A HISTORICAL REVIEW OF HELICOPTER DEVELOPMENT

by Group Captain R N. LIPTROT, C.B E

Lecture given on October 12th at Manson House, London, before the Helicopter Association and Visitors from the Royal Aeronautical Society

INTRODUCTION BY THE CHAIRMAN

Before asking Gp/Capt Liptrot to give us his lecture a few words of introduction may not be out of place It would be difficult to think of anyone better qualified to talk on the subject of rotary wing history than Gp/Capt Liptrot, as he has been intimately associated with the development of this type of aircraft for the past 20 years, and latterly in his official capacity at the Air Ministry, Ministry of Aircraft Production, and Ministry of Supply It is probably correct to say that he has had inside knowledge of every project in this country as well as a good many abroad

Gp/Capt Liptrot is a member of our Association and his enthusiasm for rotary wing flight has shown itself in a practical way during the past two years during which time he has done quite a lot of solo flying on the R 4 helicopter

I am quite certain that his personal interest and sympathy has done much towards the general advancement of the Art in this country

Finally, on behalf of the Association, may I welcome those members of the Royal Aeronautical Society who are here this afternoon as our guests and also the guests of our own members

Group Captain Liptrot —

Before commencing my lecture, I should like to express my appreciation of the great honour which you have paid me in inviting me to give what is really the inaugural lecture of the Helicopter Association of Great Britain

It is appropriate, I think, that in this first lecture, in order to pave the way to more advanced treatment of the problems, we should consider in simple terms the basic principles and make a historical review, examining early efforts to build helicopters and tracing their development up to the position which we have now reached

Ever since man began to think for himself he has wanted to imitate the flying creatures and, with their example in front of him, it was natural that flapping or rotating wings should be amongst the earliest suggestions for flying machines Even in mythology we have the story of Icarus who made wings which he fastened to his arms with wax It will be remembered that he flew too close to the sun, the heat from which melted the wax so that his wings fell off and he was hurled to his death Thus we have the first recorded case of muscular flight and, at the same time, the first structural failure in a flying machine

The problem of direct lift flight and, in particular, that of the helicopter, i e that type which derives its lift control, and propulsive thrust entirely from rotating wings, has intrigued inventors throughout the centuries and has perhaps attracted more attention than any other phase of the design of the heavier-than-air craft It is very significant that when man first thought of flight he thought in terms of direct lift, i e in rising vertically from the ground, remaining motionless at a desired height and then descending again vertically Going places when once in the air was, in his mind, quite a secondary requirement Even the Wright Brothers and others who are now famous aeroplane designers built their first models with this same idea in view, but they and many others who worked long and earnestly on the problem had little or no success Then came the realisation that a suitably shaped surface propelled through the air would create lift, and the fixed wing glider, and the aeroplane, which is a power driven fixed wing glider, were developed Our whole conception of flight thus became reversed for now, instead of rising into the air and then going forward, we were wholly concerned in going forward at a sufficient speed to rise and maintain ourselves in the air This diversion, and it was a diversion, gave us the simpler solution of the aeroplane whose characteristics were sufficiently satisfactory to attract the finance which was necessary for its development The aeroplane, of course, has made enormous strides, but it still has and will always have the shortcoming of being critically dependent on speed To their everlasting credit, however, ever since flight was first achieved, there has always been someone somewhere working on the problems of direct lift and striving towards our original idea of lift, stability, and control independent of forward speed We are glad to record that many who were led away from the seemingly insoluble problems of the helicopter to the simpler powered glider, have now seen the light and are in the forefront of helicopter development

