French Helicopters

By COLONEL R. M. GARRY.

A lecture presented to the Helicopter Association of Great Britain on Saturday, 25th February, 1950, in the Library of the Royal Aeronautical Society, London, W.1.

GROUP CAPT. R. N. LIPTROT, C.B.E.,
in the Chair.

INTRODUCTION BY THE CHAIRMAN.

From the very beginnings of aviation, France has always been right in the forefront, and that is very true of the helicopter. As a matter of fact, the very first helicopter in the western hemisphere was shown in 1784 before the Academie des Sciences by LAUNOY and BIENVENUE. That was so interesting that it inspired SIR GEORGE CALEY, the father of British aviation, to do some work on helicopters. Then in 1904, for the first time, COL. RENARD read papers, also before the Academie, in which he gave the correct design relationships for a lifting screw system, and he was the first man to describe the articulated blade system, which is today so common. In 1907, two Frenchmen built the first helicopters which lifted themselves off the ground, PAUL CORNU and LOUIS BREGUET, both in the same year, but BREGUET is always looked on as being the first of the two, because his helicopter was the first in the world to lift itself and its pilot. From that time onwards, right up to the Occupation during the last war, there has always been somebody in France building a helicopter and working on the helicopter problem. Indeed, at the time of the Occupation, there were several design offices working on helicopter projects in France. They were able to save most of their precious papers, and quietly and in secrecy they carried on working. The result was that at the Liberation the French authorities were able to commence an impressive helicopter programme. As time went on, as in every other country, finances got tight and they had to whittle down the programme, but none the less they have built and flown many helicopters, about which we are going to hear this afternoon.

COLONEL GARRY, our lecturer, is one of those who got his aeronautical training at the Ecole Supérieure de l'Aeronautique in Paris. Since 1927 he has been a member of the Corps of Aeronautical Engineers under the French Air Ministry, and he is an experienced pilot of normal aeroplanes and helicopters, and for many years he has been in charge at the French Air Ministry of Rotating Wing Development. For his work there he has been made a Chevalier of the Legion of Honour. He is also Chairman of the Helicopter Committee of A.F.I.T.A. (French Association of Aircraft Engineers and Technicians), and is also a member of our Association. Therefore there is nobody, anywhere, better fitted to give us a picture of French helicopter development, and to show us how the French designers have approached the problem and how they have engineered it.

Personally I should like to say how happy I am to have been invited to take the Chair today. COLONEL GARRY is not only an authority on the helicopter, but he is one of my greatest friends, and I am very happy to have been able to render him a little service by translating his paper, and because of the language difficulty I am going to read it for him. I will ask him to say a few words before I commence.

COLONEL GARRY.

Mr. Chairman, Ladies and Gentlemen : First of all, I would like to tell you that it is a great honour for me to have been asked by the Helicopter Association of Great Britain to give a lecture on the French helicopters.

I do not intend to speak of such researches made in France which have not led to any development ; but I think it more interesting to describe, in this lecture, the various helicopters realized in France since the Liberation.

All these helicopters have been flown, except the SO.1110—which is about to begin its flying tests—and the SE.3110, the ground endurance tests of which are to take place in the beginning of March, 1950.

My bad knowledge of the English language does not allow me to read this lecture myself ; therefore, I have asked my dear friend Captain Liptrot to be so kind as to translate and read it.

I apologize to him for this extra work and express now all my best thanks to Captain Liptrot.

Since the Liberation helicopter design offices have been created in France headed by technicians who, in most cases, had been working in the Rotating Wing field before the war. My intention is not to talk about the many design studies which have been made, many of which have not been pursued, but rather to give you a brief description of the helicopters which have actually been built as a result of those studies.

Breguet G11E.

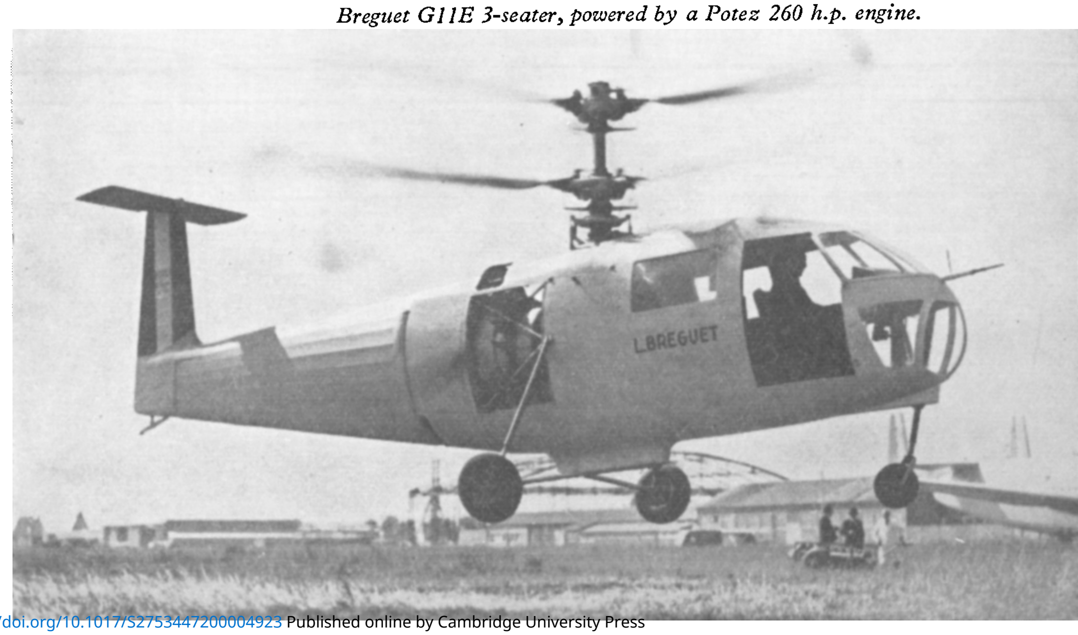
The Breguet G11E (Fig. 1), a helicopter with two, co-axial rotors, is the logical successor of helicopters built by the Breguet Company before the war.

Weighing 3,080 lbs. when carrying pilot, two passengers, and 26½ gallons of fuel, it is fitted with a fan-cooled Potez 9E nine cylinder air cooled radial engine developing 260 h.p. It has a tricycle undercarriage. The rotors are three-bladed, each 28·2 feet diameter. Its design characteristics are given in Table 1.

The front fuselage is a light alloy monocoque structure with two sliding doors, the cabin glazing giving excellent visibility. The rear fuselage is steel tubular, fabric covered. It carries a vertical fin, and a tail plane coupled to the control column in such a way as to suppress once per revolution flapping in forward flight.

The single plate clutch is semi-automatic. It is controlled by a lever in the cockpit, and the initial smooth engagement is effected by weak springs, final engagement being progressive by the action of centrifugal weights carried by the driven member. The clutch carries the cooling fan and a roller type free wheel, the rollers

Breguet G11E 3-seater, powered by a Potez 260 h.p. engine.



