French Helicopter Developments

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Professor J A J BENNETT (*Chairman, Lecture Committee*), occupying the Chair

The CHAIRMAN, in opening the meeting, said that the development of rotating wing aircraft in France had been well supported by military contracts ever since Liore et Olivier had taken a licence from Cierva to manufacture Autogiros The French version of the C 30 Autogiro with the Salmson engine, was given extensive military trials, so much so that on one occasion it had been a surprise to him to see as many as fifty of these machines in operation at an Army airfield in France The development of the helicopter had been undertaken with similar intensity and quite a number of successful types—a whole family of helicopters, in fact—had emerged

These developments were to be discussed tonight by Monsieur Legrand, who for the past five years had been in charge of the Rotary Wing Section of the Service Technique de l'Aeronautique The Association was fortunate indeed to have a visit from the French Government's leading rotary-wing engineer and to obtain from him an authoritative account of the present helicopter position in France, his experience with the Djinn and the Alouette and an indication of future trends

The Association was extremely pleased to welcome M Legrand, who was himself a member, to one of its meetings The English translation of his paper would be read by Mr McClements

M LEGRAND read the introduction to his paper, and the remainder was read by Mr McClements

INTRODUCTION

Custom requires of a lecturer that, before embarking on the thick of his subject, he gives his audience a schematic outline of his conference and some idea on how he intends to approach it Such a policy offers at least two advantages

(1) Better aware of the actual interest of the lecture, those members who so desire can discreetly leave the conference room

(2) It enables the rest of the audience to get a better grasp of the speaker's line of thinking

Far be it from me, therefore, to transgress this golden rule My lecture will be divided into three main parts The first, which will also be the shortest, will deal briefly with the overall helicopter situation in France The remainder of my conference will be devoted to more technical matters In the second part, I shall discuss the Djinn and the Alouette, in the third and last part, I shall give you a few details concerning French prototypes and development studies in progress SE 3 200, Alouette III and development of the Djinn

With such a plan, I could, of course, carry on speaking for hours rest assured, that is not my intention In preparing this lecture, I thought it unnecessary, before such a learned audience as The Helicopter Association of Great Britain, to deal with subjects already familiar to you and on which abundant comments have been published to date in the technical literature My intention is rather to discuss less familiar topics or those which are more particularly representative of French techniques My lecture will, as a result be slightly unbalanced and disjointed and I should like to apologize for this before starting

SUMMARY

The lecture is divided into three parts The first provides statistical data and general information on the helicopter situation in France The second analyses, in the light of the experience acquired in operational service, the distinctive technical characteristics of the "Djinn" and the "Alouette"

The main advantages and disadvantages of jet propulsion are discussed in the case of the Djinn It is shown that no saving in weight is achieved with such a formula as compared with a helicopter of conventional design Particular emphasis is laid on the exceptional jump take-off characteristics of this rotorcraft In conclusion, it appears that the main interest of the Djinn lies in its ease and safety of operation

As regards the Alouette, the particular problems associated with the use of a fixed wheel turbine are discussed Engine surging was the main cause of trouble when the Alouette was first brought into service This problem was solved by issuing appropriate operational instructions The importance of the collective pitch indicator in controlling such an engine is stressed The conclusion reached is that the use of a fixed wheel turbine on a helicopter is a very sound solution, which has given excellent results in the case of the Alouette II

Some information is then given on the extensive use of pneumatic equipment on both the Djinn and the Alouette

The third part of the lecture deals with the new developments under study

(*a*) General philosophy regarding the improvement of the Djinn design Principles behind the establishment of a new project

(*b*) General description and leading performance characteristics of the Alouette III, a prototype derived from the Alouette II and now in the flight development stage

(*c*) The SE 3 200, medium class helicopter operational specifications, technical description, leading performance characteristics, present status of development

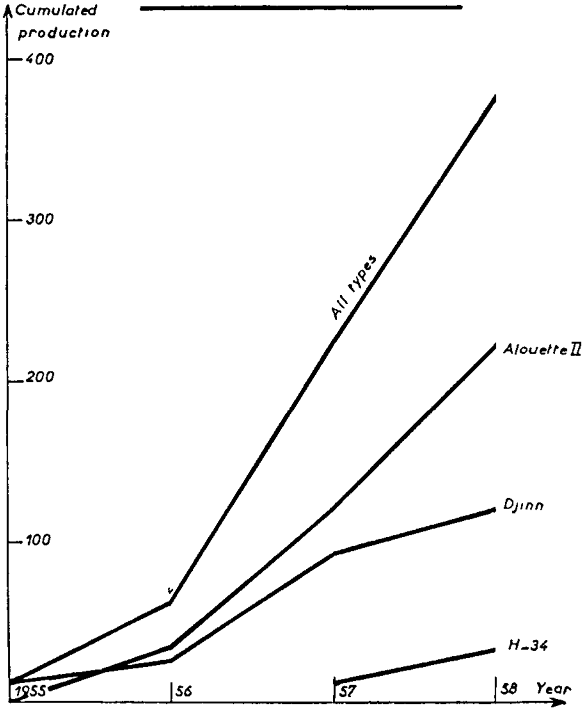
PART I

General Outline of the Helicopter Situation in France

In France, as elsewhere, the Armed Forces are by far the largest users of helicopters The three Services together, *i e* , the Air Force, the Army and the Navy, have at present several hundred helicopters in operational use, these being divided into five main types, ranging from the light two-seater to the fifteen-seat transport helicopter All helicopter research and manufacture in industry is carried out by a single company, namely the Societe Nationale Sud-Aviation