Of all that band of pioneers, pride of place must surely go to Juan de la Cierva, who, although not concerned in helicopter development, none the less paved the way more than anyone else to the satisfactory solution of problems inherent in the helicopter It was he who impressed as he was by the risks of loss of speed on the conventional aircraft, argued that while speed on the supporting surfaces was of course essential to flight, it was not essential to the aircraft as a whole He thus divorced the velocity of the aerofoil itself from that of the aircraft, by hingeing his aerofoils to a rotating centre, so that they could rotate independently to create sufficient lift for sustentation The idea, of course, was not new, since all rotating wing devices rested on the same fundamental idea, though not previously so clearly defined by other workers In developing this idea, he rediscovered other features which are vital to the helicopter and which had been propounded earlier, though never satisfactorily applied in practice, namely flapping blades to compensate for the dissymmetry of forward flight, control by tilting the rotor thrust and the high parachutal value of aerofoils, autorotating at a small positive angle of incidence His autogyro provided the missing link in the quest for our ideal and an instrument on which to study the aerodynamic and mechanical problems of the rotating wing type of aircraft Such was his success that at any time after 1932, when the C 30 autogiro was demonstrated, we could have built a satisfactory helicopter if the urge to do it and the necessary financial backing had been available

That then is the broad picture First we had the aeroplane with its fixed wing and dependent on speed for sufficient lift to support itself in flight, and with engines and propellers for propulsion, and separate organs for stability and control

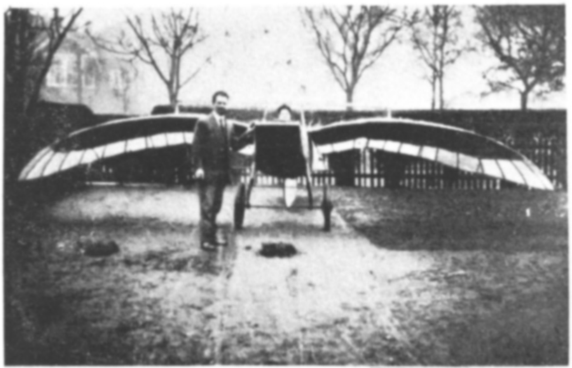
From this we had the transition to the autogiro with rotating wings, deriving its control from its rotor but still dependent on a certain amount of forward speed for its lift, though not subject to loss of control at low speeds Finally, we have the complete co-ordination of all the essentials for flight in a rotating system, power driven for propulsion and lift, and convertible by pitch reduction to the autogiro for emergency landing Thus we have the helicopter which was man's original conception of flight, but which was only reached through the intermediate development of the aeroplane and the autogiro

Let us now trace this development Even as long ago as the fifteenth century we find Leonardo da Vinci devoting several years of his life to the study of bird and mechanical flight, and he has left in his notebooks many sketches showing flying machines Of particular interest is a design showing an aircraft consisting of a lifting screw driven about a vertical axis

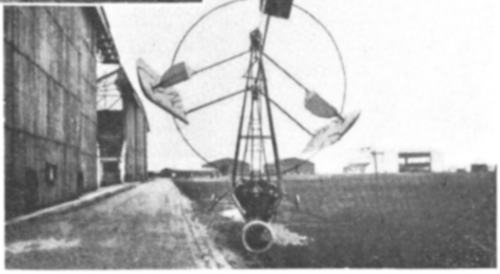
The first helicopter to fly was only a toy, the wellknown Chinese flying top, and the first helicopter to fly in the Western Hemisphere was a rather similar model, little more than a scientific toy, which was shown before the Academie des Sciences in 1784 by Launcy and Bienvenue, and since that time literally thousands of projects have been proposed by inventors all over the world The Patent Offices of all countries are full of helicopter specifications, the greater part of them, unfortunately, based on faulty physical principles and obviously impracticable

The direct lift aircraft is a heavier-than-air craft which is able to lift itself and some useful load off the ground in still air, which can hover motionless over a given spot and descend vertically under its own power and, in particular which can make a safe descent in the event of engine failure In addition, it must be able to move horizontally at the will of the pilot at a satisfactory speed, and it must be controllable and stable under all conditions of flight The possibilities for the practical use of such an aircraft are obviously far reaching and they have excited the imagination of both laymen and technicians The helicopter, that branch of direct lift aircraft with which we are concerned in this paper, is, in common with all rotating wing machines, the safest of all flying machines This is so, not only because it cannot be stalled in the ordinary sense of the term i e in that loss of forward speed only results in sinking on a level keel, but also because in conditions of low visibility use can be made of its very low minimum speed So long as power is available a landing can be made in any clear space but little in excess of the rotor diameter and, in the event of a forced landing due to engine failure, a safe descent is still possible in to a restricted area