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being carried in a flexible cage to keep them in permanent contact with the operating ramps. Then follows a double splined universal joint, the shaft of which drives two nitrided Gleason type spiral gears through two case-hardened pinions. The gear reduction ratio is 6·5 : 1, the maximum rotor tip speed being 574 ft./second. The gears drive the two rotors through concentric shafts carried in ball bearings.

The blades, which are very stiff, consist of a steel tubular spar, tapered both as to diameter and thickness, and without any welding or piercing for rivets or bolts, which carry ribs attached by special clips, and a dural leading edge. The covering is Plymax, which is a three-ply with an outside skin of light alloy to specification A.G.5 and 0·32 m/m thick. The blades are tapered and have 4° twist.

The axes of the flapping hinges (Fig. 2) intersect at the rotor axes, and hydraulic drag hinge dampers are fitted.

The control column gives cyclic pitch control by means of two coupled swash-plates, the controls for the upper rotor passing inside the shaft.

Differential collective pitch variation necessary to compensate the residual torque reaction, and to give directional control when hovering, is not obtained by the swash-plates but by displacement of the control support sleeves which carry an intermediate link. Directional control from the foot pedals is thus very stable and forces are quite normal.

The rotors are controlled by collective pitch by means of a governor driven by the rotors, which is sensitive to both angular speed and positive acceleration, and which controls a hydraulic jack which moves the swash-plates axially. Centrifugal force acts on bob-weights, and the angular acceleration on a wheel driven at high speed by a planetary train of gears. By controlling a secondary hydraulic distributor the wheel immediately increases pitch on the slightest acceleration of the rotors, so removing the lag in response inherent in centrifugal governors used by themselves. In addition an override mechanism allows the main distributor of the governor to be used as a servo to increase collective pitch at the will of the pilot, but not to reduce it. A separate " over-ride pitch lever " is provided for this purpose. This arrangement not only permits the rotor kinetic energy to be used in a forced landing, but also being a pitch limiting device it prevents collective pitch being reduced below a predetermined level in the event of power unit failure close to the ground. When

TABLE I.

BREGUET 11E GYROPLANE.—GENERAL CHARACTERISTICS.

Overall Dimensions :	Maximum dimensions	28·2 ft.
	Total length	32·6 ft.
	Total height	13·8 ft.
Rotors :	Number of rotors	2
	Number of blades per rotor	3
	Diameter of rotors	28·2 ft.
	Blade area, one rotor	32·3 sq. ft.
	Chord of the blades at 0·7R	10·1 ins.
	Maximum chord of blades	11·8 ins.
	Solidity	0·114
	Shape of blades : Rectangular with trapezoidal extension	
	Twist of the blades	4°
	Maximum rotor revolutions	385 r.p.m.
	Maximum rotational tip speed	566 ft./sec.
Fuselage :	Shape	Elliptical
	Height	6·15 ft.
	Length	3·94 ft.
Tail Unit :	Vertical fixed surface	10·76 sq. ft.
	Horizontal, adjustable	10·76 sq. ft.
Landing Gear :	Type	Tricycle
	Front wheel castoring	
	Track	9·18 ft.
	Wheel base	9·5 ft.

set at the limit of the travel it still permits the governors to instantaneously reduce pitch to the auto-rotative setting in the event of engine failure, or complete closure of the throttle. A linkage with the throttle lever, by acting on the governor spring, provides for reduction in r.p.m. of the rotors when the throttle is reduced. This governor system has been found to greatly simplify piloting the Breguet helicopter.

Helicopter NC2001.

The helicopter NC2001 (Fig. 3) has been designed by the Rotating Wing Department of the Société Nationale de Constructions Aéronautiques du Centre under the direction of the Chief Engineer, Mons. Rene Dorand.

The NC2001 is of the symmetrical configuration with two intermeshing laterally disposed two-bladed rotors, either driven by the engine or turning freely in auto-rotation. It provides side-by-side seating for the crew of two, and a cabin accommodating three passengers. The total weight is 5,940 lbs., the empty weight being 4,550 lbs. The hovering ceiling outside the ground cushion is 8,200 ft.

The undercarriage is of the tricycle type, the wheels being fully castoring through 360°. The hydraulic shock absorbers are specially designed to prevent ground resonance while running-up the rotors.

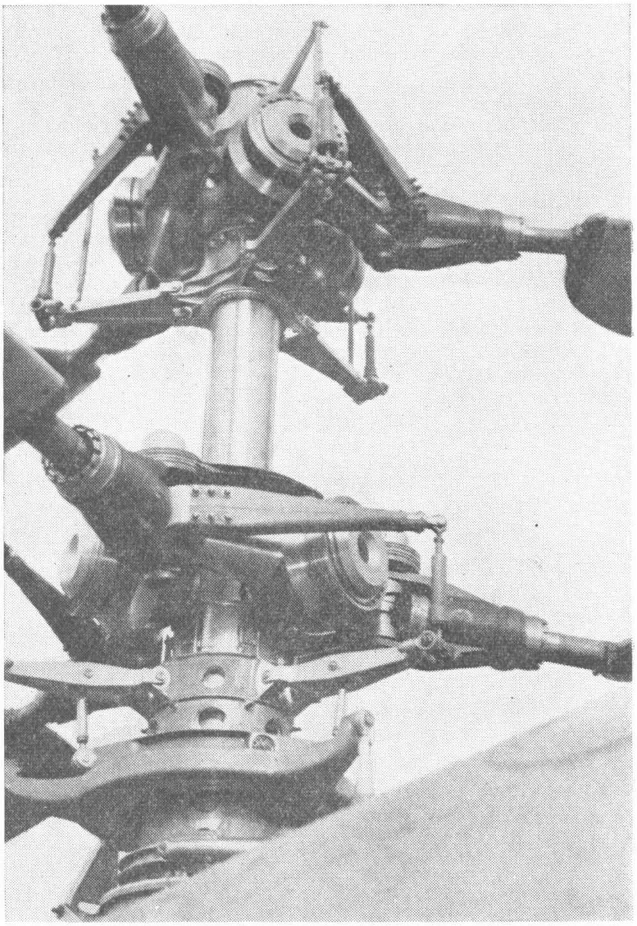

Fig. 2. Breguet G11E main rotor hubs. The axes of the flapping hinges intersect at the rotor axes and hydraulic drag hinge dampers are fitted.

The engine is a Gnome Rhone type 12S developing 575 h.p. at take-off. The reduction gear ratio between engine and rotors is 15 : 1. The normal reduction gear of the engine is replaced by a special gearbox driving two oblique shafts in a vertical plane and parallel to the rotor axes, through a clutch, free wheel and two sets of bevel gears. The two drive shafts, which have universal joints at each end, convey the drive to two rotor gear boxes symmetrically disposed about the vertical, and containing a double pinion drive to the two rotor shafts which carry the pitch control swash-plates. The rotor shafts are suspended hydraulically in a mounting whose inclination longitudinally with respect to the fuselage is automatically adjusted as a function of forward speed. The flexible mounting is very soft, allowing the torque reaction of the rotors to be transmitted without affecting the flexibility of the suspension.