FIG 1

French Helicopter Production



Three types of rotorcraft are, at present, in large scale production

(1) the Djinn and the Alouette of French design ,

(2) the H-34, built under Sikorsky licence

Among the other companies who devote most of their activity to helicopters, the following two should be mentioned The Societe des Giravions Dorand, which specialises in the manufacture of various flight simulators and in advanced research in the helicopter field, and The Societe Heli-Service, which is responsible for the maintenance of the Vertol H-21 and the Djinn

Let me conclude this brief survey by giving you a few figures

First of all, the graph shown in Fig 1 represents the development of helicopter production in France In addition to the data contained in this diagram, it should be mentioned that the manufacture of the Alouette is at present based on a total production of 600 units, that of the Djinn on 150 units

In 1958, slightly over 3,000 productive people were employed in industry on the study, development, manufacture and maintenance of helicopters For the same year, SUD-AVIATION helicopter activities brought in a revenue of 7 330 million francs, *i e*, about £6,000,000

This figure amounts to approximately 13% of the overall activity of SUD-AVIATION for 1958 Of this total, 1,543 million francs, *i e*, about £1,300,000 came from exports

PART II

DJINN AND ALOUETTE EXPERIENCE

Having made these few comments, let us now consider the helicopters which are the object of this activity First, I shall describe some of the lessons which can be drawn from the development and operational use of the Djinn and the Alouette You are, of course, aware that the Djinn is a light two-seater helicopter designed primarily for the Army It is fitted with a cold pressure jet rotor actuated by a Turbomeca Palouste IV air generator The Alouette II is a five-seater utility helicopter It has a conventional rotor mechanically driven by a Turbomeca Artouste II turbine

As I remarked at the beginning of my lecture, I will not waste your time giving you a more detailed description of these helicopters, nor will I even mention some of their original characteristics, since these are already familiar to the specialist It is worth recalling, however, that the Djinn and the Alouette are, at present, the only two turbine equipped helicopters in current operation in the world The Djinn, moreover, is the only jet driven helicopter to be mass produced

It is these unique technical characteristics which seem to be worth discussing in the light of our present experience, which is based on more than 20,000 flying hours for the Djinn and on more than 70,000 for the Alouette

In the case of the Djinn, the value of the arguments brought up for or against jet driven helicopters will be examined Among the advantages usually conceded to this type of helicopter are its greater simplicity and lightness resulting from the absence of a mechanical drive system and anti-torque rotor On the other hand, the main arguments brought up against it are its high fuel consumption and excessive noise

Let us first look at the advantages The mechanical simplification is undeniable and this has favourable repercussions on the maintenance of the helicopter and on the ease with which it can be put into service It should be mentioned, however, that the suppression of the tail rotor, which was one of the main advantages claimed by the first advocates of jet propulsion, does create certain problems, yaw stability and handling, which on conventional helicopters are normally provided by the tail rotor, must be achieved by some other means The problem is sometimes so complicated that, paradoxically, tail rotors have made their appearance on some jet driven helicopters In the case of the Djinn, the problem has been solved more simply by placing a vertical rudder in the jet exhaust of the engine and by providing two additional vertical fins The development of adequate characteristics in yaw was not, however, obtained without trouble, and even now the performance of the Djinn in this respect is still inferior to that of most current helicopters

If we now pass on to the question of weight analysis, the Table given in Fig 2 shows that, for equivalent performance characteristics, no saving in weight is obtained on the Djinn as compared with a conventional helicopter fitted with a turbine of equally advanced design, in this Table, the weight characteristics of the Djinn and the Alouette are compared The scale effect has been eliminated by dividing the weights in both cases by a reference gross weight, which has been chosen as the weight for which hovering outside the ground cushion is possible at sea level in standard conditions It can be seen that, contrary to general belief, the jet driven helicopter of this type is slightly heavier than the conventional helicopter This apparent paradox is due to the fact that the transmission gear of a mechanically driven helicopter is comparatively light and that the weight saved by its disappearance is more than compensated by the increased weight of the engine and rotor This difference would, of course, tend to disappear and even to reverse if engines of greater thrust/weight ratios became available, for information purposes, the weights corresponding to hypothetical engines twice as light as the ones presently available have been added in brackets in the Table of Fig 2 This shows that, even then, the empty weight of the two types of helicopters remain practically similar

To avoid any misunderstanding, I should like to make two important comments before leaving the subject

(1) The above remarks are not intended to prove that no weight saving can be obtained with helicopters equipped with jet driven rotors, the

FIG 2 WEIGHT BREAKDOWN, DJINN *versus* ALOUETTE II

Item	*Weight* (*% gross weight* *)	
	Djinn	*Alouette II*
Airframe and controls	17 3	17 9
Fixed equipments	5 2	5
Rotor	14 6	10 8
Transmission	0 4	7 2
Power Plant Group	15 (7 5)	9 4 (4 7)
Empty weight	52 5 (45)	50 3 (45 6)

* Gross weight allowing hovering out of ground effect at sea level, standard atmosphere

comparison is only true in the particular case of the Djinn It does not necessarily apply to helicopters of much greater tonnage or equipped with different types of propulsion systems

(2) Comparison of empty weights does not, in the present instance, give a true picture of the actual performances of the Djinn In fact, because of its outstanding jump take-off capabilities, it can carry distinctly heavier payloads than mechanically driven rotorcraft This brings me to mention particularly this question of jump take-offs, which is a very special feature of the Djinn and, more generally of all jet driven helicopters of similar type Indeed, owing to the great inertia of the rotor and to the large r p m variations allowed, the kinetic energy available is much higher than in the case of ordinary mechanically driven helicopters