It is in the required characteristics mentioned earlier, namely horizontal translation, stability and control, that the real difficulties of the problem lie, and very few of the earlier inventors in this field of flight appear to have seen the problem as a whole In most cases they appear only to have considered the requirement of obtaining sufficient lift to sustain the aircraft As long ago as 1904 Colonel Renard read papers before the Academie des Sciences in which he developed the theory of lifting screws to quite a considerable extent, and formulated the correct relationship between horsepower required, weight to be lifted and airscrew dimensions Today, with our present knowledge, any competent propeller designer could provide a



PASSAT flapping wing



MOINEAU paddle wheel

The Sikorsky R 5

The Doblhoff jet helicopter

rotating system to give adequate lift for hovering flight

As we have seen, the desired characteristic of hovering flight demands aerodynamic surfaces which have a velocity independent of the forward speed of the aircraft as a whole, and we have three main possibilities —

1 Ornithopters in which the wings flap or oscillate

2 The type in which the aerofoils are mounted like the blades of a paddle wheel

3 The type in which the lifting system consists of blades attached to a hub rotating about a substantially vertical axis This type has always held the field and has at last given us entirely practical helicopters capable of being put to practical use It is this type which we shall discuss in what follows

Let us now look at the special problems

TRANSLATION

In horizontal motion with a system of rotating aerofoils, the difficulty arises that the surface, which at any instant is advancing into the relative wind, has a higher velocity than the retreating surface and, therefore, exerts a greater lift In the absence of special arrangements, this inequality of lift gives rise to an inconvenient overturning moment Several arrangements have been proposed to overcome this difficulty

(a) The cyclic change of resultant blade velocity can be avoided by arranging for a cyclic change of blade velocity, so that when advancing the blade would have a smaller angular velocity than when retreating Such a method, however, involves excessively high angular accelerations and the solution is impracticable

(b) Variable blade area or telescopic blades which can be retracted on the advancing side and extended on the retreating side This method again is obviously impracticable

(c) The use of pairs of systems rotating in opposite senses, the pairs being either superimposed, side by side, or in tandem

(d) Other schemes assume constant angular velocity and, consequently a cyclically changing relative velocity in forward flight, but propose to compensate by means of a cyclic change in blade characteristics governing lift, e g by flaps or similar means

(e) A cyclic variation of blade angle or what is commonly called " feathering " The disadvantage of this method is that it involves rigid blades and the structural problem is made more difficult by the heavy periodic bending moments which it imposes at the blade roots, both in the flapping and drag senses

(f) By blade flapping The principle of the flapping blade was described in very early helicopter patents, but it was only when Cierva rediscovered it and applied it to his autogiro that its importance in the achievement of practical flight with rotating wings was appreciated

It has the merit not only of suppressing the overturning moment caused by the aerodynamic dissymmetry of forward flight, but it also suppresses vertical bending moments at the blade roots and it minimises the effect of gusts on the aircraft In point of fact the suppression of the overturning moment is not complete, owing to the inertia of the blades which so influences the motion of the blade about the flapping hinge, that the almost complete suppression of rolling in forward flight is accompanied by a pitching moment This, however, is in point of fact beneficial, since flapping produces pitching of the aircraft due to the backward inclination of the lift vector, and, since flapping increases with forward speed, the aircraft becomes more tail heavy with increasing speed Flapping, therefore, contributes to longitudinal stability

Nearly all early helicopters used pairs of rotating systems, though since the advent of the autogiro the common form has been a single rotating system with articulated blades Feathering blades have been used with some success and they and lift controlling devices at the blade tips are beginning to be developed once again Feathering blades, indeed, are becoming of much greater interest One of the disadvantages of flapping is that it introduces a dissymmetry in the plane of rotation As a result of the tilt of the tip path plane with respect to the axis of rotation due to flapping and the upward coning of the blades, there is a geometrical dissymmetry in the plane at right-angles to the axis of rotation This makes it necessary to introduce a drag hinge which, together with the flapping hinge, constitutes a universal joint The natural frequency of oscillation about the drag hinge makes it necessary to introduce some form of damping, and either friction or hydraulic dampers have commonly been used This damping, however, restricts the freedom of movement otherwise provided by the universal joint and periodic bending moments are re-introduced at the blade root There is no such dissymmetry with a feathering rotor and so no drag hinge is necessary The introduction of the drag hinge, which gives an additional degree of freedom of oscillation for each blade, has probably been responsible for more vibration troubles than any other step taken during the development of the rotating wing, and it may be that if the same amount of development work had been applied to feathering blades, instead of flapping blades with a drag hinge, many of the troubles which have delayed the development might have been avoided

