| | |
|---|---|
| Specific fuel consumption | |
| Turboprop, lb /h p /hr | 0 6 |
| Jet, lb /lb /hr | 0 9 |
| Specific weights, powerplant | |
| Turboprop propulsive system, lb /h p | 0 8 |
| Jets, installed, lb /lb | 0 2 |
| Propeller efficiency at cruise, per cent | 80 |
| Propeller figure of merit in static thrust | 0 70 |
| Weight of fixed equipment, lb | 11,524 |

## APPENDIX II

### Jet STOVL Transport

The weights, dimensions, power and thrust installed, and major assumptions used in arriving at weight and performance estimates for the jet STOVL airplane are as follows

| | | |
|---|---|---|
| Weights, lb | | |
| Empty | | 42,105 |
| Useful load | | 31,895 |
| Operational | 2,155 | |
| Payload | 13,500 | |
| Cruise fuel | 12,900 | |
| Hover fuel | 3,340 | |
| Gross | | 74,000 |
| Dimensions | | |
| Wing area, sq ft | | 1,000 |
| Wing span, ft | | 96 |
| Overall length, ft | | 96 |
| Installed thrust, lb | | |
| Wing jets (32 at 2,000) | | 64,000 |
| Nose jets (5 at 2,000) | | 10,000 |
| Major assumptions | | |
| Zero-lift drag coefficient | | 0 0257 |
| Effective wing span, ft | | 81 5 |
| Specific fuel consumption, lb /lb /hr | | 0 9 |
| Specific weight installed thrust, lb /lb | | 0 2 |
| Weight of fixed equipment, lb | | 11,524 |

## Discussion

The **Chairman,** in expressing thanks to Mr Zimmerman for his excellent presentation of the subject, said it seemed that jet-lift and the jet-wing principle were not in general competitive with rotor-lift It appeared that their field of utilisation was very different, although they might have the common objective of independence of airfields for take-off and landing Their application was mainly to long-range aircraft capable of flying at high subsonic or, perhaps, supersonic speed, whereas the role of the helicopter was for relatively short-range operation Did Mr Zimmerman agree with this generalization ?

The Author in his paper had considered the lifting turbojet almost exclusively as an auxiliary power system Did he consider this to be its appropriate application in the future, or did he think that eventually a battery of turbojets would take over the whole responsibility of power for take-off and landing and not merely be used as a source of auxiliary power ?

**Mr Zimmerman** expressed agreement concerning the role of the helicopter For operations in which hovering was itself a primary part of the mission and where any appreciable amount of time had to be spent on hovering flight, he did not see anything that approached the helicopter in efficiency, but for operations where hovering was only incidental and efficient cruising at high speeds for moderate or longer distances was necessary, some other type of machine was needed

On the question of the use of the turbojets for propulsion as compared with, for example, the use of propellers, the type of power plant which would be used for propulsion depended almost entirely on the speed regime in question For moderate and relatively low speeds—i e, 300-400 m p h—it seemed that propellers were indicated for propulsion At higher speeds, either by-pass engines or turbojets would be used, but whether they should be the small turbojets or the larger turbojets, he would not like to say

The **Chairman** explained that what he meant was the use of turbojets for direct lift during take-off and landing Throughout the paper, the lifting turbojet was considered as an auxiliary and not the main source of power, whereas in the future it might provide all the power required for VTOL or most of the power for STOL

**Mr Zimmerman** agreed that they might be able to do the entire job His feeling was that having the propulsion power plants, it was desirable to get as much aid as possible from them during the take-off and landing phases He was not, however, prepared to say that the use of lifting engines also for propulsion was out of the realm of possibilities, because, as yet, not enough was known about all these possibilities

**Mr I M Davidson** (*National Gas Turbine Establishment, Pyestock*), speaking as a visitor, said that although this was his first visit to the Association he felt certain that tonight's lecture was one of the most interesting and most important that its members had heard

He was, however, surprised to find that so little was said in the paper concerning rotor lift, not so much in connection with the helicopter, but in relation to the kind of thing that one had seen in patents in the past—for example, rotors incorporated in the wings, the object being to get high Froudian efficiency It would seem that not only on the score of efficiency, but also for reasons of noise, it was most important to take this sort of system into account However, Mr Zimmerman no doubt had his reasons, and one could only discuss the propositions he had put forward concerning the short take-off and landing