This kinetic energy reserve can be brought out by giving you two significant figures

(*a*) Engine cut, the Djinn can fly for 5 seconds on the kinetic energy of the rotor, whereas in the case of a conventional helicopter the corresponding figure is only approximately 0 7 seconds,

(*b*) If we now consider the Djinn loaded so that, at maximum engine power, the helicopter can just hover at ground level, the kinetic energy reserve available in the rotor enables it to climb 150 ft vertically, the corresponding value for a conventional helicopter does not exceed 30 ft

It is obvious, from these figures, that a jump take-off in overload conditions is an easy and safe manoeuvre with the Djinn, whereas it is always an acrobatic performance with a conventional helicopter In fact, the Djinn can take-off vertically right up to its service ceiling! In practice, of course, it is customary to stay well below this limit, in order to have enough reserve power available for cruising flight

These considerations will enable you to understand why the jump take-off capability of the Djinn is systematically included in the normal operation of this helicopter Under ordinary military operational conditions, the ratio between the gross weight of this helicopter and the power available at the rotor is equal to 8 7 kg /ch (19 lb /h p), the corresponding useful load is equal to 440 kg (approximately 1,000 lb), *i e* , 54% of the overall weight Those who know the amazing performances the Armed Forces can sometimes squeeze out of their equipment may, however, consider that these figures are not sufficiently convincing, let me therefore conclude this analysis of the jump take-off by pointing out that it enabled the Djinn to obtain its U S airworthiness certificate at a total weight 10% higher than that which would have been granted a conventional helicopter You are probably aware, indeed, that, under U S regulations (CAR, Part 6), the maximum allowable gross weight must be such as to permit take-off inside the ground cushion under certain temperature and altitude conditions This requirement is imposed in order to ensure a sufficient safety margin under normal operating conditions Compliance with this specification would have restricted the maximum weight of the civilian version of the Djinn to 700 kg (1,545 lb) but, in fact, the C A A authorities have agreed to raise it to 760 kg (1,680 lb) This derogation was granted following the demonstration that, at such a weight, a jump take-off is safer than a normal take-off at 700 kg

You have no doubt observed that, on several occasions, I have used the expression "safe operation", it is this feature, which, in addition to the simplicity of this rotorcraft, constitutes, in the opinion of its users, the main advantage of the Djinn This safety of operation stems from a number of factors, which I will now enumerate briefly

(*a*) Minimum number of vulnerable mechanical components,

(*b*) Absence of anti-torque rotor, a component which is vulnerable to damage during manoeuvres on obstacle ridden terrains or liable to constitute a hazard for ground personnel,

(*c*) Ease of control due to the low disc loading and to the great inertia of the rotor, it should be pointed out in this connection that the Djinn, unlike conventional helicopters, has no limiting speed-height envelope

This exceptional safety is brought out by the fact that despite very severe operating conditions, particularly during military operations, no fatal accident has yet been experienced with mass produced Djinns

But the time has come to examine the disadvantages of jet driven helicopters We will first discuss their high fuel consumption

Unfortunately, in this respect, the Djinn has but confirmed the estimates of the design engineers For the same payload, its fuel consumption is, about twice that of a turbine powered transmission helicopter and three times that of a piston engined transmission helicopter This high fuel consumption is the inevitable consequence of the type of propulsion system adopted The overall propulsion efficiency, expressed as the ratio between the mechanical power available at the engine shaft and the power available at the rotor, is equal to 34% as against 87% in the case of a mechanically driven turbine helicopter

It is also worth observing that the design adopted for the Djinn involves certain penalties as regards other performance characteristics It has already been seen that this rotorcraft takes-off normally at exceptionally high weight/h p ratios once in the air, less power is available than in the case of conventional helicopters As a result, the cruising and climb speeds will necessarily be lower too

There now remains the question of noise In reality, this defect is not very noticeable on the Djinn As there are no afterburners at the rotor tips, noise from the nozzles is maintained at a sufficiently low level not to be troublesome Most of the noise comes from the engine compressor, this has been reduced by fitting a silencer in front of the inlet As a result, the noise in the cabin is normal for a helicopter Moreover, measurements made in the neighbourhood of this rotorcraft have shown that below 60 m (66 yds) the Djinn is noisier than a mechanical piston engined helicopter, whereas above this distance it is less noisy

To sum up briefly the case of the Djinn, it can be said that the main reason for its success can be attributed to its simplicity and safe operation characteristics, because of these features, its use can be considered for civilian or military applications under conditions where the use of a conventional helicopter would prove impracticable

Let us now pass on to the Alouette and in the main discuss the engine

You are aware that this helicopter is equipped with a fixed shaft turbine, the Turbomeca Artouste II In 1954, when the design specifications of the Alouette were drawn up, such a choice involved a certain amount of risk since, at the time, it was generally acknowledged by most experts that a turbine of this type could not be used on a helicopter Since then, the tens of thousands of hours successfully flown with the Alouette have demonstrated, once again, that you must always beware of experts Let us not be unfair, however, since their objections were justified and were based on the presence of a number of problems which, had they not been solved, would have resulted in failure Even today, most helicopter manufacturers are afraid of encountering difficulties with such a type of turbine and prefer to use the free wheel turbine