It should be pointed out that even with flapping blades, it is possible to maintain symmetry in the plane of rotation by mounting the hub on a universal joint and allowing the axis of rotation to tilt with the tip path plane, so that the axis of the hub and of the tip path are always coincident

CONTROL

In early helicopters control was sometimes sought either by surfaces hanging in the downwash from the rotors, by differential changes of blade angles between the pairs of rotors, causing differences in the lift of the individual rotors, by a cyclic change of blade angle which gives control by tilting the lift vector in the appropriate sense by tilting the whole rotor in the desired direction, or by variable pitch airscrews or rotors mounted about appropriate axes The only one of these methods which is poor is the first one, since it not only introduces extra weight and drag due to the surfaces and the structure necessary to support them but it is ineffective when the rotor is in autorotation in the event of power unit failure, since the air flow over the surfaces is then in the opposite direction and the pilot's controls become inverted All the other methods are in use in practical helicopters which are now flying, the only new method being that of cyclcic variation of the lift characteristics of the blade by lift increasing devices, such as flaps, instead of the cyclic variation of blade angle

STABILITY

The subject of the stability of helicopters is far too large a subject to deal with in a paper of this character and a whole series of papers could be devoted to this one subject I shall content myself merely with pointing out any special features on the helicopters which I shall describe, which have a bearing on the stability problem

ANTI-TORQUE CONTROL

Whenever we have a rotor driven by an engine through gearing, we have a torque reaction which would result in the fuselage turning about the rotor axis in a direction opposite to that of the rotor itself The methods used to overcome this torque reaction are characteristic, and they afford a means of classifying helicopters which I shall use in drawing a historical picture of the development

The expedient of employing two rotors rotating in opposite senses is perhaps the simplest of all means of dealing with torque reaction, and it has been used on many helicopters It has the merit not only of balancing the torque reaction from the individual screws, but also of eliminating the rolling moment in translation There are several possible configurations of pairs of rotors all of which have been used from time to time Up to the size within which we can build a practical rotor the single rotor is the most attractive though it introduces special problems of its own in arranging for torque balance

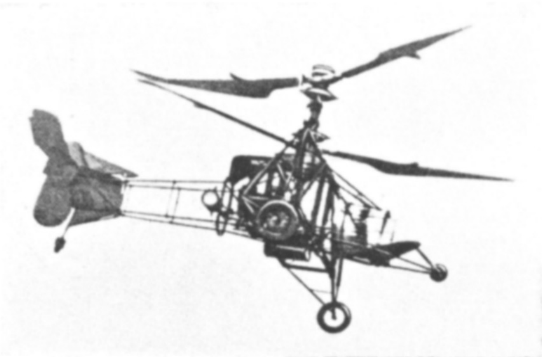
The alternative methods which have been used for balancing rotor torque are presented in what follows, and photographs of representative aircraft are reproduced

I **Twin Superimposed Co-axial Rotors** Examples are —

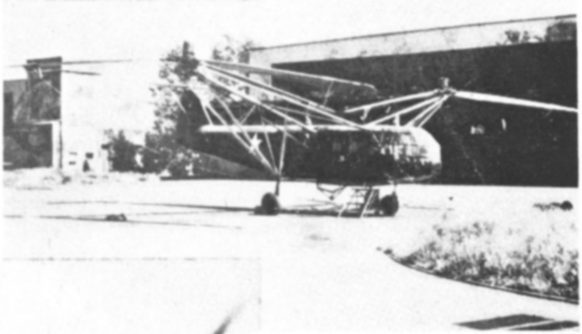
(a) *Breguet* Even so long ago as 1907, Monsieur Louis Breguet built a helicopter with four lifting screws each consisting of four biplane blades So far as I am aware, this was the very first helicopter which could lift itself and its pilot In 1931 Breguet, who in the meantime had become famous as a builder of conventional aeroplanes, returned to the helicopter and, in collaboration with Monsieur Dorand he built another also with two co-axial rotors He achieved considerable success and the aircraft made many flights both in hovering and in translation up to a speed of some 50 m p h