The noticeable feature of the paper was that there was a tendency to go from the vertical take-off and landing to the short take-off and vertical landing, then, gradually, the vertical landing went out of the picture, and one wondered what was left The only figure quoted seemed to be of an airfield length of the order of 400 ft, except, of course, in the case of the large aircraft, when one would presumably be thinking in terms of 2,000 ft

It appeared that if one was giving up the idea of vertical operation with this class of aircraft, possibly one was not doing the right thing economically in holding on to the idea of a machine which, whilst being primarily a short take-off and landing machine, could execute a vertical manoeuvre if necessary Would Mr Zimmerman not agree that there was a possibility that if it was decided to go for short, as opposed to vertical, take-off and landing operations, it might be possible to get a much more efficient machine by giving up the idea of the vertical performance capability altogether?

The reasons for that suggestion were twofold Of the problems which the Author had mentioned, one was the question of the operating cost It was, of course, far too early yet to talk about the operating cost of these machines One did not even know what the machinery would look like in the end On general grounds, however, it could be argued that the less there was of variation of types of machinery within the same aircraft, the lower would be these costs In other words, if the costs were to be kept down, would it not be a good plan to try to use only one type of engine in the machine rather than have two entirely different sorts of engine?

The other reason was the question of passenger or public reaction It was interesting to see the figures of 45° climbing angle and 0 6 G acceleration One's experience was that even in motor cars, passengers complained when 0 2 or 0 3 G was applied This, combined with the sort of thing that would be practicable if only one type of engine was used, suggested field lengths of 1,000 to 1,200 ft rather than the 400 ft suggested in the paper



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Did Mr Zimmerman consider it really essential to get down to the small figure of 400 ft, which, after all, had arisen historically from the requirements of the helicopter Might there not be room for machines of short/medium range which would require a field length of the order of double or treble that figure?

**Mr Zimmerman** replied that there were two reasons why he had not discussed ro or lift at greater length in the paper He had not dealt with it in the normal sense because relatively, as against the members of the Association, he was completely unprepared to discuss the subject He had not discussed the fan in the wing, even though he had considered it seriously, because he could not see how he could work it in and do the other things he wanted to do There was, however, so much that was not yet known concerning the interaction between a wing and a fan in the wing that he felt he could not say anything very solid, and rather than be drawn into a discussion, he had omitted it Admittedly it was a very interesting field and one which was being investigated both in Britain and in America

His reply to the interesting question of going away from the vertical landing was that he could give only his own point of view, although there could, of course, be many others When he first entered the aeronautical world in 1929, there were some fairly good STOL aeroplanes

Over the years it was noticed that these aeroplanes which had to have an airport anyway could always be improved by taking some of the gadgetry off, and increasing the airport size, and as time went by there was a return to the use of the big airport Operation from really small airfields had not proven feasible until the building of a machine which was capable of vertical flight and yet everybody knew that many helicopters, if they were really required to climb up vertically from a small field, would be in a sorry predicament

The helicopter was, in fact, a machine which in many cases did require some kind of ground run Possibly it made a run after it had risen from the ground, but at least it took some ground room to climb out

As a result, the requirements for heliports thus far had tended to be around the 400 ft size Whether this would be the eventual development, one did not know It was, however, likely that heliports in the big cities would come—they were, in fact, already coming The wise course, therefore, was for somebody to design an aeroplane that would use these heliports for inter-city operations, and it would be done most efficiently by using as much ground run as was available On the other hand, a machine that is to operate satisfactorily from these small areas must have fundamentally the control and stability and the basic power available, so that it could hover if necessary

The thing that was wrong with the STOL aeroplanes that Mr ZIMMERMAN had seen was that although they could be landed in a very small area by an expert pilot under perfect conditions, it was dangerous to operate them in this way because they did not have the kind of control and stability that was required to do the job This answered the question about giving up the vertical capability To operate from the really small airfield, it was necessary to have that capability Although it was not used except in emergency, it was necessary to have it

There was a strong case to be made for using only one type of engine Earlier N A C A papers had used only one type of engine The change in this paper was deliberate in order to ascertain the reaction to it