It is not my intention to enter on a systematic discussion of the relative advantages of the free wheel and fixed wheel turbines Excellent reports have been published recently on the subject, particularly in Great Britain I shall limit my analysis, in the particular case of the Alouette, to the main problems associated with fixed wheel turbines

The first objection which is raised against this type of turbine is the risk of speed instability of the rotor-turbine system In practice, this risk is only present when a temperature regulator is used for power control It does not exist if the turbine is controlled either by the fuel supply or by a speed governor It is this latter type of control which has been adopted on the Alouette One of its great practical advantages is that no throttle control is needed, the pilot only has to actuate the collective pitch control and does not have to worry about rotor speed the governor takes care of that

The complete study of the speed regulation technique used on the Alouette has, however, shown that a few precautions must be taken in designing the governor

> First, it must prevent too considerable a drop in rotor r p m when sudden additional power requirements are imposed on the engine,
> Second, it can, at some settings, induce sustained torsional oscillations of the rotor-transmission-turbine assembly

A satisfactory compromise was fairly easy to arrive at on the Alouette, but the studies involved seem to indicate that the problems may in some cases be more difficult The use of a fixed wheel turbine also gives rise to two other important problems, which will be dealt with together since, though different, they have in fact the same origin these are the risk of overheating and compressor surging

These two phenomena occur, indeed, when an excessive power demand is made on the engine As regards overheating, it is, of course, obvious that exceeding the allowable temperature limit can only have a deleterious influence on the life of the engine, even though, as is frequently the case, no apparent damage is caused

I shall dwell a little more on the problem of compressor surging This phenomenon does not occur, as in the case of a turbojet or a free wheel turbine during engine acceleration, but when an excessive power demand is made on the engine Of course, this critical surge power is function of engine r p m and atmospheric conditions It manifests itself as a series of detonations similar to the noise of a machine gun The phenomenon is dangerous, as it can cause serious damage to the engine (due, in particular, to overheating) and, even more, because it results in an immediate loss in power at the precise moment when the pilot is endeavouring to increase it It must therefore be prevented at all cost

It is theoretically easy to avoid the risk of overheating and surging, it is only necessary to define operational limits such that the power requirements, for all flight conditions, are always well below the critical power at which surging or overheating appears

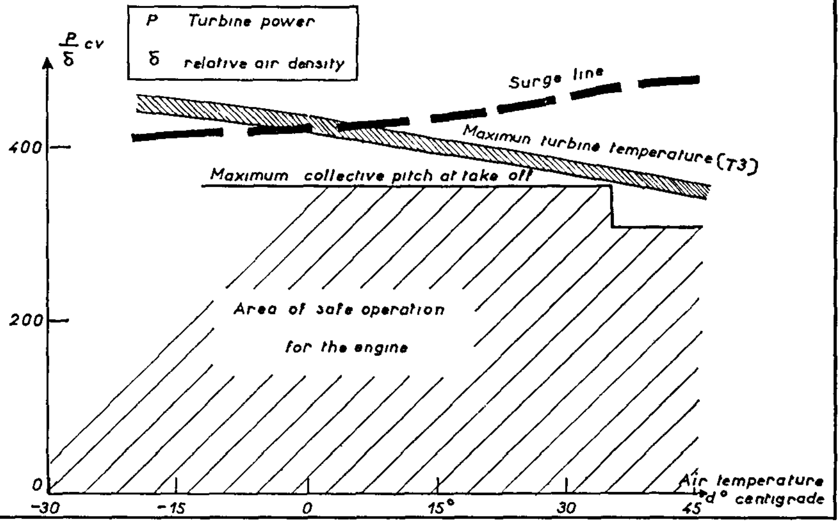
This is easier said than done It should indeed be pointed out that although the satisfactory operation of the engine inside the allowable flight envelope had been carefully checked during prototype tests, some cases of overheating as well as numerous cases of surging were experienced with the turbines when the Alouette was first brought into service In many of these instances there were no harmful consequences, in others some damage was done to the engines and there were a few instances which resulted in more or less serious accidents Analyzing these incidents, it was found that they were due to the fact that the pilots had no practical means of knowing, for any given flight condition, the power limitations not to be exceeded There is, indeed, no intrinsic limitation to the power developed by the turbine, as is the case with a piston engine or a free wheel turbine The greater the power requirement, the greater is the flow of fuel supplied by the governor to maintain the speed It is for this reason that the pilots come to place too great a trust in their machine and tend to use it in ever more severe conditions, until the day when surging suddenly appears without forewarning It should also be pointed out that, to prevent engine overload, a nozzle temperature indicator is not a satisfactory instrument On the one hand, in small turbines like the Artouste II, the jet temperature distribution is too heterogeneous for an accurate and reliable indication of engine operating conditions to be obtained, on the other hand, the response of the pyrometer is too slow to be usable during manoeuvres

This problem has been completely solved by the adoption of a number of measures The first really efficient remedy was devised by a group commander eight days confinement to the first pilot who experienced a case of surging! This highlights the fact that the real problem was, indeed, to obtain exact compliance with the operational limitations defined for the Alouette particularly as regards permissible take-off weights under various altitude and temperature conditions It seemed necessary, nevertheless, to provide the pilot with a simple means of knowing, at any instant, the limit which must not be exceeded by the engine The instrument was there, it merely required reading properly the one I am alluding to is the collective pitch indicator If the question is examined with care, it is apparent, in fact, that this instrument provides a sufficiently accurate indication, for every flight condition, of the power absorbed by the rotor as compared with safe power available at the engine The collective pitch indicator thus becomes the most important flight instrument The fundamental instruction is that the collective pitch must not exceed a certain maximum value in powered flight It is thus possible to ensure efficient protection, under every flight condition, against the risk of overheating and surging Fig 3 shows the flight envelopes thus obtained compared with the surging and temperature limits Moreover, to facilitate the pilot's task during difficult manoeuvres, the collective pitch control has been fitted with an elastic stop, which must not be overstepped in powered flight

