# Discussion

The **Chairman** said that they had certainly listened to a very interesting paper at a timely moment on gas turbines and boost systems No organized discussion had been arranged but he had no doubt that despite the clarity with which the Author had presented his case there would be queries on certain aspects

**Dr E S Moult** (*de Havilland Engine Co*), said that he would like, first of all, to compliment Dr MORLEY on his very excellent paper, the masterly way in which he had delivered it and the lucidity of his presentation It covered the subject so adequately that he felt there was little scope for questions and none at all for criticism

His personal knowledge of helicopters was limited but he had had some experience of the supply of power plants for them and—though this might be heresy before the Association—he realised the marginal nature of their operation in difficult circumstances Because of this, considerable pressure was put upon the engine builder to produce more horse power for less weight and the response of the helicopter to this was most marked Hence there was a great attraction in the possibility of boosting for short periods or having extra power for very little additional weight

This was just another way of saying that helicopters had tended in the past to be over-loaded or under-powered Such a state of affairs might reflect on their operation and reliability and that was something to be avoided Above all, the helicopter must maintain a reputation for safety, reliability and good service

The coming of the gas turbine had, in his opinion, helped the position considerably It had given the constructor a very compact, light and flexible unit albeit with a fuel consumption a little heavier than the equivalent piston engine However, helicopters were designed mainly for short-period duration—a matter of a few hours only—so that installed engine weight was vitally important whereas fuel consumption was not quite so important

Moreover, there was a flexibility in the gas turbine in that it could be overloaded in emergency with safety How far that could be done depended on the operating margin of temperature, the blade material, and its creep properties The Author had mentioned the system of cooling the turbine with water but he would like him to comment on the use of air-cooled blades in helicopter engines If the effects of high temperature on the blade could be avoided it would be possible to have durability as well as high performance Personally he thought that the helicopter designer would take advantage of what was offered in this direction and ask for something else to give an emergency boost He would like the Author's comments on how turbine cooling, however achieved, would affect the question of rating

On the question of operating temperatures, he might be wrong in his percentages, but he had understood the Author to say that there was a difference of about 8 per cent between the one-hour rating and the emergency rating Eight per cent at 1,200 K was equivalent to 95°C or 100°C and that was a terrific rise unless the blades were cooled He wondered whether the Author considered that after such an emergency one should be prepared to reject the engine or, alternatively, limit the number of emergencies or their duration before an overhaul He would like to know how the Author would propose to legislate in operation to safeguard the safety of the power unit

Dr MORLEY had discussed the use of the hot tip jet which appeared to be an interesting method of pouring in extra power in an emergency It would be interesting to know how the problem of light-up at the tip compared with that in a stationary combustion chamber and what happened if there was light-up on some blades and not on others

He had enjoyed the paper tremendously and he thought it would be of great value to the prestige of the Association

The **Author,** in reply, thanked the speaker for his remarks Coming from one of his calibre and experience they were much appreciated

The speaker had touched upon several dubious points on the frontier of knowledge but he would do his best to answer them With regard to the best system of blade cooling, probably, in designing an engine, air cooling would be regarded as a normal part of the gas turbine, because of its cost and the special internal arrangements required Full advantage would be taken of it in all normal flight conditions, but he did not think it fitted in with emergency conditions which should never happen It was in the twin-engined machine where it was necessary to try to meet failure of one engine , if there never were an engine failure the emergency rating would never be required It seemed to him that the use of air cooling did not quite fit in, but the use of a coolant which would be available for a short period had a greater potential

Depending on the way of looking at it, one would either reject an engine after it had been subjected to emergency load or one would arrange in type testing to take a fair number of emergency periods before having to reject the engine His own opinion was that it would be far better to regard the emergency loading along with the normal operation of the engine as a rating which would be cleared on a type test, so that if used in flight it would not be necessary to reject the engine immediately afterwards That point had not been properly investigated They were still in the stage of progress and so far they had found that by uprating the engine by putting up its turbine temperature for a short time, to find how much extra load it could take for 2½ minutes, they would be able to reach the necessary power margin of about 25 to 30 per cent They hoped to clear it as part of the type test of the engine as an emergency rating and so get permission to use the engine after it had been subjected to the emergency power