The paper had not dealt with the use of intermediate size airfields There was, however, a real place for an intermediate range aeroplane that would operate from moderate sized airfields No doubt such an aircraft would be developed Possibly it might be a jet flap aeroplane This, however, was another vast subject

A big question in his own mind—he had not seen studies to convince him one way or the other—was the choice between a jet flap and a turbo-prop aeroplane He sometimes thought that if jet transports had been available before propellers were known and then somebody had suggested putting in a propeller to cure the faults of the jet transport, it would have been hailed as a great solution

**Mr R A Shaw** (*Ministry of Supply*) (*Member*), said he had enjoyed hearing the paper and had been intrigued by the way in which the Author had obtained his short and vertical take-off characteristics in the old-fashioned English way by more or less having some turbo-jet engines pointing downwards

It was not possible to obtain from the paper an idea of the margin of the excess of lift over weight which the Author had assumed must be available Apart from facing the engine-cut case, the designer must provide sufficient surplus lift to give a pilot the equivalent of air brakes so that the pilot could arrest his vertical velocity before he hit the ground

Another intriguing point was how the safety of the multiple slipstream vertical take-off or short take-off aircraft was affected by depending on the reliability of its control mechanisms Analysis of aircraft accidents appeared to suggest that variable pitch airscrews were fairly unreliable machinery, and if there were only six airscrews on the wing a failure in the pitch control of one of them could hazard the aircraft

It would be interesting to hear from Mr ZIMMERMAN concerning the nature of the control problem of these aircraft at slow speeds when a good deal of the lift was due to the forced slipstream Landing in cross winds or gusty conditions seemed likely to involve special difficulties If a graph showed that between zero speed and 20 knots, the airscrew thrust dropped 50 per cent , it would appear that the machine would be difficult to handle if the wind was gusting

From observation of the tests in the wind tunnel, it seemed that very violent control movements were being used on all controls to maintain reasonably steady flight Presumably the models were approximately correct in inertia terms and although the pilots were forced to use the on-and-off controls, they were using them quite a lot and they were using them over their full movement for quite a proportion of the time Did the Author, therefore, have any views on the flight handling problems of high lift systems of this type?

**Mr Zimmerman,** replying to the question of the margin of vertical lift, said that what he had actually done was to consider the machines as what he had called STOVL—short take-off but vertical landing—and accordingly he had designed them so that they had just enough power to hover with full gross load on the assumption that the normal operation would be take-off with a short ground run, and that when landings were made or hovering flight was necessary, the pilot would have a margin which would be represented by the weight of the fuel which had been consumed He had not actually attempted to make close designs

It might be found that that was not really a reasonable policy What the Author had done, however, was to assume that if it was desired to make a true vertical take-off with this type of aeroplane, it would be done with part load This was, admittedly, an arbitrary approach

The question of the safety of propeller aircraft using pitch control mechanisms was rather similar to the question of the safety of helicopters with two rotors Those machines were absolutely and completely dependent upon pitch control all the time that they were in the air, and yet they had good safety records It was done by using mechanical control of their pitch

Mr ZIMMERMAN felt strongly that a machine of the type he had described should have mechanical interconnection of the pitch control mechanism, so that there was not the question of propellers running away This was inexcusable in this type of machine There would still be propeller failures, but they would be greatly reduced in number

The nature of the control problem at low speeds or under gusty conditions was a problem to which all the answers were not known One of the reasons for building the test bed aircraft—they were not described in the paper, but most members would know about the VTOL tilt-wing and deflected slipstream aircraft in America—was to try to get a fix on what the problems in flying really were on the backside of the power required curve It had been found that on getting to low q's, one was forced to use reaction controls It then became a question of making those reaction controls powerful enough to overcome anything that was produced by the gust

At the same time, it was obvious that when flying at, say, 15 knots, with the power required only half of that required in hovering, if a sudden gust reduced the relative speed to zero it would be necessary to be able to apply full power immediately This was not an easy problem Only by flying the full-scale flying test beds in the regime would it be possible to find out how serious the problem was

**Mr J S Shapiro** (*Servo Tec, Ltd*) (*Founder Member*), endorsed the view that although the Association was proud of its whole lecture programme, tonight's lecture had been outstanding In its way it was a milestone in thought and the Author had



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provided something special He had presented the results of his long experience in a subject to which he was obviously devoting a great deal of work and thought