To conclude this question, I shall say that our experience with the Alouette has proved that the risk of overheating and surging must not be held against the use of a fixed wheel turbine Operational instructions and

FIG 3

ALOUETTE II – Limitation of engine power by collective pitch –



means of control can be devised to avoid this trouble completely The few difficulties encountered when the Alouette was first brought into service can, finally, be ascribed to the necessary adaptation of both personnel and control equipment to the peculiarities of a new type of engine

One question which immediately comes to mind, however, is whether the power limitations imposed do not penalize the fixed wheel as compared with the free wheel turbine, since the latter can operate, without danger, right up to its maximum power This argument is, in fact, of little value, by remaining constantly below the maximum power of the engine, under normal operating conditions, increased operational safety is ensured In cases of emergency, extra power can be obtained from the engine, the helicopter can thereby be saved, even if the engine is eventually damaged beyond repair With a free wheel turbine, an equivalent reserve of power can only be provided if, as in the preceding case, the power of the engine is maintained, under normal conditions, at a fraction of the maximum power Experience has proved moreover that, in any case, a helicopter must be equipped with derated turbines if a reasonable operational life is to be achieved

This brings me to the subject of the operational life of the Alouette turbine When the engine was first brought into service, its operational life was relatively short scarcely 200 hours As a result of the operating instructions drawn up for the engine, which I described in detail above, and thanks to the numerous internal improvements introduced on the engine itself, the present position is greatly improved The time between overhauls has now risen to 350 hours This figure is expected to increase to 750 hours in the near future and later to 1,000 hours The values reached are now comparable to and even better than those of the piston engines used on helicopters of the same category

To complete this survey of the problems encountered with the engine of the Alouette, I should like to mention that it is not absolutely necessary, technically speaking, to insert a clutch between the turbine and the rotor If a sufficiently powerful electrical energy source is available, it is possible to start up the engine with the rotor engaged This was done quite commonly on the Alouette prototypes, using the helicopter battery Starting up was, however, too marginal, especially in cold weather, for this to be possible on the production version But it is not impossible, if sufficiently powerful batteries become available, for this method to be contemplated for helicopters of similar types it is but a question of weight analysis

In conclusion, our experience has proved that the use of a fixed wheel turbine is quite sound and does not involve any intrinsic difficulty, like all

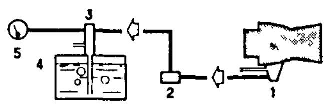
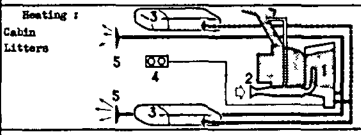
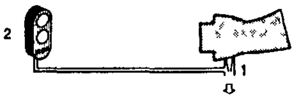
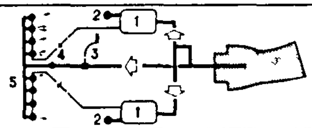
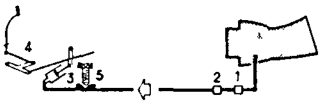
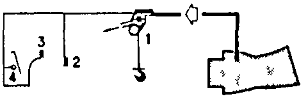
FUNCTION		NAME	DIAGRAM
Fuel level indicator DJINN	Measuring	Fuel contents gauge (Sud Aviation)	 1 Pressure regulator 2 Water separator 3 Transmitter 4 Fuel tank 5 Indicator
Heating of cabin and litters DJINN and ALOUETTE	Inducing pressure or suction	Heating venturi (Société BERTIN)	 1 Heat exchanger 2 Venturi 3 Litters 4 Controls 5 Cabin diffusers
Supplying vacuum operated blind flying instruments		Instrument venturi (Société BERTIN)	 1 Venturi 2 Blind flying instrument panel
Supplying spray equipment DJINN and ALOUETTE		Crop-spraying equipment (Sud Aviation)	 1 Tanks 2 Tank pressure gauge 3 Motor operated cock 4 Spray boom pressure gauge 5 Spray boom
Cyclic control trimming DJINN and ALOUETTE	Adjustable forces	Trim cylinder (Sud Aviation)	 1 Water separator 2 Filter 3 Trim cylinder 4 Cyclic control 5 Trim control
Supplying air operated rescue hoist ALOUETTE	Mechanical power	Rescue hoist (AIR EQUIPMENT)	 1 Hoist 2 Hoist operator station 3 Pilot station 4 Controls

Fig 4 Equipment operated by compressed air bled from Turbine-Engines

advanced equipment, one must learn to use it I do not wish to imply thereby that free wheel turbines have no advantages, I just want to point out that in the case of the Alouette the choice of this formula has given excellent results

It may, by the way, interest you to know that, for experimental purposes, we have had an Alouette equipped with a free wheel turbine It also flew quite satisfactorily during tests, but showed no significant advantage from the standpoint either of performance or of ease of operation

Before leaving the Djinn and the Alouette, there is one aspect of their instrumentation to which I would like to draw attention that is the extensive use of pneumatic equipment on these rotorcraft It was indeed tempting to make the fullest possible use of the compressed air available in the turbo-engines, denoted p2 for short, in order to design simpler and lighter instruments than the conventional ones This possibility was particularly valuable in the case of the Djinn which, as you know, has no airborne electrical network

A complete set of p_2 actuated instruments has thus been designed and developed for a variety of purposes measurement, trimming, pressure or vacuum operation of certain pneumatic systems, mechanical power Other applications can be imagined and, personally, I would have derived much enjoyment out of designing some kind of p_2 actuated sound emitting instrument trumpet, whistle or siren, unfortunately nobody asked me for one, probably because helicopters are already considered sufficiently noisy without!