The speaker had also made the important point that the 8 per cent temperature margin meant a considerable jump in the temperature, but it must be remembered that the normal maximum power of the helicopter would be set at somewhat less that the normal maximum temperature of the turbo prop engine because a helicopter was normally used for the greater period of its life taking-off and hovering

With regard to the tip burners he readily agreed that there were still quite a few important unknown factors and, as he had mentioned earlier, the discussion offered in the paper was tentative They had the experience of Fairey's who were building up knowledge, so far as ignition was concerned there was a high centrifugal pressure behind the fuel to start the jet up By a proper choice of air pressure ratio it was possible to get a good compromise with even burning and reasonable economy of weight

There were still problems, especially in regard to ignition and regularity of thrust from each rotor unit but he thought that the problems could be solved It was a matter for a combined attack by the engine designer and the rotor designer He had been surprised to find when he had worked out the capacity for boost in a mechanical drive that if the boost power was taken from the mechanical drive and put into a compressor for pressure jets at the rotor tips, almost double the power of the engine could be obtained It was not practical, however, to go up to such a high pressure jet power because of the space required in the rotor blades for the ducting

**Mr A Stepan** (*Fairey Aviation Co Ltd*) (*Member*), said that he would like to discuss the pressure jets and the likelihood of only one jet lighting up In general the lighting up of a pressure jet was less sensitive than in the normal turbine because the compressor was running and it delivered a certain pressure and therefore one was not confined to very low pressures and temperatures such as might be encountered at the lighting up of normal gas turbines For that reason there was no necessity for torch ignitors It could be done with normal sparking plugs so long as the speeds in the chambers were kept under a certain level and that in itself had to be matched by various arrangements In the Rotodyne that problem had been solved satisfactorily

Although the lighting up of a pressure jet as a boost system would not in itself be a major problem, the use of a pressure jet as a boost system where it was necessary to start up and clutch in the compressors would, of course, cause a certain delay if the compressor was not running Time was required to run up the compressor and there would be a certain time lag before everything was ready for the lighting up

Another point was the lighting up of only one unit That was something which was likely to be of interest Supposing the compressor was running and was supplying air to both chambers and then supposing both chambers were lit up—one might be running on four chambers as a boost system—one of the jets might go out, which would be equivalent to it not lighting up at all The system would not be unbalanced because what happened at the moment when it went out was that the total power dropped but there was not much differential power between the cold and hot jets since the thrust of the jets depended entirely on the pressure inside the jet When one went out what happened was that much more air went through that particular jet and the compressor had to deliver more air It might not be able to do that in which case the pressure would fall and the difference in thrust between the cold air jets and the hot running jets was entirely caused by the difference in pressure due to different pressure drops between the centre of the hub and the tip unit because more air went to the cold unit, the speed being higher through the duct, and the air arrived with less pressure and therefore the thrust was less If one imagined a system with no pressure drop in the ducting then the gross thrust of the cold and hot jets would be equal, although of a lower order in the case of tip failure In case of emergency if one jet went out there was no undue unbalance of the rotor but only a small unbalance which he had just explained

The **Author,** in reply, said that he had found the speaker's remarks rather comforting He would like to take him up on the point about the time lag in the auxiliary compressor drive In the Rotodyne the auxiliary compressor was driven from a hydraulic clutch and there was of necessity a time lag in that system , but for a boost system in which the auxiliary compressor represented only a small fraction of the engine power the difficulty could be got over by changing to a mechanical clutch which had a shorter time lag

**Mr T L Ciastula** (*Saunders-Roe Ltd*) (*Member*), said that the rocket-on-rotor system which has been jointly developed by Napier's and Saunders-Roe, was a very simple system There were no moving parts in it and no serious development problems were encountered He could confirm from his Company's experience that when flying with the rocket booster system, if one or even two rockets went out of action or when delivering uneven thrust, vibrations in flight were not extremely severe

One of the problems which would have to be solved in connection with the practical use of the system was an operational solution of fuel handling and refuelling in field conditions This was perhaps just as big a problem as the system itself

He would like to ask the Author if he would say a little more about Fig 4 which was a system of boosting a free running turbine by means of pressure jets, the air being provided by bleeding it from the compressor In the case of a single rotor twin engined helicopter, supposing that for some reason or other one did not use full one-hour power in hovering, then in the case of one engine failing the remaining engine would have to first be accelerated to its full power, then the booster itself brought into operation and he thought that this could lead to an unacceptable time lag before full power of the engine and the booster were developed