It was difficult to discuss in a few words something like a complete aircraft project which differed so much from everything else Whether it was well or badly integrated, every aircraft was, and must be, an integrated conception One was, therefore, at a loss to criticise any separate feature, because the combination alone would show whether or not the proposals had a successful future

Mr SHAPIRO's first question concerned something about which he had always been curious and although there was presumably an answer, he would be glad to know it in general terms When the Author spoke of the deflection of the slipstream reaching about 90 per cent of the thrust in the downward direction, there was a suggestion that the ideal—namely, 100 per cent —was being approached Was 100 per cent in fact the ideal? There were many such conceptions in engineering where the ideal was suggested, but there was no physical basis for it One did not think that there was a physical basis for it in this case A similar instance was the efficiency of a boiler, which could be 120 per cent Here again, it might be possible through entrainment to get an ideal of about 100 per cent It would be interesting to know whether there was any kind of framework for thinking in terms of a figure of merit which approached the ideal

In the specification, it was said that the aircraft should land safely in the event of power failure, but it was not clear where it was supposed to land safely Since these things had undergone the process of trying to evolve helicopter conceptions capable of a transport role, they were matters of crucial importance

On the question of the three minutes' hovering, it seemed that one could almost classify optimum configurations by the number of minutes of hovering that were required and questions of fuel reserve, which, again, were interconnected with the question of where the aircraft was to land if one of its engines failed

It was sometimes very difficult to judge these matters It was said that airlines were operating on a profit margin of 1½ per cent , whereas tonight there was talk of 20 per cent margins, which might revolutionise everything It was, therefore, necessary to be careful not to talk in terms that were too sweeping The duration of hovering and the margin of fuel—in other words, the distance to be covered in order to land again—was an extremely important point

Mr SHAPIRO's next point was what he described as his own particular pet, but Mr ZIMMERMAN had raised it He had always expressed the view that if 400 ft heliports were built, something other than helicopters would operate them He regarded it as almost an article of faith that the justification for the helicopter was vertical flight At a previous meeting, he had tried to assemble enough forecasting skill to put forward the idea of vertical operation in its extreme form *i e*, helicopter operations from a roof with a width of no more than 80—90 ft

The difference between 80—90 ft and 400 ft in the centre of a city was enormous and decisive and Mr Shapiro had been able to show that operating in this fashion the helicopter landing would cost 2s per passenger movement, which, when all the costs were taken into account, was not approached even by the inter-city bus, the operation of which required stations and other facilities

Matters of economics were essential, but economics were very often distorted by the fact that airlines did not pay for airports Undoubtedly, there was room for the intermediate range machine Indeed, once the helicopter abandoned its true role of vertical flight, something intermediate would become the proper way of using fields where there was a width of 400 ft This was another problem to which one would like to know the *precise* answer A take-off run of 400 ft would require a field of 800—1,200 ft Therefore, with a 400 ft field, the run must be no more than 150 ft , if as much Had this aspect been taken fully into account?

**Mr Zimmerman** said that he would like first to deal with Mr SHAW'S comment regarding control movements on the flying models It was true that there was a great deal of control movement As these were bang-bang controls, any application produced full deflection There was an appearance of the use of a lot of control power However, in many cases these were actually being used as verniers by very quick and rapid motion They went one way and then the other in this vernier operation to simulate the partial movement of the control in a conventional aeroplane The only defence of this technique as regards its comparison with an actual aeroplane was that good correlation had been found between what the pilot had been able to do with the aeroplane and what people experienced in handling them had been able to do with the models It was a matter of experience and comparison of such things

For example, on the Convair pogo stick, the correlation was very good between the full-scale aeroplane and the model It was possible to predict what could and what could not be done and some of the troubles that would arise with the aeroplane Therefore, despite the difference in control techniques, there was fairly good correlation This did not fully deal with the question about the gust effect, the answer to which must be obtained from the full-scale machine

He agreed with Mr SHAPIRO that the efficiency figure used in the paper was not fully supportable, because there was nothing to say that it was impossible to obtain more than 100 per cent When embarking on the programme, it was fondly hoped that more than 100 per cent might be achieved , but it had never been possible to do so, except in certain cases with a single rotation propeller with a simple tilt-wing configuration, where the plane wing straightened out of the slipstream In the other cases, however, the figure always fell below 100 per cent If somebody could produce a configuration which would get the efficient mixing that produced more than 100 per cent , it would be very desirable There was nothing which said that it could not be done