I shall make special mention of three devices which led to considerable weight saving

(*a*) The heating and demisting devices on the Djinn and the Alouette, in which hot air is circulated by means of a p_2 actuated venturi,

(*b*) The blind flying instrumentation on the Alouette, in which light vacuum instruments are used Here again the vacuum is obtained by a p_2 actuated venturi,

(*c*) Finally, the rescue winch on the Alouette which is also pneumatic

In Fig 4 are shown schematically the main pneumatic instruments fitted on the Djinn and the Alouette

PART III

NEW DESIGNS

I have now come to the last part of my paper, which will deal with the new designs and prototypes presently being developed Most of these are concerned with the definition of new helicopters derived from the Djinn and the Alouette and with the development of a medium class helicopter, the S E 3 200

As you know, one of the secrets for success with aircraft lies in the continuous development of a family of models, in which each benefits from the experience acquired with its predecessors This practice is even more to be recommended in the case of helicopters, since considerable time and expense can be saved on the development of essential components such as blades, hubs and transmission units In particular, the potentialities and operational life of these components can quickly be raised to high values by making use of the knowledge already acquired regarding their behaviour in service

Detailed studies concerning the development of the Djinn have been in progress for a long time already, these concern both technical improvements and the operational requirements which must be met On the technical side, our first effort was directed towards reducing the fuel consumption, which is one of the main disadvantages of this type of formula

In the first instance, it can be expected that, other factors remaining unchanged, the rapid increases in turbo-engine efficiency will lead to significant improvements in the near future In would be possible, today, to design an engine of approximately the same weight as the present one, but capable of developing 20% additional power for the same hourly fuel consumption In other words, the specific fuel consumption of this new engine would be about 20% lower Later, the use of more advanced techniques would enable the fuel consumption of turbines to be reduced to about 65% of its present value

The fuel consumption can also be reduced by acting on the thermodynamic propulsion cycle Theoretical studies show, in fact, that the propulsion efficiency can be significantly improved by using a lower compression ratio than the present one, which is equal to about 4 at maximum rating Optimum efficiency is achieved for a compression ratio lying between 2 and 3 It is for this reason that preliminary designs, centred around "tailored" turbo-generators, were prepared and investigated

The results were rather discouraging, since the improvements in fuel consumption were almost entirely offset by the increased empty weight of the helicopter The fact that power must be transmitted through increased volumetric flows results in a notable increase in the weight of the engine, hub and blades The fuel consumption per pound of total weight is effectively improved but, when calculated per pound of payload, the improvement is much less significant

This, moreover, also creates constructional complications as regards both the engine and the airframe, a factor which goes against the wishes of the operators As I have already indicated, the great advanatge of the Djinn design, from the point of view of the operators, lies in the fact that it is an economic helicopter, simple to use and sturdy Everything that tends to impair these features must be discarded, even at the cost of a certain loss in performance

It was thus finally decided in collaboration with the Army that this principle would govern the design This has resulted in a project, which has been designated the Djinn III

This helicopter, whose general shape is very similar to that of the present Djinn, would nevertheless be distinguished by its greater power and flight endurance But I must again insist on the fact that most of our efforts were directed towards achieving design simplicity and safety of operation Expressed as a motto, our objective was to try and reduce the machine to a "set of pipes and strings fitted round the engine" It is estimated that, in the future, this helicopter could replace to advantage all the light observation aircraft of the Army

Fig 5 The Alouette III

For the moment, no construction has yet been ordered, mostly, as a matter of fact, for financial rather than technical reasons, since you know that even "pipes and strings" are none the less costly in aeronautics

In comparison, development of the Alouette is more advanced You are perhaps aware that the Alouette III, which is closely derived from the Alouette II, has been undergoing flight testing since the 1st March this year This helicopter was designed and constructed by Sud-Aviation under a contract of the 'Direction Technique et Industrielle de L'Aeronautique ' The major guiding principles which governed this project were the following

(1) To use a turbine of more advanced technical design than the Artouste II, this is the single shaft turbine Artouste III, built by the Societe Turbomeca, which exists in two versions

(*a*) The Artouste III, of 500—550 h p maximum power, which is being used for the early prototype tests ,

(*b*) The Artouste III-B, of 700—750 h p maximum power, which will equip the Alouette III before long

These figures are to be compared with the 360—400 h p of the Artouste II It should also be pointed out that the actual power required by the helicopter will never exceed 450 h p

(2) To take advantage of this greater engine power to increase the payload and improve the performance characteristics of the helicopter, particularly at altitude and in hot weather

(3) To use as many mechanical components of the Alouette II as possible This policy can be adopted on account of the resistance and endurance demonstrated by most of these components in operation This, of course, does not exclude the reinforcement of certain items, in order to obtain an operational capability equivalent to that of the Alouette II

(4) To better adapt the airframe of this helicopter to the accomplishment of a number of missions (*a*) ambulance evacuation , (*b*) rescue at sea , (*c*) flying command station, etc