An oil pipe between the two diaphragmed compartments forming the suspension permits free differential movement between the two rotor shafts, while simultaneous movement of the two is damped as is necessary in order to transmit longitudinal and lateral control movements.

The rotors are attached to the drive shafts by universal joints, the drag hinges of which are damped by two hydraulic dampers common to the two blades, one of which damps simultaneous movement, while the other damps any differential movement between the blades.

Pitch change of the blades by rotation about a pitch changing hinge is provided by a combination of torsion bar and mechanical and rubber buffers.

The torsion bar, which is cylindrical, and whose diameter is calculated to give a suitable elastic restraint to the blades rotating about their pitch changing axis, only carries part of the centrifugal load, the other part being taken by the two sets of buffers. The rubber buffers, which can work in torsion, provide a security device in the event of failure of the mechanical stops.

Lateral and longitudinal control is obtained by cyclic pitch variation of the blades of the two rotors. Pitching control by movement of the control column causes the same tilt of the two swash-plates governing the blade angle. Lateral control from the same column causes a greater lateral tilt of the swash-plate of the right rotor, if the column is displaced to the right, and *vice-versa*. This is to ensure that the blades of one rotor cannot foul the hub of the other rotor.

Directional control by foot pedals is obtained by differential variation of the collective pitch of the two rotors, and by longitudinal and lateral tilt in opposite senses of the virtual axes of the rotors. This is done in order to suppress all interaction between the directional control and the control about the other axes.

Fig. 3. NC.2001 5-seater, powered by a Gnome Rhone 575 h.p. engine.

A single lever, which is very easy to adjust, controls simultaneously the pitch and throttle opening by an electrically operated linkage.

In the event of power unit failure, the reduction in engine torque, indicated by a torque measuring device, operates a small electric jack which moves the single control back to the zero setting. The jack moves the control by means of an elastic link which enables the pilot to over-ride the control in the event of sudden reduction of pitch due to failure of the engine close to the ground.

In addition the blade attachment is so arranged that there is a reduction of incidence when the coning angle of the blades increases, so eliminating any danger of loss of rotor speed.

Helicopter Nord 1700.

The Nord 1700 (Fig. 4) is an experimental two-seater undertaken as a private venture, without State assistance, by the Société Nationale de Constructions Aéro-

Fig. 4.

nautiques du Nord, under the direction of Mons. Bruel. The object was to try out a number of novel arrangements designed to simplify both construction and pilotage. Its principal characteristics are :—

Total weight	2,090 lbs.
Engine power	160 h.p.
Rotor diameter	32·8 feet.
Length (without rotors)	23·94 feet.
Height overall	10·8 feet.
Undercarriage track	8·5 feet.

In the interest of simplicity and saving of weight a two-bladed rotor was used. Each blade, in which chord and aerofoil section are constant from root to tip, is built up of a solid dural spar, dural ribs, a dural nosepiece and a thin dural sheet skin. These components are assembled by clamping together, and no rivets or bolts are used (except at the hub attachment), a method which gives the maximum resistance to alternating load fatigue. This solution, covered by a SNCAN Patent, gives a simple and quick construction for quantity production and one not requiring skilled labour. Moreover, several sets of blades, not specially matched, except for obvious accidental damage, were rigorously inter-changeable due to the method of construction and were used on the aircraft without any special adjustment being found necessary.

The engine is a Mathis G7.R air cooled radial developing 160 h.p., and mounted

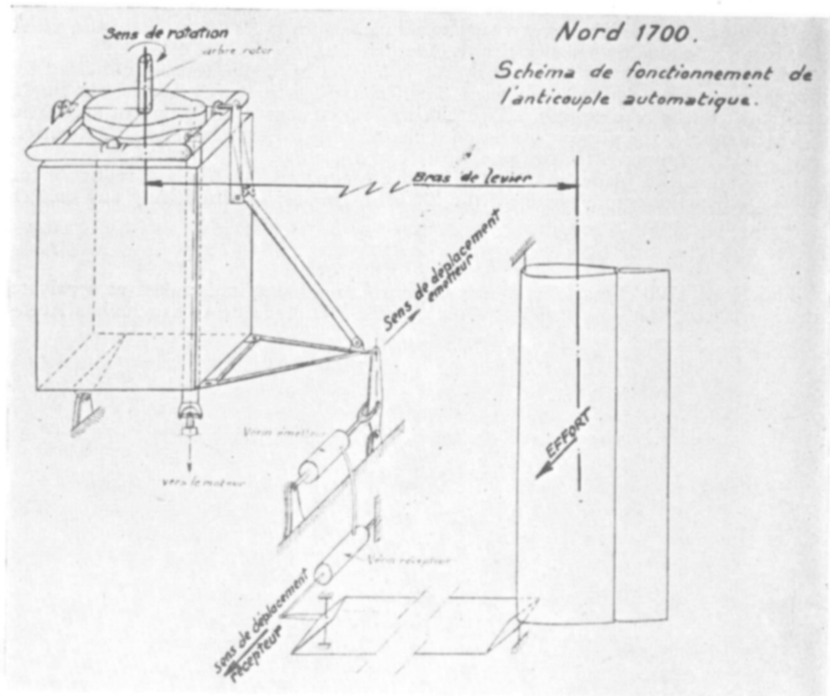

Fig. 5.

with its crankshaft vertical. The Nord 1700 is the first French helicopter to have the engine installed in this attitude.

The tail end is in accordance with a Bruel Patent. A fan screw blows a current of air to the rear over vertical and horizontal control surfaces suitably arranged. The fan is mounted inside a cowling ring which screens it from gusts when hovering and from variations in the rotor downwash, so increasing its efficiency, and at the same time giving protection to ground personnel. Unprotected screws or rotors at the tail have shown themselves to be a serious source of danger. The effectiveness of this system has been proved by flight trials both hovering and in forward flight.

This tail arrangement is used not only to compensate the torque reaction from the rotor, but also the vertical surfaces provide directional control, and the horizontal surfaces longitudinal control. It is thus possible to eliminate the disadvantages of complicated arrangements such as cyclic pitch control with its swash-plates and levers, and to prevent any disturbing vibration being transmitted back to the control column.

The rear screw is quite standard fixed pitch, and so simple and relatively cheap. Another advantage is that it is possible to taxi with the rotor stopped so eliminating any risk of overturning in gusts or high winds.

Deflection of the vertical surfaces (Fig. 5) is controlled by a hydraulic torque measuring device so that the rotor torque reaction is compensated automatically.

The rotor (Fig. 6) is fully articulated and without drag hinge dampers. Vertical vibration is damped out by a pneumatic system located at the top of the rotor.

On starting up, until a predetermined rotational speed is reached, the blades are held rigidly in forks and at zero pitch, so minimising the effect of gusts. When the r.p.m. reach the safe figure the blades rise, free themselves from the forks and automatically take up the correct pitch setting. This same arrangement also automatically puts the rotor into auto-rotation if the engine fails in any regime of flight where the blade angles are higher than those for auto-rotation.