**Mr Shaw** suggested that a favourable ground effect was rather like 110 per cent thrust efficiency

**Mr Zimmerman** agreed that one could look at it on that basis , but that was not quite a proper use of the word " efficiency "

The reply to the question of landing safely in case of a power failure was that the paper did not assume complete power failure but the failure of one major unit out of four One of the significant features about the power-required curve of these aeroplanes was that as soon as there was appreciable forward velocity, there was a tendency to have considerable excess power, which meant that the pilot could fly away if power failure occurred, if the altitude of the machine was sufficient to permit development of forward velocity It was similar to the dead man's curve for a helicopter

The machines should be built so that under any condition they would either do no more than make a hard landing, which might be uncomfortable but would not kill anybody—they should come down right side up—or be able to fly away and find an airport To give them enough thrust capabilities so that no matter what happened they could always continue to hover, would be fairly difficult

He had unwittingly given Mr SHAPIRO ammunition concerning one of his pet projects and he really did not know what to say in that respect Obviously, to adopt the use of heliports where machines had to leave straight up, would make it more difficult to operate this kind of aeroplane Mr ZIMMERMAN did not know the answer

In reply to the comments concerning the take-off run, it would have been noticed that in one case the paper quoted a 171 ft take-off run, or rather more than the 150 ft which had been suggested as a safe limit No one was yet in a position to say what would be the safe margin Obviously, it was not possible to use the full 400 ft , the run must be something reasonably less Where, however, there was a lot of excess power available at moderate speeds, it might be possible to use more of the 400 ft than might ordinarily be thought possible

**Mr T Nettleton** (*College of Aeronautics, Cranfield*), added his congratulations to Mr ZIMMERMAN, both for his excellent paper and the photography in the film The demonstration of the dynamic behaviour of the various models in hovering and transition had been extremely helpful

Mr ZIMMERMAN had introduced the concept of designing a VTOL or STOL fixed-wing aircraft to be comparable to a conventional aeroplane in cruising flight in terms of propulsive power and sizes of control surfaces, etc , and of providing the extra thrust and control required for hovering and low speed flight by means of auxiliary light weight jet engines

Could this approach be applied to rotary-wing aircraft as well? For example, an autogyro could be designed to have better forward-speed handling and performance characteristics than a helicopter By means of a jump take-off it would have excellent short take-off potential If hovering was not a prerequisite, could tip rockets be used to stretch the jump take-off capabilities of the autogyro and to make its rotor independent of the main propulsive system, thus avoiding the complexities of mechanical drives or of pressure-jet systems?



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The duration of rocket thrust could be quite short, being sufficient only to prolong the jump until a reasonable forward speed for climbing had been reached The independence of the rotor and main propulsive system would permit the maximum possible forward acceleration of the machine to be developed during the jump

The greater part of the weight penalty associated with the auxiliary power would be consumed on take-off and hence the machine would be lighter in cruising flight than if a mechanical or pressure jet rotor drive had been used for the take-off

Although the scheme appeared simple perhaps the cost of rocket fuel, even for short duration might be too high Another possible drawback was the question of rocket reliability and the safety of liquid rocket fuels However, several rocket-on-rotor helicopters had been flown, and among them was the Rotawings " strap-on" type of helicopter Hence the system should not be too dangerous

Perhaps Mr ZIMMERMAN would care to comment on the use of rockets and rocket fuels as an auxiliary power source

**Mr Zimmerman** replied that he was not sure how he should comment on Mr NETTLETON'S remarks What he had asked was whether a machine with rockets for the jump take-off—which conceivably could be used for vertical landings also—would be a better machine than Dr Hislop's Rotodyne This was a question which it might be wiser to pass on to Dr Hislop

He was not sure that a liquid fuel rocket was necessary in view of the development of solid fuels that was on the way The use of a solid fuel might conceivably help the problem a great deal