The main differences between the general design of the Alouette III and that of the Alouette II are as follows (*a*) general body shape of the helicopter, (*b*) tricycle landing gear, (*c*) larger cabin fitted with sliding doors and capable of transporting, in addition to the pilot, 6 seated passengers, or 2 wounded on litters and 2 seated passengers

A general view of this helicopter is given in Fig 5 The main numerical characteristics will be found in the Table drawn up in Fig 6 That of Fig 7 shows the main performance characteristics of this helicopter equipped with the production engine, the corresponding performance figures of the Alouette II are also shown, for information purposes You will observe particularly that the performances of the Alouette III do not deteriorate over a wide range of altitude and temperature conditions, this, of course, as I have already remarked, is due to the large reserve of power available on this helicopter

"Last but not least", I will now complete my lecture by a description of the S E 3 200 This helicopter, which is now in the prototype testing stage, was designed and built by Sud-Aviation under a contract of the Direction Technique et Industrielle Little information has yet been published on this rotorcraft since, until recently, it was still classified secret It is a medium class helicopter, the technical specifications of which were established to meet the joint requirements of both military and civilian operators The main missions planned for this helicopter are the following

Ground Support Missions (*a*) Assault troop carrier or logistic transport for both men and equipment , (*b*) Ambulance evacuation

Fig 6 Alouette III—Leading Particulars

Cabin	6/7 seats or 2 litters plus 3 seats
Power Plant	Turbomeca Artouste III-B 700/750 h p
Rotors	
Main Rotor	3 blades—
Diameter	11 m (36 ft)
Disc loading	20 kg /m^2 (4 1 lb /sq ft)
Tail Rotor	3 blades—
Diameter	1 m 84 (6 ft)
Weights	
Empty weight—	
Standard	
7 seat version with VHF radio and rotor brake	1040 kg (2,300 lb)
Gross weight—	
Normal	1900 kg (4,200 lb)
Overload	2100 kg (4,630 lb)
Dimensions	
Overall length (blades folded)	10 12 m (33 ft 2 in)
—width (blades folded)	2 55 m (8 ft 6 in)
—height	2 95 m (9 ft 8 in)

Naval Missions (*a*) Anti-submarine warfare, (*b*) Mine-sweeping

Civilian Missions Regular city-to-city transport capable of carrying between 20 and 30 passengers according to the distance

The general configuration of the S E 3 200 design is the following

Single rotor helicopter, equipped with an anti-torque rotor, notable for its high disc loading This configuration was adopted, first, because for naval applications, in which the helicopter is based on board ship, its dimensions must be kept as small as possible and, second, in order to reduce to the utmost the constructional and maintenance problems associated with the transmission gear and the blades This high disc loading does not constitute a hazard from the point of view of safety, since the helicopter is equipped with three turbines This three-engined configuration was considered, in the present state of the art, to be the most satisfactory compromise to meet the conflicting requirements of safety, simplicity and performance The three engines are located on top of the fuselage, in the immediate neighbour-

FIG 7 ALOUETTE III—PERFORMANCE DATA

	ALOUETTE III *with Artouste III-B Engine*	ALOUETTE II
Empty weight	1040 kg (2,300 lb)	880 kg (1,940 lb)
Normal gross weight	1900 kg (4,200 lb)	1500 kg (3,310 lb)
Overload gross weight	2100 kg (4,630 lb)	1600 kg (3,530 lb)
Normal useful load	860 kg (1,900 lb)	620 kg (1,370 lb)
Overload useful load	1060 kg (2,330 lb)	720 kg (1,590 lb)
Performance at normal gross weight		
Hovering ceiling— (standard atmosphere)		
—In ground effect	3,750 m (12,300 ft)	2,000 m (6,560 ft)
—Out of ground effect	3,000 m (9,840 ft)	1,300 m (4,260 ft)
Hovering ceiling— (temperate summer std plus 22°C)		
—In ground effect	3,000 m (9,840 ft)	1,200 m (3,930 ft)
—Out of ground effect	2,200 m (7,220 ft)	400 m (1,310 ft)
Service ceiling— (standard atmosphere)	4,000 m (13,100 ft)	3,000 m (9,840 ft)
Maximum speed— (standard atmosphere—sea level)	200 km /h (124 m p h)	180 km /h (112 m p h)
Cruise speed— (standard atmosphere—sea level)	190 km /h (118 m p h)	170 km /h (106 m p h)
Fuel consumption at cruise speed— (standard atmosphere—sea level)	0 85 kg /km (3 lb /mile)	0 9 kg /km (3 2 lb /mile)
Practical operation at very high altitude— Take-off and landing with 250 kg (550 lb) payload (standard atmosphere)	6,000 m (19,650 ft)	3,700 m (12,140 ft)

Fig 8 The S E 3200

hood of the main reduction gear unit Two of the engines are located side by side in front of the rotor, the third behind it

On the prototype model, the engines are free wheel Turmo III-B turbines, built by the Societe Turbomeca They are 750—800 h p engines On the production helicopter, the Turmo III-C version, of 1,000—1,100 h p, will be used Its power will be limited on the helicopter to about 900 h p The layout of the central cabin, which is located beneath the rotor and the engines, has been chosen so that the various missions planned for this machine can easily be carried out It is fitted with two sliding doors and two floor traps Moreover, the tail of the helicopter can be swung open so that bulky loads can be introduced into the cabin