(b) *Berliner* In 1905 Emile Berliner in America had tried to build a helicopter with two co-axial rotors but without any success In 1920 he and his son Henri built and flew another of the same type, which, however, was lacking in stability and control Three years afterwards the son built yet another This aircraft was derived from a Nieuport monoplane by replacing the wing by two lifting screws, one on each side The elevator was supplemented by an auxiliary propeller mounted on a vertical axis and lateral control was effected by vertically movable flaps in the downwash from the rotors Little success was achieved, though during its flight trials the aircraft rose to a height of some 2 ft and made hops up to 30 yds at a speed of some 30 m p h

(c) *Pescara* Between 1920 and 1925 Pescara constructed four helicopters all of the same general type They had two superimposed co-axial lifting systems, the early ones with six



An early Breguet machine



The Focke F A 223

The Piasecki P V 3

The Flettner Fl 282

and the later ones with four biplane blades which could be warped either all blades together or cyclically By warping the blades at the moment when they passed through any desired azimuth, the lift vector was displaced in azimuth towards the side where the blade angle was increased and so a moment giving control in the desired direction was produced The same principle was used for inclining the axis of the aircraft, in order to obtain a horizontal component of the total lift to provide translation in the desired direction By warping the two rotors differentially he obtained a yawing moment to turn the aircraft in the desired direction Pescara was also one of the first to understand the principle of autorotation and, with the blades at a small angle of incidence, his aircraft were able to descend freely and under control in the event of engine failure It will be seen that these helicopters satisfied practically all the desiderata which I have mentioned The main fault, as in all other twin superimposed systems, was that they were unstable

In 1924 the second of these helicopters put up very interesting performances, flying up to 700 yards in horizontal flight and staying in the air up to a maximum of 12 minutes

(d) *Karman Petrosczy* This helicopter was produced during the 1914-1918 war to replace kite balloons for observation purposes Its construction was carried out under the direction of Professor von Karman the wellknown aerodynamic technician, and the lifting screws were designed by Herr Asboth whose work will be described later

It consisted essentially of two superimposed wooden propellers, driven in the first place by an electric motor and subsequently by three 120 h p Le Rhone engines No control was provided and stability was assured by a 3-cable mooring system With Le Rhone engines the weight was 3,520 lb of which 660 lb was useful load, and the screws were 19 8 ft in diameter It rose to heights up to 150 ft and stayed in the air for considerable periods, the maximum being one hour

(e) *D Ascanio* This helicopter created history in 1930 by being the first to make a record recognised by the Federation Internationale in the Helicopter class The following performances officially recognised by the F A I —Vertical ascent to 60 ft , a straight flight of 560 yards, a duration of 8¾ mins , and a closed circuit over 1 kilometre

The aircraft had two superimposed co-axial 2-bladed rotors each of 39 ft diameter turning in opposite senses The blades were articulated, being free to flap by being mounted on a horizontal hinge, and they also had freedom in pitch They were stablised by a small tailplane at the blade tip and their angle was controlled by an elevator The aircraft also had three small auxiliary variable pitch screws, one vertical on one side to provide yawing control, the others horizontal—one at the side to give lateral control and the other on the tail for longitudinal control and to tilt the aircraft for forward flight The aircraft weighed 1,680 lb and the engine developed 95 horsepower

(f) *Asboth* Asboth, to whom I have referred earlier in connection with the design of the lifting screws of the Karman Petrosczy helicopter successfully built and flew four helicopters The fourth aircraft, built in 1928 had two wooden screws mounted co-axially Control was provided by six surfaces movable about horizontal hinges and hanging in the downwash from the screws I had the great pleasure of personally carrying out flight trials on this helicopter and I found that it was stable and controllable, could make a vertical ascent at about 300 ft per min and could hover indefinitely The maximum height attained during trials was about 100 ft , the maximum distance some 3,000 yds at a speed of the order of 12 m p h The aircraft was very crude indeed, but it achieved considerable success, the one feature which was lacking being that no provision was made for a safe landing in the event of engine failure Asboth, however, was convinced that if he had had a free wheel incorporated, his special fixed pitch screws would have remained in autorotation and that a safe rate of descent would have been achieved The aircraft weighed 1,080 lb , the screws were each 14 ft in diameter and the engine developed about 110 h p

