree of pitch control, it was mainly the flap which was controlled and only partly the pitch, so that the mechanical advantage between the pilot's control and the blade pitching moment was such that the existence of those fluctuating pitching moments would not be felt too much by the pilot In the case of thermal jet driven helicopters there was no question of feed-back of those moments to the pilot, but there was a question of the air flows, which was important

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Mr Langdon said he took it that the question of flutter could be avoided by suitable design

M Dorand said that at present everybody put the aerodynamic centre, the torsion axis, the centre of gravity and, if possible, the elastic axis at 25 per cent When using the jet flap it would be necessary completely to change the outlook in that respect and to change the position of those axes The relative position depended on the ratio between the natural frequency in torsion and the natural bending frequency of the blade If the natural torsional frequency was above the natural flexural frequency, which was usually the case, the elastic axis should be in front In that case, when the torsional natural frequency was above the flexural natural frequency the best arrangement was to have the elastic axis in front, then the aerodynamic centre and finally, at the rear, the centre of gravity, which was much easier to achieve than the present position If the two frequencies were equal, then the centre of pressure must be inside the radius of gyration of the moment of inertia of the blades If the torsional natural frequency was lower than the flexural natural frequency, then the centre of pressure and the centre of gravity must be on the same side of the elastic centre

Mr J M Harrison (*Westland Aircraft*), said that preceding speakers seemed to have covered most of the points which one might be tempted to raise, and after seeing what Mr Langdon had brought upon his head, he intended to avoid anything of a major nature

There were, however, two aspects which seemed to have been glossed over One was very important They had all heard the effect of discharging a hot high pressure jet when it was concentrated in a circular tube He would think intuitively that spreading the efflux along a slot should reduce the noise considerably He wondered whether M Dorand could comment, and state whether his organisation had made any measurements or had obtained any qualitative information

M Dorand replied that the tests which had been carried out in a laboratory were noisy, but that it was possible to speak during the testing The jet flap was 2 ft × 2 mm in thickness, and the ejection velocities of the order of 500 metres/sec

Mr Harrison re-emphasised the importance of the point It would be one of the big advantages of using a jet flap if the noise were reduced He did not know whether there was anyone else present able to comment

Forgetting for the moment the rather ingenious device of the pneumatic flap, M Dorand had mentioned that mechanical solid flaps were also being developed Presumably they would be operated by a mechanical linkage which would include torsion members He imagined that there would be some difficulty in development since the transmission must be very flexible and would lead to lost motion of the flap He felt that there might be some undesirable cross-couplings due to flexure of the blade

M Dorand said that his organisation had a system which it believed would not be affected by centrifugal forces, and it was intended to try it on the rotor very soon It would be controlled by radio

The **Chairman,** in closing the meeting, congratulated M Dorand on having achieved such satisfactory results in his investigations relating to this new application of the jet flap and expressed the thanks of those present to M Dorand for his valuable Paper He also thanked Mr Shapiro for acting as interpreter

The vote of thanks to the Author was accorded unanimously by acclamation

WRITTEN SUBMISSION BY M DORAND

The following information has since been supplied by Mr Dorand in response to Mr Langdon's question

COMPARATIVE TESTS OF THE FLATTENED JET PIPE AND THE ELLIPTICAL JET PIPE FITTED TO A THERMAL JET DRIVEN ROTOR OF 10 5 M DIAMETER

(Tests carried out at Lyon/Venissieux in 1948)

(1) *Power absorbed by the rotor W_R*

Air inlet vanes were closed and the rotor was turned by driving with an electric motor equipped with a torque measuring device

It was found that, for the same aerodynamic adjustment of the rotor and the same speed of rotation, the power absorbed by the rotor is lower by about 8% in the case of the slotted jet pipe (form drag reduction of the blade tip)

(2) *Measured propulsion efficiency*

For the same adiabatic power W_a delivered to the rotor by the hot gas generator, the peripheral speed U and the jet velocity V_J are slightly greater in the case of the slotted jet pipe, which is the result of Clause 1

The measured power transmission efficiency of the fluid motor, $\eta_T = \frac{W_R}{W_a}$, is greater by 6—7 per cent in the case of the slotted jet pipe

It is probable that this apparent benefit arises from the reduction in the profile drag which is due to the blowing through the slot This benefit conceals the unfavourable effect due to the nearer position of the pressure centre of the slotted tube in relation to the rotor centre

(3) *Overall benefit*

The addition of the two benefits makes the overall benefit reach 14—15 per cent in favour of the slotted tube