The fuel tanks are located on each side of the fuselage, they are jettisonable The helicopter is equipped with a tricycle landing gear To avoid corrosion problems, particularly in sea atmospheres, no magnesium alloy is contained either in the structure or in the main mechanical components A general view of the helicopter is shown in Fig 8 The main numerical characteristics concerning the S E 3 200 in its present version will be found in the Table of Fig 9

The main performance characteristics of the S E 3 200, again in its present version, will be found in the Table of Fig 10 The improved fuel consumption and range obtained when flying on two engines only are particularly worth noting The performance characteristics of the production version will be considerably improved, due to the higher power of the engines

Here now are a few details on the present status of the tests

First of all, it is essential that an aircraft of this size be subjected to thorough resistance and endurance tests on the ground before being allowed

FIG 9 S E 3 200—LEADING PARTICULARS

CABIN Internal dimensions—

Length	7 m (23 ft)
Width	1 90 m (6 ft 3 in)
Height	1 83 m (6 ft)

POWER PLANTS

3 Turbomeca TURMO III-B (Prototype) ,
rating per engine 750/800 h p
3 Turbomeca TURMO III-C (Production Model) ,
rating per engine 1,000/1,100 h p

ROTORS

Main Rotor	4 blades—	
	Diameter	15 m (49 ft)
	Disc loading	42 kg /m² (8 6 lb /sq ft)
Tail Rotor	4 blades—	
	Diameter	2 50 m (8 ft 4 in)

WEIGHTS

Empty weight (standard version with radio and navigation equipment)	4,500 kg (9,900 lb)
Normal gross weight	7,500 kg (16,500 lb)
Overload gross weight	8,000 kg (17,600 lb)

DIMENSIONS

Overall length (blades folded)	14 90 m (49 ft)
Overall width (blades folded)	5 20 m (17 ft)
Overall height (blades folded)	4 70 m (15 ft 5 in)

FIG 10 S E 3 200 PERFORMANCE DATA—(PROTOTYPES)

WEIGHTS	
Empty weight	4,500 kg (9,900 lb)
Normal gross weight	7,500 kg (16,500 lb)
Overload gross weight	8,000 kg (17,600 lb)
Normal useful load	3,000 kg (6,600 lb)
Overload useful load	3,500 kg (7,700 lb)
Performance at normal gross weight (standard atmosphere)	
Hovering ceiling	
—In ground effect	1,800 m (5,900 ft)
—Out of ground effect	500 m (1,640 ft)
Service ceiling	3,300 m (10,800 ft)
Maximum speed (sea level)	255 km /h (160 m p h)
Cruise speed 3 engines operative (sea level)	240 km /h (150 m p h)
Cruise speed 2 engines operative (sea level)	210 km /h (130 m p h)
Fuel consumption at cruise speed, low altitude	
3 engines operative	2 3 kg /km (8 15 lb /mile)
2 engines operative	2 0 kg /km (7 1 lb /mile)
Maximum range with normal fuel tanks (3,000 ltrs)	
3 engines operative	1,000 km (620 miles)
2 engines operative	1,200 km (745 miles)

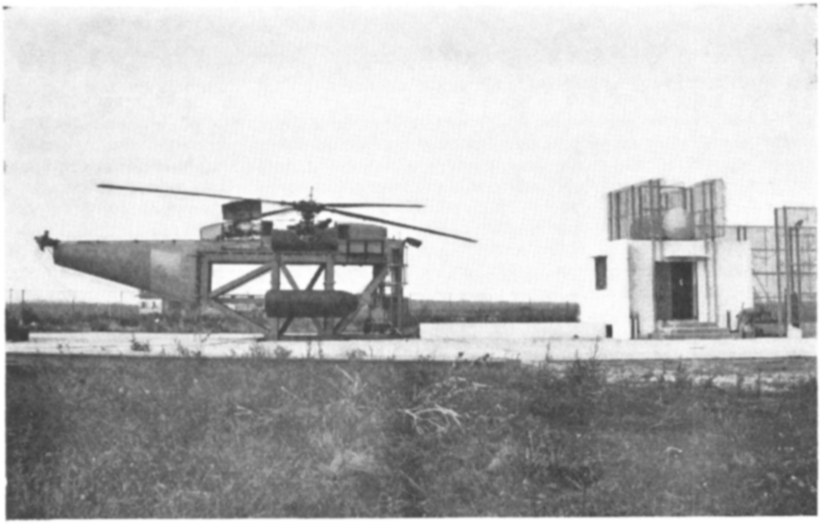


Fig 11 S E 3200 Endurance test rig

to fly It is for this reason that, in addition to the many partial laboratory tests carried out, an endurance test rig was ordered for the transmission unit and the rotor This test rig reproduces exactly the engine installation, transmission components and rotors of the actual helicopter It has been in operation since August, 1958 A general overall view of this endurance test rig is shown in Fig 11

As a result of the tests conducted on this rig, a number of improvements have already been incorporated It will be used intensively for a long time yet in order to determine the mechanical life of the various components The first prototype rolled out of the factory in the early days of this year and was subjected to an intensive ground testing programme before being allowed to make its maiden flight which is scheduled to take place any day now

Testing of the second prototype is due to begin soon

CONCLUSION

Having come to the end of my lecture, it now only remains for me to thank you for your kind attention Because of the general nature of this paper, I have had to leave out many items which might have interested you I have in mind, for example, the numerous armaments designed for the various types of helicopters in operation and the flight simulator successfully built by the Societe des Giravions Dorand I hope, however, that what I have said has enabled you to get a picture of the overall French helicopter situation and to understand the main problems with which we have been confronted as a result of the technical designs adopted