2 Pairs of Rotors Side by Side

(a) *De Bothezat* In 1921 de Bothezat built the first helicopter ordered by the U S Army Air Force It was a very crude affair but, nevertheless, it carried out many flight trials, and in 1923 it actually lifted a pilot plus passenger It was too heavy, very complex and unstable

(b) *Oemichen* In 1920 Oemichen constructed a helicopter which consisted of a fuselage carrying an engine driving two lifting screws each of two blades The sustaining screws were 20 8 ft in diameter, the engine developed 25 h p and the total weight was 750 lb The aircraft was not able to lift itself and a small balloon was added, therefore, partly to give the necessary extra lift and partly to stablilise it With the balloon fitted a number of elementary flights were made the maximum height reached being 16 ft and the distance in horizontal flight 60 yds Following on this early attempt, Oemichen built a second helicopter consisting of four lifting systems with five auxiliary variable pitch airscrews for control with two propellers for propulsion and an additional screw in front for yawing control This helicopter is historic because in May, 1923, it successfully made several flights of from 600 to 700 yds , hovered for 5 minutes over a fixed point and in May, 1924, was the first to cover an officially observed closed circuit of one kilometre The maximum performance actually realised was a flight of 14 mins , a maximum height of 50 ft and a maximum distance of 1,850 yds , carrying a useful load of 440 lb in addition to the pilot

(c) *Focke* The first satisfactory helicopter was the Focke Achgelis type 61 which was demonstrated in Berlin in 1937 The blades were articulated and cyclic pitch control was used for longitudinal and directional control For lateral control the angles of all the blades of one rotor were increased, while the angle of all the blades on the other rotor was decreased The aircraft weighed some 2,300 lb and the engine developed 160 h p It held the following records recognised by the F A I —

Height, 8,000 ft
Time 1 hr 20 mins 50 sec
Speed, 76 m p h
Distance in closed circuit 50 miles
Distance cross country 143 miles

In 1938 Luft Hansa had ordered a civil 6-seater helicopter from Focke and during the war this type was developed into a military type, the FA 223 Its characteristics were —

Empty weight, 7,200 lb
Normal useful load, 1,300 lb
Max useful load 2,300 lb
Horsepower, 1,000 b h p
Dia of each rotor, 39 ft
Max speed, 110 m p h
Cruising speed, 80 m p h
Eudurance, 3 hrs

During the war also Focke had commenced the design of a large weight carrying type the FA 284 This type was intended to carry armoured cars, small tanks etc , across rivers and act as a mobile crane for lifting bridge girders into place

Its estimated characteristics were —

Horsepower, 2 BWM 801 engines each developing 1,000 h p
Dia of each rotor, 59 ft
Empty weight, 18,000 lb
Fuel and oil, 1,560 lb
Crew, 440 lb
Max freight load, 15 200 lb
Total weight, 35,200 lb

This project was abandoned, after a good deal of design had been done, in favour of the simpler alternative of building two FA 223 lifting systems on to a common fuselage This aircraft also was never built

(d) *G J Weir Ltd* Quite independently of Focke and at about the same time a small single seater helicopter of the same general type as the Focke was built in Glasgow by Messrs G & J Weir, Ltd , who were associated with the Cierva Autogiro Co Their designer was Mr C G Pullin In 1939 they also built a bigger 2-seater aircraft with a Gipsy 200 h p engine This aircraft flew successfully and was intended to be the basis of yet a bigger design to fulfil a definite operational duty Unfortunately, owing to the war position, this project had to be abandoned