In some of the American flying models, use was made of small hydrogen peroxide rockets Although a great deal of care was exercised in working with them, no difficulty had been experienced and no danger caused to anyone There was, however, need for care and special handling devices The logistics might be undesirably complicated with the liquid fuel, but it was not beyond the bounds of possibility that it might be possible to use a solid fuel with cartridges inserted before a flight

**Dr H Roberts** (*Fairey Aviation Co Ltd*) (*Founder Member*), considered that some of the last remarks required an answer Fairey's had been investigating all sorts of schemes before coming to the idea that the Rotodyne represented a solution at least as good as most of those which could be offered In particular, they had considered schemes on the lines of Mr NETTLETON'S suggestion of autogyros with some kind of tip boost They had reached the conclusion that there were an enormous number of different possible techniques for doing the job When it came to deciding which was the best, they had reached no unique solution but decided that the Rotodyne as it stood seemed fairly good in relation to all of them and it could, in fact, stand up to the competition

In all these things, the critical stage after producing a helicopter was that it must be sold to the airline, who in turn must sell it to the public Two issues therefore arose first, could the airline make any money out of it, or was it economically feasible , and second, was it the type of aeroplane that the public would like and use ?

The quesiton of the economics must depend to a large extent on the percentage payload which could be obtained from the aeroplane In view of the enormous complexity of the designs illustrated tonight, involving drive shafts with clutching arrangements, wing swivels and other devices, it would seem somewhat difficult to produce and build an aircraft based on such designs in which the payload was not almost completely swallowed up by the weight of mechanical and structural parts

On the Rotodyne, to get feasible answers, some enormous effort had been made on weight reduction and general paring—by good design—to get the sort of figures that were needed To go to the same extent when considering the designs which had been described tonight might not be sufficient , in fact, the payload would probably suffer to such an extent that the result might be a highly uneconomic or even impractical aeroplane

Public reaction to an aircraft was important If something looked complicated, potential users would not understand it They probably had the feeling that simplicity spelt safety With all that was liable to happen—wings tilting and engines retracting, for example—the public might not take kindly to the machine In any case, and this might well be the last straw that condemns such designs to oblivion, the noise level would be such that the public in the vicinity of the landing site would take to it even less

**Mr Zimmerman** recalled that he had not answered Mr DAVIDSON'S comments concerning the accelerations The paper itself raised the question of whether the public would accept these high accelerations America, however, was talking of sending people into outer space, with accelerations of goodness knows how many G In comparison, the problem with the aircraft was a rather minor one Whether the public would accept it, one simply did not know The result might depend upon the approach that was adopted in " selling " the machine to the public It might be a matter in which clever salesmanship would play a good part

A similar answer could be given to Dr ROBERTS' remarks concerning public acceptance Whether people would be frightened by a tilting wing or a big flap that deflected, one could not say It might depend upon how the aircraft was " sold " by the operator Admittedly these machines were more expensive They could only be sold on the basis that they did a job considerably better than anything else

Admittedly, some of the assumptions in the paper on the subject of a reasonable and useful payload might have been optimistic Only very clever design would produce from these aircraft the sort of payloads indicated in the paper, but Mr ZIMMERMAN felt that, that might be possible Only time would show the result

It was also true that noise was a serious problem The paper had, in fact, spoken of possible acoustic treatment of the heliport Some optimistic opinions had been expressed about the ability to reduce the noise of jet engines, but the results had not yet been seen

**Dr D A Spence** (*R A E, Farnborough*), agreed that the paper represented a landmark on the subject of integrated lift The last meeting of the Association had also been concerned with this subject, but he was still not sure what was implied by the use of the word " integrated " in this connection In his view, the jet flap represented integrated lift in that the lift and the thrust both came from the same source

Page 150 of the paper attributed the rediscovery of the principle to Davidson and Poisson-Quinton What was important in the principle discovered by Davidson was that it was possible—ideally, at any rate—to realise the full thrust of a jet which was delivered through a trailing edge slot and at the same time to control the lift, whatever might be the deflection of the jet This was one meaning of integrated lift as distinct from a system in which there were separate propulsive and lifting engines

Earlier in the discussion, Mr DAVIDSON had spoken of the use of separate engines for propulsion and lifting What the Author presumably had in mind was to put half the power into the jet flap and half into the main thrust An advantage in doing this, in addition to the obvious one of increasing the thrust efficiency of the propulsive system, might be the avoidance of landing with excess thrust One difficulty of the jet flap on landing might prove to be that in order to keep up the lift sufficiently, there was so much thrust that the tendency was to go too fast If it was possible to cut out half the propulsive thrust simply by cutting the engines at, say, the tail, presumably this would be avoided