Rolling manoeuvres are effected very simply by displacing the rotor head parallel to itself laterally. The rotor axis is always fixed with respect to the fuselage. A drive shaft with a motor car type universal joint at each end allows movement between the fixed engine and the moving hub reduction gear box.

Auxiliary blades, called "pilot blades," are fitted 90° ahead of the main rotor blades, and regulate the pitch of the latter as a function of their own flapping. This reduces flapping of the main rotor blades and so reduces vibration.

[CAPT. LIPTROT here interpolated the following explanation :—

As will be seen from the hub photograph the pilot blades are back-coupled to the following main rotor blade in such a way that as they flap upward they make the main blades feather in the sense to reduce pitch. One function of the pilot blades is therefore to reduce flapping by the introduction of feathering. They have a further function in that they are capable of axial movement, which is restrained by springs. As the rotor speed increases the pilot blades move outwards and the movement is arranged to increase main blade pitch. By suitable choice of spring and blade linkage the designer has achieved an automatic correlation between r.p.m. and pitch, and at the same time the arrangement is one which automatically reduces the blade angles to the auto-rotative setting in the event of power unit failure. The throttle is thus the normal pitch control, but the automatic system can be over-ridden by a separate collective pitch lever so that the pilot can make rapid fine pitch adjustments for precision hovering, and he can also increase pitch at will for energy landings in auto-rotation. This override is obtained by a linkage to the pilot blades controlling their radial movement, and so over-riding the centrifugal control.]

The rotor head can also be displaced parallel to itself in the longitudinal sense to trim for C.G. variation and take load off the stick.

The correction of lateral displacement of the C.G. when carrying pilot and passenger of different weight is made automatically by mounting the seats on a balance linkage coupled to the lateral control.

Fig. 6. Nord 1700 rotor head pylon.

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The Nord 1700 has carried out numerous tests : the first take off under a protective netting took place on September 14th, 1948. During tests spread over four months there was no modification of principle or any replacement of any major part. The tests, however, were interrupted by a failure due solely to the conditions under which the tests were made, *i.e.*, restriction of displacement of the aircraft under its protective netting. Moreover the tests demonstrated that there was practically no inter-action of one control on another, this being due to the tail arrangement and the automatic correction for torque reaction.

HELICOPTER SUD. EST. 3110.

The SE.3110 helicopter (Fig. 7) has been designed by the Rotating Wing Department of the Société Nationale de Constructions Aéronautiques du Sud Est. under the direction of MESSIEURS. MARCHETTI and RENOUX.

The general layout has been determined by the following considerations :—

(1) To obtain as high a rate of climb as possible.

(2) To land in auto-rotation with as low rate of vertical descent as possible.

(3) These two conditions were looked upon as being essential safety factors.

Other performance characteristics, and in particular, high speed performance, have been controlled by the two first considerations, and all the time one has to try to ensure that the maximum power of the engine can be used, without any limitations being imposed by vibration, by avoiding stalling of the retreating blade even when flying at altitude. The two first conditions have fixed the rotor diameter, rotational speed, and horse power required from the engine. The third condition has determined the solidity chosen and made reduction of parasite drag necessary.

The constructional principles on which the design was based are :—

(1) A monocoque fuselage giving lowest drag for minimum weight and maximum useful volume.

(2) A nine-cylinder air cooled radial engine, mounted with crank shaft vertical giving low installed power-unit weight per h.p., and steadier torque, and lower height than would be necessary with an in-line or flat engine. This latter makes it possible to arrange a large cargo compartment under the C.G.

(3) Controls similar to these already tried out on the SE.3101 with the addition of trimming by means of longitudinal cyclic pitch control.

(4) Simplification of pilotage by adequate linkage of controls in order to obtain automatic correction of torque reaction and pitch throttle co-ordination.

(5) Maximum reduction in maintenance work, and increase in working life of moving parts, by a very careful study of the lubrication system.

Fig. 8 gives the principal dimensions of the SE.3110 and Table II gives weight and performance. The engine is a Salmson GNH, nine-cylinder air cooled radial installed with the crankshaft vertical, develops 203 h.p., at 2,150 r.p.m. at take-off.

Fig. 7. SE.3110 powered by a Salmson 203 h.p. engine

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It is enclosed in a dural cowl through which air from two fans, one on each side of the fuselage, is passed.

The engine is bolted directly on to the lower face of the transmission box, which is of welded steel and provides the support for the engine/rotor assembly. The transmission box itself is attached to the fuselage by a pyramid structure of welded steel tubes. The transmission box provides :—

(*a*) The gear trains driving the two cooling fans.
(*b*) A centrifugal clutch.
(*c*) A double epicyclic reduction gear.
(*d*) A pawl type free wheel.
(*e*) The gear train for the tail rotor drive.
(*f*) The main rotor drive shaft.

Lubrication is by two special engine-driven pumps.

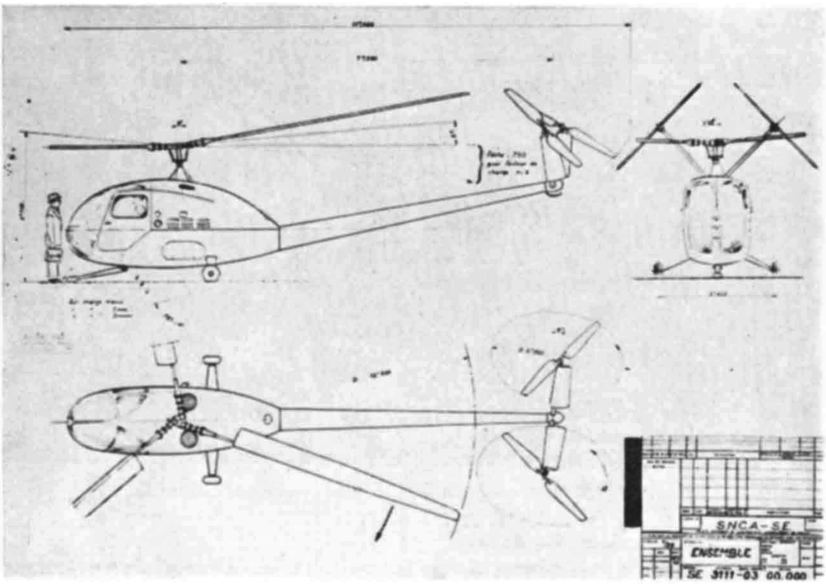

Fig. 8. Principal dimensions of the SE.3110

TABLE II. S.E.3110.—WEIGHTS AND PERFORMANCE.

Empty equipped weight		1,584 lbs.
Disposable load		616 lbs.
Total weight		2,200 lbs.
Powers :	Nominal	175 CV.
	Maximum	203 CV.
	Maximum speed at sea level	93·8 m.p.h.
	Cruising speed	76·2 m.p.h.
	Climbing speed in forward flight	885 ft./min.
	Climbing speed in vertical flight	295 ft./min.
Performance :	Ceiling in horizontal flight	14,750 ft.
	Ceiling in hovering flight	1,970 ft.
	Range	175 miles
	Duration	3 hrs.