Finally, he would like to express his view that in all emergency systems, the problem of time lag was of great importance With normal application of power this problem presented considerable difficulties and the same, of course, applied to any booster system, that is to say, the time lag must be reduced to an absolute minimum One could easily imagine the great difficulties which would arise if a large helicopter hovering in bad weather conditions, required a sudden application of the boost system if time delays of orders as large as 8 seconds occurred This would be completely unacceptable He did not know the maximum acceptable time, but stated that for the rocket booster system this time lag was quite small and, in fact, was just a little more than 1 second

The **Author,** in reply, after thanking the speaker for his remarks, said that he also thought that the principal virtue of the rocket-on-rotor system was its simplicity It had proved a very successful boosting system although there was development work still to be done

The endurances shown in Table 6 were short compared with a mechanical system and that was because of the appetite of the rocket for fuel The table did not show the complete story because of the light weight of the rocket system In the Skeeter the whole system weighed something like 36 lbs and he understood from Saunders-Roe that if it was necessary to unship the system in the case of a boost not being required there would be only 5 lbs of extra weight left in the machine That was very good, and the system which weighed only 36 lbs complete would take a nice weight of hydrogen-peroxide—about 90 lbs

He was glad that the speaker was interested in the composite system for the twin-engine arrangement It certainly tickled one's imagination He thought that an arrangement with one auxiliary or boost compressor for, say, two engines would be found satisfactory The gearing would be arranged so that whichever unit failed the boosting compressor would come in Delay was a problem, and there it must be remembered that the auxiliary compressor would only take a fraction of the total power and a mechanically driven clutch would be feasible The optimum air pressure ratio was not high, being only of the order of 2 or 2½ to 1, so that there should be no difficult starting-up problem With the rocket-on-rotor system the pilot pressed a switch The switch sent current into a solenoid which operated a peroxide valve The liquid ran through feed pipes into the decomposer and was changed into steam, which then had to flow round a right angle bend to generate the thrust It was nevertheless very quick He thought that there was a good chance of a pressure jet system being successful provided that the rotor and engine were developed as one to make it successful He agreed that it could not be done straight away

**Mr Hollis Williams** (*Westland Aircraft Ltd*) (*Member*), said it was surprising that the H T P rocket on rotor system had not progressed further than one or two test installations One would have thought that for military operations, under high altitude and temperature conditions, the system would be ideal

However, when it came to the point, the military services have not been anxious to have the problem of handling H T P fuels under difficult circumstances, and preferred to adopt the method of increasing the boost of the existing engines, even at the expense of a reduction in overall time

Although at Westland we have from time to time considered fitting rocket-on-rotor systems to our helicopters, in practice we had always compromised by installing a more powerful engine Of course, there is always the possibility that the bigger engine is not available

We have been rather interested in the last of the boost systems the author had mentioned—the auxiliary engine One can see that it might lead to interesting solutions under certain conditions

If it were possible to obtain just the size and shape of engine required, there would probably be no advantage in a boost system, but in present day conditions it will probably not be possible to obtain just the size of engine required, and in the case of turbines it might only be possible to obtain a fixed turbine in the particular size when a free turbine might be desired If one considered the pros and cons of an auxiliary engine it might be found to give advantages in certain cases

The **Author** said that he entirely agreed with what the speaker had said

**Mr E R Alexander** (*Ministry of Supply*), said that the Author had mentioned one point which had puzzled him slightly In referring to a helicopter with an auxiliary engine the Author had mentioned using it on take-off Surely if a helicopter was loaded up until an auxiliary engine became a necessity for take-off the value of the auxiliary would be nullified in the case of failure of one of the other engines

The **Author,** in reply, said that evidently the speaker's thoughts were similar to his own It appeared to him that the auxiliary engine had got to be bigger than a certain size and that size was quite considerable, namely, of the order of the size of the main power plant If two engines were fitted plus an auxiliary of nearly the same size the operator would want to make use of it on take-off In any case it would have to be started up because as an emergency engine, the pilot might need to make use of it just after take-off If there was a bad failure it often happened just after take-off For that reason he thought that the auxiliary would be used for take-off He would like to know whether anyone disagreed

**Mr Hollis Williams** said that he took rather a different view of the problem Suppose in a particular power size it was only possible to obtain fixed turbines, but on the other hand a small free turbine was available, then it might be worth while to consider using the small free turbine as an auxiliary to start the rotor and probably operate several other services as well