Dr SPENCE hoped he would be forgiven for making two detailed aerodynamic points concerning the drag of jet flap wings The configuration in Fig 10 was of a swept-back wing Presumably, it was contemplated as being in the 400 knot range, and one wondered whether, with the jet flap wing, sweep-back was as necessary as it would be for a wing of conventional shape flying at the same speeds, because with the jet flap there was a reduction of the suction peaks over the forward part of the wing and some of the induced lift was provided at the rear part of the wing Thus one would expect that the critical Mach number and the drag rise were reached at a rather higher speed

The Author had remarked that little was known about the drag of jet flap wings Some of the work done at R A E tended to suggest that it was not too difficult to allow for the effect of aspect ratio, at any rate in the case of a full-span flap The drag could be separated into the profile drag and an induced component which was associated with aspect ratio, and such experimental data as was available suggested that the latter could be fairly adequately estimated

**Mr Zimmerman,** in reply, suggested that " integrated lift " was a matter of definition He had tended to designate as powered lift systems those wing-power-plant arrangements in which large amounts of power were used to get high effective lift coefficients What a truly accurate definition would be, Mr ZIMMERMAN was not prepared to say

In the work which he had described, there had been a tendency to differentiate between boundary layer control and jet flap at the point where the curve contained a knee, which represented the point where flow re-attachment was complete, and above which what was called the super-circulation or the jet flap principle arose

He hoped he had not made a wrong statement about the rediscovery by Davidson and Poisson-Quinton, but he had given the impression which he had gained 3,000 miles away of what actually took place If he had given the wrong impression, he was glad to be corrected

The purpose of the suggestion of the use of part of the engines as pure thrusting engines was not altogether clear Obviously, with the device shown in the paper for the aircraft which was a long-range transport using moderate field lengths, the arrangement discussed could almost be considered a kind of boundary layer control , the normal jet engines were used in the normal way and the jet flap arrangement was used simply to get a high lift coefficient It was, therefore, on the borderline of being a boundary layer control configuration

With the jet flaps, it was possible to increase the drag by using higher and higher flap deflections At least, this was what the wind tunnel tests seemed to indicate This gave the possibility of coming down even though a large amount of power were used, particularly if only partial span flaps were used

Fig 10 of the paper was derived from a hypothetical jet transport aircraft of the type about which a lot of people were nowadays talking and which had enough wing sweep to delay the drag rise to a high subsonic speed When flying at high speed, the aeroplane in question simply had the jet flaps inside covered up, so they had no effect In the case of the straight wing aeroplane, where the jet was used all the time, the assumption had been made that although the wing was fairly thick, the flow through the wing at the thicker portions would help somewhat in avoiding the high drag rise which would be associated with this thick wing

He was glad to know that R A E might have better information concerning the drag of the wings A certain amount of work had been done in America Assuming that the wing acted as a wing and had its normal induced and profile drag, there was a somewhat better thrust recovery than would be indicated by the 1-minus-the-cosine figure There was, however, insufficient information to be definite about it The indications were that there was some recovery, but it was not yet possible to say how much High Reynolds number tests had not been made under sufficiently controlled conditions, and further information on this aspect would be welcomed

**Mr H B Irving** (*Consultant to Westland Aircraft*) (*Member*), said that like the Author, he had no solution to the serious problem of noise, but when Mr SHAPIRO was deploring the idea of departing from vertical ascent and descent, it occurred to him that these two might be coupled By keeping to vertical ascent and descent, was there not more chance of dealing with the problem of noise or, at least, of getting a palliative for it?