The drive for the tail rotors consist of an oblique shaft in the fuselage, and auxiliary multiplier drive with pick up for the rev-counter drive and a long shaft extending to the tail and supported in four floating bearings. The tail unit consists of a gear box carrying two struts on which the two two-bladed rotors are mounted. Fig. 9 shows the main rotor hub and the cyclic pitch controls.

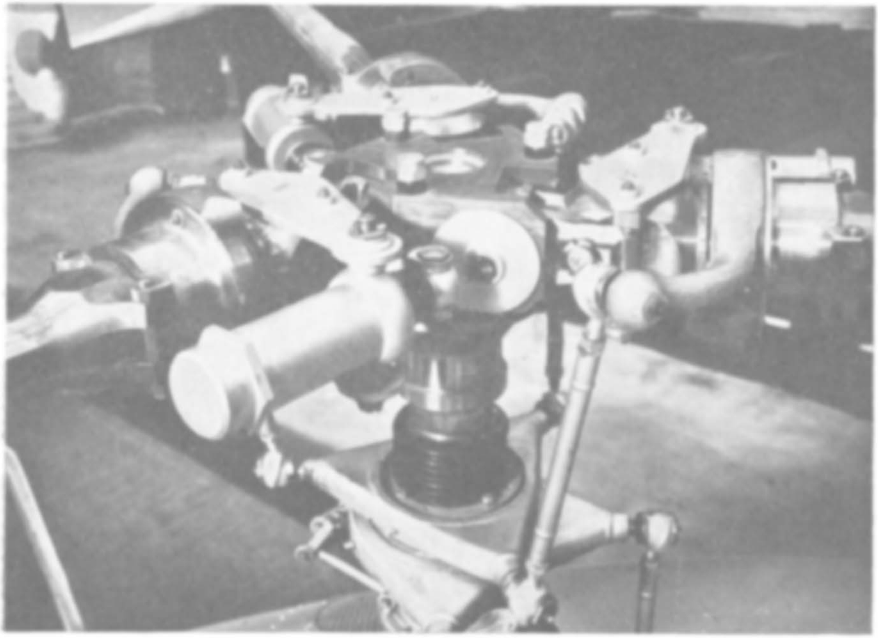

Fig. 9. SE.3110 main rotor hub and cyclic pitch controls.

Pitch/throttle/anti-torque co-ordination.

The pitch/throttle/anti-torque linkage is provided to ensure as good co-ordination as possible between the main rotor pitch, engine power, and tail rotor pitch so as to make it unnecessary for the pilot to have to make constant adjustments to throttle and tail rotor pitch.

Description of linkage system (Fig. 10).

The system is based on the fact that over the range of speed used the engine torque only depends on the extent to which the carburettor butterfly throttle is opened. Its novel feature lies in a direct connection between the anti-torque controls and the carburettor lever so arranged that the torque correcting movement is proportional to engine torque, and in a linkage between the pitch lever and the motor cycle throttle grip providing :—

(*a*) Starting and warming up the engine by rotation of the throttle grip at low pitch.
(*b*) In flight, maintenance of constant rotor speed (or slightly increasing with pitch) when the collective pitch lever alone is adjusted.
(*c*) Adjustment of rotor speed by the throttle grip.
(*d*) No action of the pitch lever on the throttle or anti-torque controls when the throttle grip is closed (energy landing in auto-rotation).

Carburettor/anti-torque control linkage (Fig. 11).

The displacement of the carburettor lever as a function of engine torque is not linear. The non-linearity of the linkage of the carburettor lever *A* and the control

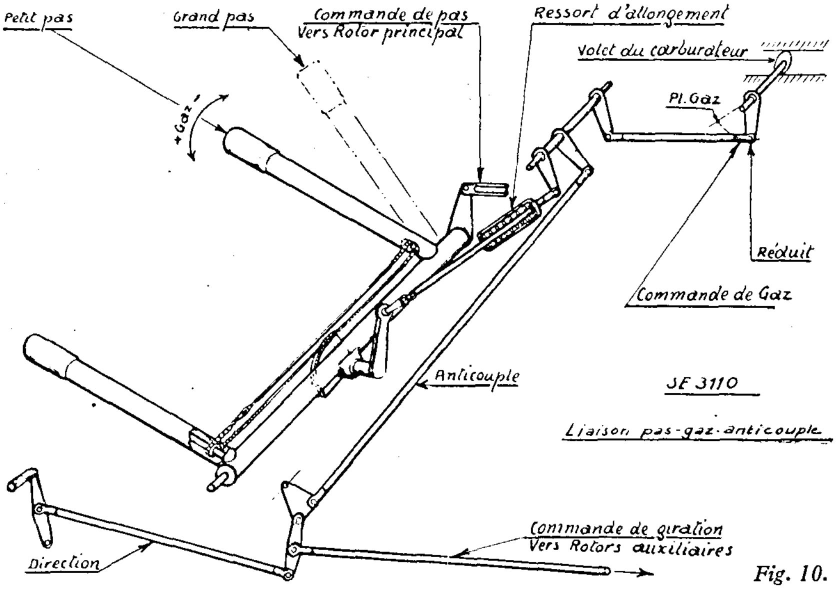

Fig. 10.

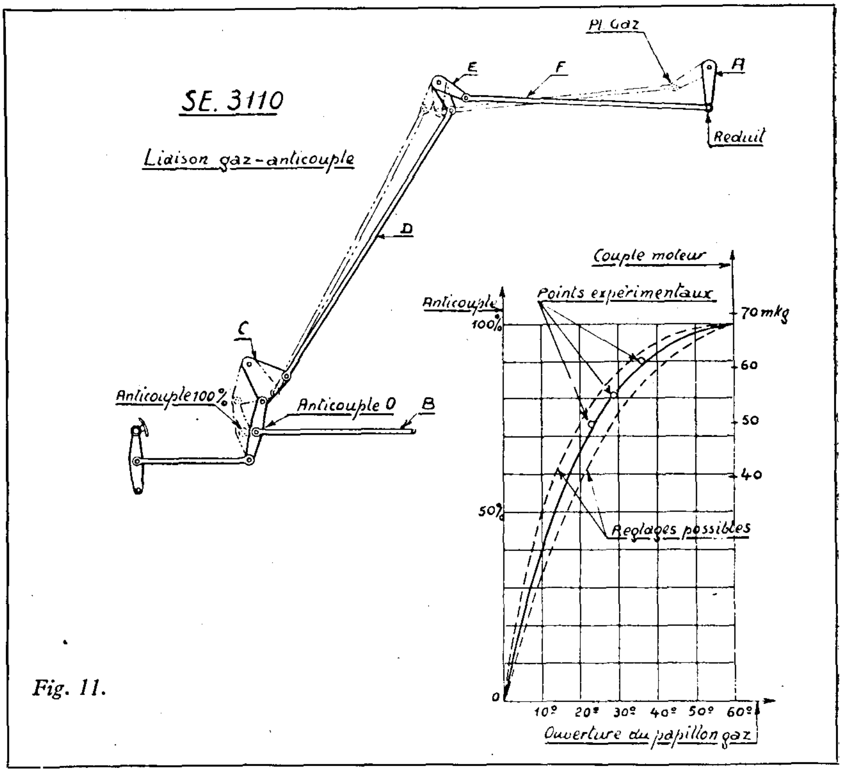

Fig. 11.