Since it was possible to obtain turbine power at low cost in weight, a small auxiliary could perform many useful functions and could be a useful stand-by in the event of a partial power failure on the main engines

The **Author** said that use might be made of the auxiliary engine for starting the rotor by clutching in, but it would not simplify the clutching of the main engines They would still be free turbines

**Mr Hollis Williams** pointed out that he had suggested that it might not be possible to obtain free turbines in the size required, but that the auxiliary could have advantages in connection with fixed turbines

The **Author** said that he would like to reserve judgment because in the case of most technical drive problems it was necessary to think quite hard to see if they worked out the way required

**Mr T G G Newbery** (*Ministry of Supply*) (*Member*), said that one or two small points had occurred to him while listening to the paper One was in connection with the turbine on the tip of the rotor and the suggestion that boosting could be obtained easily by re-heat He did not know whether it was as simple as that If anything was put on the tip of the rotor it must be kept small and his impression was that the introduction of re-heat on a jet engine involved a long extension of the tail pipe That brought them more into the line of something like the pulse jet engine than a small compact turbine and he wondered whether the penalties would be worth the advantages In a case like that he wondered whether it would not be better to allow a reserve in the capacity of the turbine itself so that extra power was available in emergency even if it meant a shorter life

The other point he wished to raise was the question of boosting a fixed shaft turbine Most of the Author's remarks had related to the free-power turbine engine where it was possible to increase the speed of the gas generator section without having to increase correspondingly the speed of the power turbine and consequently of the rotor What would be the case with a fixed shaft turbine ? Would it be possible to obtain increased power without materially increasing the speed of the rotor ? Could it be done simply by increasing the temperature or would it mean increasing the speed as well ?

The **Author,** in reply, referring to the application of re-heat to turbo-jets mounted at the tip of the rotors, said that the question of the difficulty of re-heat was one of degree The problems of building a turbo-jet engine to be run at the rotor tip were immense and although there were degrees of what was impossible he thought that the remark in the paper on the use of re-heat with a turbo-jet was worth very little because of the great difficulty of developing a turbo-jet engine for a rotor tip application If the difficulties could be got over and a suitable turbo-jet were built, then the extra problems associated with re-heat would be small by comparison

On the question of a fixed shaft engine, such an engine had a very steep power curve and as it was not possible to run on constant r p m and keep on the economical part of the engine operating curve it would be necessary to lose something He thought that the helicopter rotor designer would wish to keep the rotor at the same speed as between take-off and emergency conditions If that was so, with a fixed shaft engine the designer would have to give way on the economy of the engine at normal maximum conditions Boosting a free power turbine could be done by increasing the compressor r p m and the rotor r p m could be kept constant or adjusted according to requirements, but with a fixed shaft engine the maximum engine speed dictated the rotor r p m so that the cruising could only be done by coming away from the normal power curve and that meant loss in economy

**Dr E S Moult** said that he would like to raise a point of historical interest Rotation from reactionary jets, no doubt, went back to Hero but who had first derived lift from tip-jet reaction ? Major B C Carter had produced a propeller at the Royal Aircraft Establishment which he had called the 'flaming sword,' as it was driven by flaming tip-jets That had been over 25 years ago he wondered whether there was any earlier references to the use of jets to produce thrust from a rotating aerofoil

The **Author** said that many people had considered the pressure jet but so far as he knew Major CARTER at the R A E was the first to propose that an airscrew should be driven by burning the fuel at the blade tips He thought that Major CARTER'S idea was that it would be the main propulsion of the airplane

**Mr Alexander** said that that was more than 30 years ago

**Dr H Roberts** (*Fairey Aviation Co Ltd*) (*Founder Member*), said that he was a little bemused with regard to the definitions of some of the terms which had been used in the lecture and discussion He would have thought that if fuel was burned in the normal way and the products of combustion fed along the pipe to the tip jet and more fuel then burned at the jets, then that effectively constituted a re-heat system and he could see no difference between that and the conventional system He thought that controllable re-heat nozzles would be very difficult to engineer and that some alternative form of nozzle may well be required