The noise could not be destroyed at source, but with really vertical ascent and descent it might be possible to envisage a helicopter rising out of and landing into a sort of huge hollow "gasometer," with a height of perhaps 100 ft or more and a similar diameter The sides of the gasometer need not necessarily be solid In fact, it would be better if they were not solid but were formed of acoustic "splitters"

Was it not possible also that, by suitable control of the blockage ratio of the "splitters," a favourable ground effect could be obtained on the lift up to a considerable height when the helicopter was ascending or descending inside the "gasometer"? In addition, the sides of the gasometer need not necessarily be parallel but might be slanted outwards to give a shielding effect over a wider area This was no more than fanciful talk, but it was perhaps worth throwing out the idea

**Mr Zimmerman** said he was glad to hear that there was already one approach to the acoustical solution Such ideas should be thought about, because something had to be done In connection with noise, his colleagues were looking into the effect of reducing the noise by exhausting the jet through a narrow slit and he believed scientists in England had done work of this nature also There was certainly a definite improvement in the noise of the jet engine which could be taken advantage of in connection with the jet flap The practical benefit achievable may depend greatly on the aircraft configuration Nevertheless, a definite improvement was possible

**Dr G S Hislop** (*Fairey Aviation Co Ltd*) (*Member*), who added his gratitude to the Author for a memorable lecture and a wonderful evening, said that he wished to refer to some more practical aspects He was extremely worried about some of the operational problems involved in using multiple power plants all connected together One problem was to satisfy the authorities of the airworthiness thereof

Not only were there sometimes six or eight turbo-prop engines all connected together, but Mr ZIMMERMAN had reiterated the point that not only the drives, but the control systems also must be interconnected As Dr ROBERTS had mentioned, this was likely to play havoc with the weight estimates and it was likely to be an extremely formidable problem in proving reliability , and whether this agglomeration of mechanical devices was, in fact, an increase in safety was very doubtful

Furthermore, in order to produce a balance on thrust and control, to bring in a a large number of jet engines also raised its problems Mr ZIMMERMAN had, admittedly, referred to these, but they could stand a little more thought

At one point, the paper said, " if one of the power plants fails " and in this instance the Author was referring to one of the jet engines There were altogether something like 15 jet engines in addition to the turbo-props in this proposal If one of the 15 jet engines failed, it was necessary to be able to cut it out There must be 15 high pressure cocks, 15 low pressure cocks, 15 sets of engine instruments and 15 sets of engine controls, all to be monitored and read In the event of a failure of one of these it must be sensed, selected and cut out

When other protagonists of the proposal had been tackled on the point, they admitted that it was difficult and suggested putting them in banks of six to simplify the arrangement The corollary of that, however, was that if one of the six engines failed, all six would go out There was then a serious problem of control and thrust One had not lost one-fifteenth or one-fiftieth, but six-fifteenths or six-fiftieths

The ideas put forward by Mr ZIMMERMAN tonight were very stimulating but they must be gone into in considerably more detail to see whether the proposals for multiple power plant systems were as attractive as had been suggested Dr HISLOP had grave doubts about the practical problems involved as to whether these could be made really workable propositions

The suggestion of a length of 400 ft for heliports postulated the ability of helicopters to be able to take off and land vertically, but to ensure the order of safety to which one was accustomed on fixed wing transport operations, even though the helicopter could take off in a space no greater than its physical dimensions, the operational staffs had decided that to provide acceptable safety, a length of 400 ft into the prevailing wind must be provided If the newer conception put forward tonight required a 200 ft or 300 ft run for take-off or landing, one could be certain that this would mean an actual length four or six times as long The need for such a cleared area at ground level in a city centre would make the site impossibly expensive and hence quite unsuitable for direct inter-city travel

**Mr Zimmerman** replied that Dr HISLOP had raised some obviously good points and he tended to agree with him He should, however, make it clear that he was not interested in selling these configurations himself, because he was not sure that they were too good either ! He had introduced them to stimulate the discussion

The question of operating the number of power plants involved and of being able to cut out the correct one when something went wrong, was a terrific problem Whether it could be solved was a big question

Mr ZIMMERMAN was not quite so worried about the safety of the gearing and shafting system and the mechanical inter-connection of the propellers He was fairly confident that this could be done, partly as a result of helicopter experience, in which these things had been done fairly satisfactorily

It was a fair assumption that if an aircraft required to make a run of 200 ft , somebody would want an 800 or 1,000 ft runway for it One could only try these things and see what developed Certainly, the answer could not be provided at this stage It would have to depend upon actual experience in the long run to see what had to be contended with

The vote of thanks to Mr ZIMMERMAN, proposed by the **Chairman,** was then put to the meeting and was carried by acclamation



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