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shaft *B* is obtained by a dead centre effect in the linkage *CDE*, in association with an adjustable dead centre in the linkage *EFA*. The practical curves obtained are shown as the diagram, which gives carburettor butterfly opening as abscissae against % travel of the anti-torque control as ordinates. Points obtained on the engine test bench are indicated.

Pitch/throttle grip/carburettor linkage Figs. 12, 13).

The twist grip throttle *G* operates by cable the sector *H*, which is mounted on the spindle *P* of the collective pitch control, and which is in one piece with the lever *J*. The latter by the ball joint *R* and the rod *T* operates the link *E* which is coupled to the carburettor lever *A* and the anti-torque control *B*. The spring *S* allows full throttle opening for normal pitch settings while at the same time allowing maximum pitch to be applied.

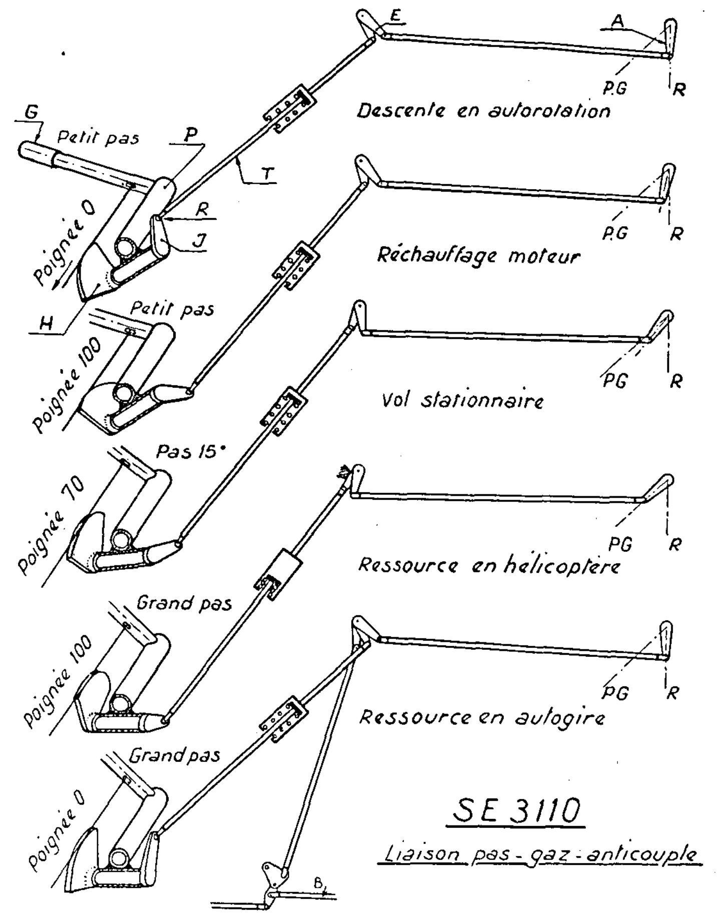

Fig. 12.

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When the twist grip is closed (position *O*) the ball joint *R* is near to the spindle *P* and the linkage *PRE* near to dead centre. Movement of the pitch control only very slightly moves the throttle. When the twist grip is full open (position 100) the ball joint *R* is separated from the spindle *P* and movement of the pitch lever causes a much bigger carburettor opening.

Fig. 12 shows the positions of the system for different operating cases.

Figure 13 shows graphically the linkage relationships for different twist grip positions between pitch setting as abscissae and the anti-torque control (or butterfly opening and main rotor torque which are related to it) as ordinates.

The dotted lines show the relation between rotor torque and pitch angle for various loadings and for hovering at sea level at the engine speeds shown. For instance, point *A* corresponding to hovering flight at 2,050 r.p.m., at a weight of 1,050 kgs. (2,310 lbs.) demands a pitch setting of 15° 20′ for a twist grip opening of roughly 70%. The anti-torque control is at 92%, the rotor torque is 475 m/kgs. (3,440 lbs./ft.) and the carburettor butterfly is open 40%.

The graph also shows the line showing the centrifugal clutch engagement at 850 engine r.p.m., corresponding to a butterfly opening of 5° 30′ roughly, that is to say a 50% opening of the twist grip at low pitch setting.

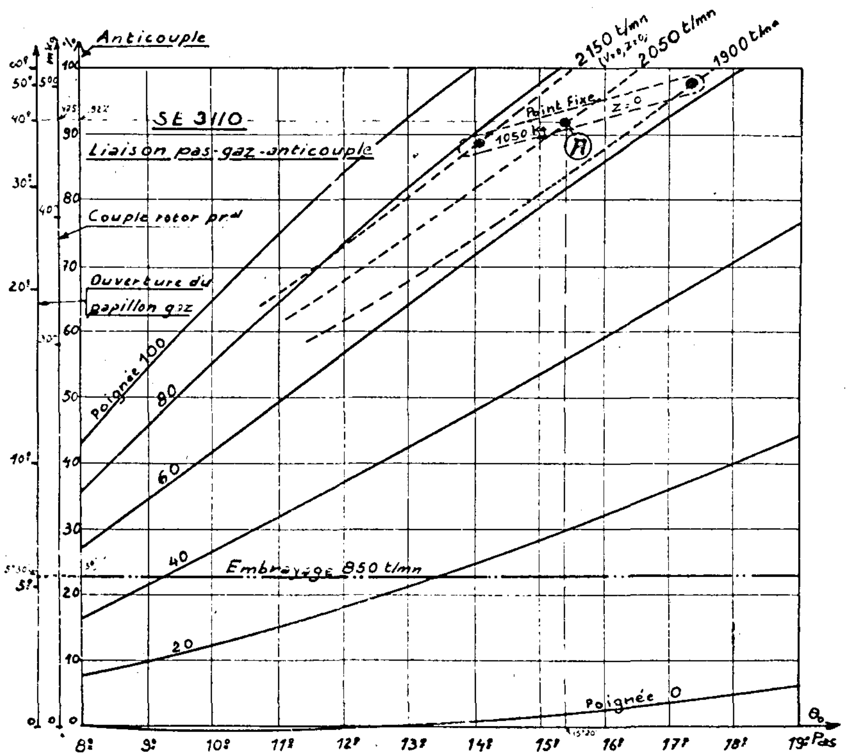

Fig. 13.

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The Rotating Wing Department of the Société National de Constructions Aéronautiques du Sud Ouest, under the direction of MONS. PAUL MORAIN, has devoted itself to the development of jet propelled helicopetrs.