With regard to pulse jets, he agreed that the thrust decreased rapidly at high inlet velocities If, however, the inlet was positioned at a point not at the tip but at say 50 per cent of the radius while at the same time exhausting at the tip then full benefit would be obtained from the reduced inlet velocity and maximum benefit obtained from the exhaust momentum Under these conditions, there would be a positive gain and the pulse jet was then competitive

He had understood the Author to say that the rocket was providing the only successful system He was, however, under the impression that there was an efficient ram jet boost system working in the United States

If tip burning was used there was a tremendous variation in the exit area unless tip burning was used throughout the flight Addition of fuel at constant exit area was possible only if a weak mixture was being used to start with If it was intended to stop tip burning at some stage, it was essential to fit exit control actuators otherwise there would be very little thrust when burning was stopped

With regard to the question of an auxiliary engine, he had some time ago proposed a 2½ engined helicopter but this had received little support by the Ministry of Supply, possibly because at the time the two main engines would have been piston engines One of the criticisms always levied against a mixed engine system is that maintenance workers who dealt with one type of engine would not normally deal with the other This appeared to him a rather dubious argument and he thought that sooner or later we should have mixed engines not only on helicopters but on aeroplanes as well

He did not believe that the auxiliary engine need be as large as 60 per cent of the main engine and considered that a case could be made for an engine of only 50 per cent

Finally, he had some doubt on the practicability of the gas turbine feeding air to a tip jet as a boost system for a direct drive helicopter The complexity of trying to feed air to the tip was quite large, in fact it would be necessary to engineer a blade which had the physical characteristics of both the jet and the direct drive systems The performance losses would be high in normal flight since larger thickness chord ratios would be necessary and overall it would not appear to be a very attractive proposition Unless the tip jet unit could be buried it would give extra losses He did not in fact believe that such a boost system was possible for direct drive helicopters

The **Author,** in reply, agreed that a system in which there was burning at the rotor tips was similar to the re-heat system It was also similar in some ways to the ram jet system For a boost system attached to a mechanical drive it had been found best to accept air from the compressor at a pressure of the order of 2 times atmospheric pressure

The speaker had said that the design of the tip jet would spoil the aerodynamics of the rotor blade He himself was speaking as someone who knew nothing about the design of rotors but his assistants had tried to lay out the duct paths in rotor blades and he thought that boost flows which would give a 50 per cent boost could be fairly easily accommodated in some rotor blades, particularly for small helicopters

Then the speaker had asked about the variation of nozzle area at the rotor tip He was aware of the point but thought such complexity would not be required with fuel being burned at the tip jet nozzles for boost only

With regard to the size of an auxiliary engine for a twin engined helicopter, he thought that a half engine was too small to meet the needs of flight on one engine If the helicopter was to fly at a condition needing the minimum of power, with one engine out then it appeared that the auxiliary would have to have more than 0 6 of the main engine take-off power

A short film of the first public flight of the Westland Wessex was then shown This aircraft had a single Napier Gazelle direct drive free turbine engine

The **Chairman,** in proposing a vote of thanks to the Author said that none of those present had any doubt at all about the tremendous advantages which would accrue to helicopters from the power which the gas turbine would make available Most pilots at some time or other had been critical of lack of power and now hoped that extra power would be put into their hands Having had experience of those occasions when pilots did not have it and got away with it, he could not help feeling that there were great possibilities for some form of power augmentation when it came to passenger transport operation from the very small sites which would no doubt exist in the centre of cities The more quickly a pilot could climb away from the site, the better the prospect of his coping with an emergency in the event of power failure He had been impressed with the marked improvement in the Skeeter's rate of climb following use of the R O R system

The Association as a whole owed the Author a debt of gratitude for coming along and putting his thoughts before them They were living in an exciting age and he thought that the gas turbine would do for the helicopter what it was doing for the aeroplane The Author had presented his ideas with such clarity and in so authoritative a manner as to make them easy to follow This paper would stand the test of time and all could profit from reading it He supposed that most people had different ideas about how to get what they wanted, but the paper had stimulated a most interesting discussion by encouraging other experts to contribute to the fund of common knowledge He had pleasure in proposing a hearty vote of thanks to the Author for his interesting paper

The vote of thanks was carried by acclamation

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## NOTICES

### Members' Subscriptions, 1958-59

Members are reminded that subscriptions fell due on 1st April, 1958

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### Annual Dinner, 1958

The Annual Dinner of The Helicopter Association of Great Britain is being held on September 4th at the Dorchester Hotel, London, W 1