This type of helicopter is, of course, the subject of considerable research all over the world. Many experimental jet propelled helicopters have succeeded in flying, the first in Austria towards the end of the war, others in America during the last two years. The principal characteristic of jet propelled helicopter is the absence of a mechanical drive to the rotors, the blades instead being driven by gases expelled from nozzles at their tips.

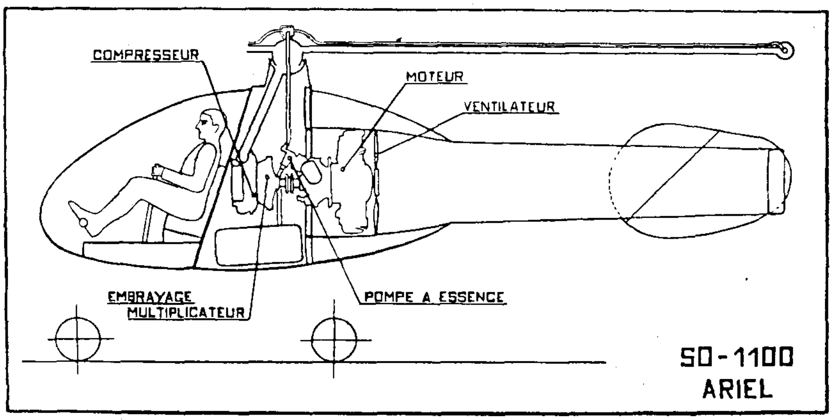

Fig. 14.

This simplification brings the benefits of low first cost and low maintenance cost because it does away with clutches, free wheels, and gears operating under very severe conditions, all of which demand high quality materials and high class workmanship, and need frequent overhaul. Equally these components in a mechanical drive account for a percentage of the gross weight of the aircraft, which increases with increasing size and gross weight.

Moreover single rotor mechanically driven helicopters have to have some torque compensating device such as a tail rotor, which causes a pure loss of some 10% of the engine power and is the cause of many mishaps when manoeuvring near the ground. Jet propelled helicopters are quite free from this disadvantage.

As an offset to the quoted advantages, jet propelled helicopters have the disadvantage of using more fuel than mechanically driven types. From the point of view, however, of operating costs this is compensated, particularly for big aircraft operating over relatively short distances, by the increased useful load and by reduced amortisation and maintenance charges.

The jet propelled helicopter is thus a definite thing of the future.

The line of attack chosen by SNCA. S.O. (Fig. 14) is to have an engine or gas turbine driving a compressor in the fuselage. The compressed air is passed through the hub, which has rotating joints, and is then directed through the blades to combustion chambers located at the blade tips. The fuel fed at low pressure into the hub is then delivered by centrifugal force along the blades where it is atomized under very high pressure by the jets in the combustion chamber. It is ignited by a spark plug and the products of combustion are ejected through nozzles so giving the propulsive force which drives the rotor.

This scheme of using a compressor has the advantage of burning less fuel than

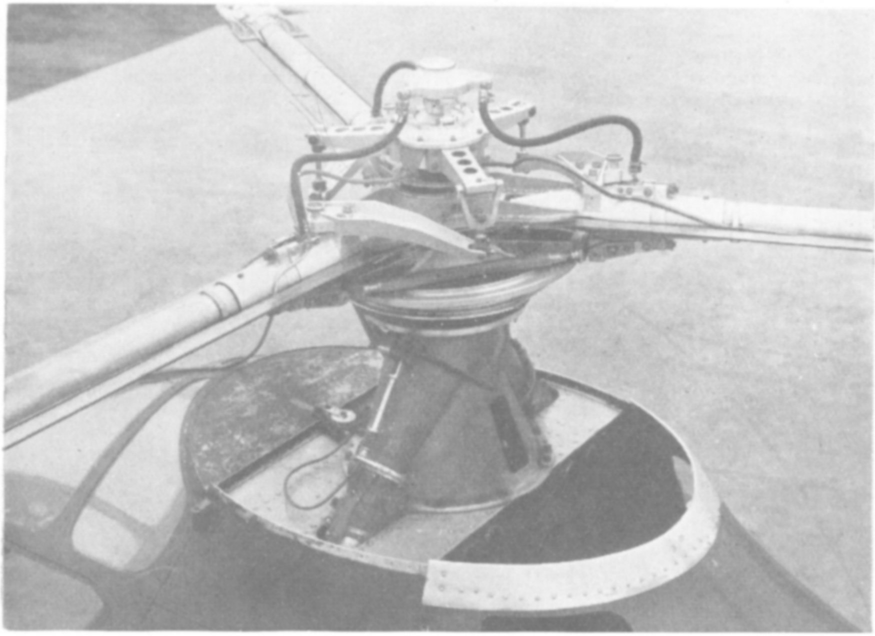

Fig. 15. SNCA-SO Ariel. Rotor hub is mounted on a universal joint and is free to tilt.

the alternative ram jet or pulse jets which have been developed in America. It has a further and very important advantage in that the drag of the small reaction units at the blade tips is negligible when they are not in operation. Any failure of the jets therefore does not interfere with the auto-rotational characteristics of the rotor, and the aircraft can land with complete safety just like a gyroplane ; on the other hand, due to the high drag of ram jets and pulse jets, the problem of satisfactory auto-rotation in their case has not yet been solved in practice.

As well as the propulsive system the SNCA S.O. helicopters present the following special features.

The hub (Fig. 15) mounted on a special or universal joint is free to oscillate. It can therefore tilt so as to lie in the plane of rotation, so reducing to a minimum the displacement of the blades relative to the hub. This arrangement, plus the fact that the hub is not subjected to any torque, makes it possible to do without drag hinges with all the difficulties of bearings, dampers, etc., which they involve.

The blades are attached to the hub by two leaf springs located one on each side of the tubular spar extension which serves at the same time as an air duct and a droop stop. These leaf springs provide the equivalent of flapping hinges, and their flexibility in torsion allows blade pitch change by a conventional spider arrangement. The various features of this arrangement all contribute to ease of maintenance of the hub.

The blades are of composite wood and metal construction assembled by glueing, the hollow spar which is of dural and of elliptical cross-section being surrounded by hard wood with a balsa trailing edge. The whole is fabric covered and enamelled.

The control column and the collective pitch stick with a twist grip throttle are of the usual type.

Directional control by pedals operates two rudders, one on each side of the tail, whose hinge line is at 45°. The down-wash from the rotor acting on these rudders gives adequate directional control when hovering.

S.O. 1100 "Ariel."

This is the experimental machine (Fig. 16) commenced in 1946 and which made its first ground running trials in 1947. Several flights were made during 1948 and in the spring of 1949 the final phase of testing was reached and has now been completed.

The thermo-propulsive system is now working very well, and the aircraft has shown good manoeuvrability and excellent stability characteristics. It is particularly

Fig. 16. S.O. 1100 "Ariel."

free from the vibration to which all mechanically driven helicopters, even those which have been developed far enough to be put into commercial operation, are subject. It is fitted with a Mathis G7 engine developing 160 h.p., which drives a "Turbomeca" compressor through a step-up gear box. The gross weight is 1,870 lbs.

S.O. 1110 "Ariel II."

This two-seater (Fig. 17) has an engine/compressor unit consisting of a Mathis G8 developing 200 h.p. and a "Turbomeca" compressor (Fig. 18). It has the same rotor, 35·8 feet diameter, as the S.O. 1100. Its empty weight is 1,595 lbs. As its normal gross weight is 2,475 lbs., the useful load of 880 lbs. is thus 35·5% of the gross weight. The estimated performance at a gross weight of 2,475 lbs. is :—

Maximum speed	107 m.p.h.
Vertical rate of ascent	295 ft./min.
Hovering ceiling	4,900 feet.
Cruising speed	85 m.p.h.
Best climb...	985 ft./min.
Normal cruising range	156 miles.

For a still air cruising range of 62·5 miles the pay-load, including pilot, is 660 lbs. at normal take-off weight. The aircraft is undergoing flight trials at the present time.

During 1950 a three-seater version with a "Turbomeca" gas turbine/compressor unit will be completed (the S.O. 1120). The ratio of useful load to gross weight will increase to 57·5% and the general performance will be higher than that of the S.O. 1110.

The S.O. 1110 and S.O. 1120 will be capable of performing all the duties appropriate to this size of helicopter, *e.g.*, training, army, co-operation, observation, rescue, crop dusting, etc.

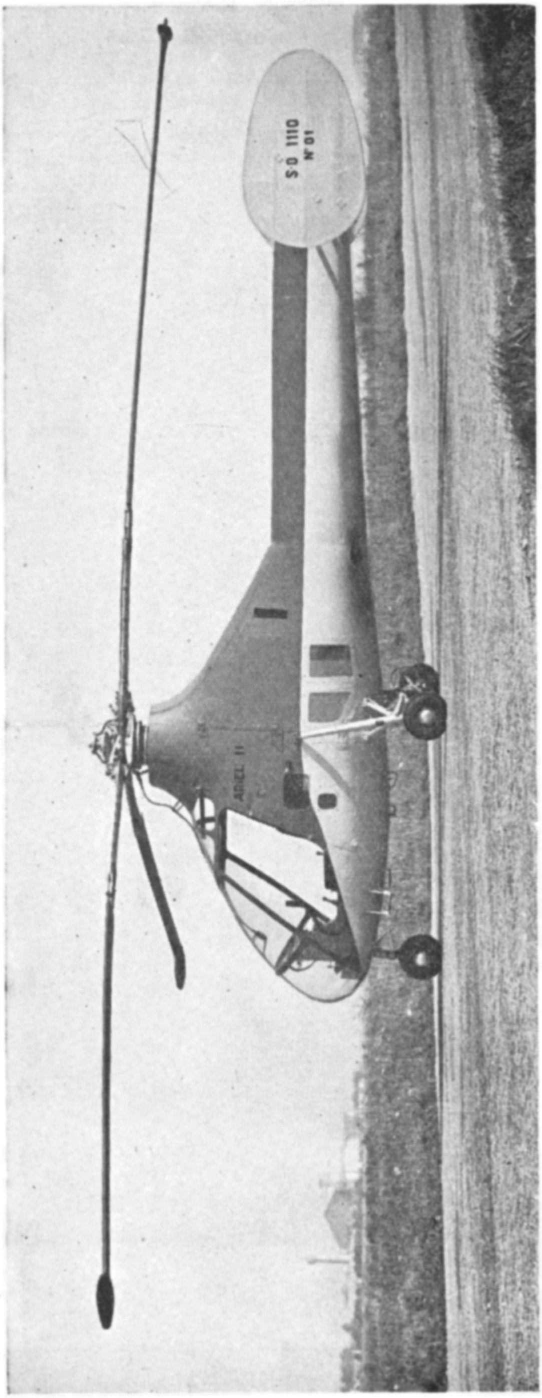

Fig. 17. S.O.1110 " Ariel II " powered by Mathis G8 (200 h.p.) and " Turbomeca " engine/compression unit

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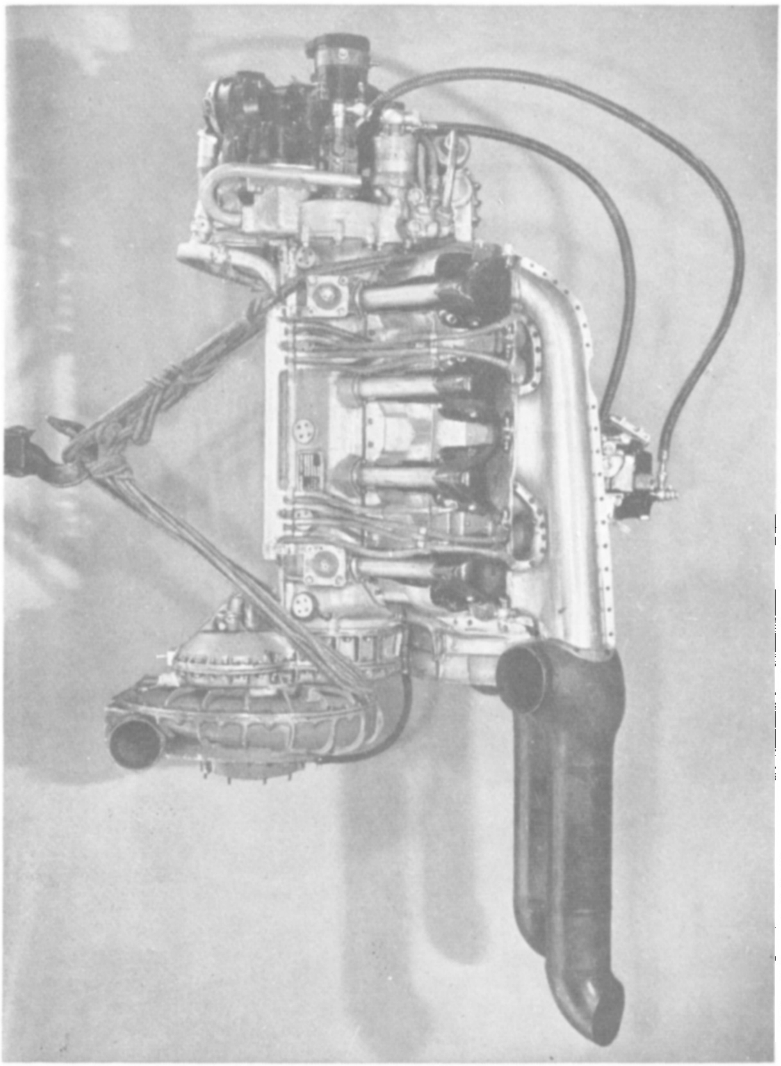

Fig. 18. Ariel II power unit consisting of a 200 h.p. Mathis 68 engine with a turbomeca compressor.