(e) *Platt-le Page* Following the success of the Focke Achgelis type 61, the U S Army Air Corps ordered its second helicopter from Platt-le Page The aircraft the XRI was engined by a Wasp Junior developing 450 h p and weighed about 5,500 lb Control, as usual, is by cyclic pitch control of the blades The aircraft made its flight trials in 1943 but, in spite of many tests including several flights of quite long duration, it is not yet developed into an entirely satisfactory type, and official interest in America seems to be waning

(f) *Landgraf* A most interesting type with twin side-by-side rotors is the Landgraf It is only a small single seater with a Pobjoy 85 h p engine and weighing 850 lb , being intended only as a laboratory aircraft to test out principles and to gain experience on which bigger aircraft could be designed It has a maximum speed of 135 m p h cruising speed of 100 m p h and an endurance of 1½ hrs It differs from almost all other helicopters in that the blades are rigid and that instead of cyclic pitch change of the blades—a method which tilts the lift vector—the blades are fitted with ailerons at the tips These ailerons are deflected cyclically, so displacing the lift vector in the required sense to give either the desired control or translation The arrangement has the merit that the centre of gravity can be located even at 15% of the rotor diameter in advance of its axis of rotation, and that it is stable longitudinally

Trimming for variation of centre of gravity position is simple and the response to control is positive without the lag which is characteristic of cyclic pitch control

3 Rotors in Tandem

(a) *Florine* Very great interest was created at the Antwerp Exhibition of 1930 by the Florine Helicopter In this aircraft the two rotors, as distinct from all other helicopters with twin rotors, turned in the same sense The torque reaction was balanced by tilting the rotor axis one to one side the other to the opposite

(b) *Piasecki* Piasecki, a young American engineer, built a small helicopter of the same general type as the Sikorsky, and he achieved such success that he was given an order for a cargo helicopter the now well known PV3 by the American Navy Bureau

The estimated characteristics of the aircraft are —

Horsepower, 550
Dia of each rotor, 41 ft
Empty weight, 4,300 lb
Freight load, 1,000 lb
Total weight, 6,400 lb
Max speed, 110 m p h
Cruising speed, 84 m p h
Endurance, 3½ hours

This solution is of considerable interest, since it permits us to build bigger helicopters economically, by using two of the rotors complete with power units and transmissions from smaller types already developed The configuration itself is also attractive, since it is stable longitudinally and permits longitudinal trimming over a wide range of movement of the centre of gravity

4 Two Intermeshing Rotors

About 1938 the Cierva Autogiro Co and Dr Bennett their Chief Technician, had proposed that in the interest of reduction of size, weight and drag, the hubs of the side-by-side arrangement should be brought close together with an angle between the axes to ensure that the blade would not foul during flight This type was never built in Great Britain but the following examples have been built elsewhere

(a) *Flettner* During the recent war, Flettner in Germany constructed a small 2-seater with two intermeshing 2-bladed rotors, known as the Fl 282 It was intended to operate from cruisers for observation purposes

Its characteristics are —

Engine, 140 h p
Dia of each rotor 39 5 ft
Empty weight, 1,400 lb
Gross weight, 2,200 lb
Max speed, 90 m p h
Vertical rate of climb 300 ft per min
Hovering ceiling 1,000 ft

(b) *Kellett* The Kellett Co in America, who were licencees of the Autogiro Co of America, have also constructed an aircraft, the XR 8, with intermeshing rotors to which the name Synchropter " has been given Its estimated chracteristics are —

Engine power, 250 b h p
Empty weight, 2,140 lb
Useful load, 650 lb
Total weight, 2,790 lb
Max speed, 105 m p h
Cruising speed, 85 m p h
Hovering ceiling, 3 000 ft
Max ceiling in translation, 13,500 ft

Kellett is also building a bigger aircraft, the type XR 10, which is estimated to have the following characteristics —

Engines 2, each developing 525 h p
Dia of each rotor, 65 ft
Empty weight, 7,500 lb
Useful load, 2,800 lb
Total weight, 10,300 lb
Max speed, 125 m p h
Cruising speed, 90 m p h
Endurance, 3 hrs (for increased duration auxiliary tanks are provided, increasing the endurance to 6½ hrs)
Hovering ceiling, 6,000 ft
Max ceiling, 20,000 ft

(Note —In the other load case with normal fuel and maximum freight of 3,750 lb , the total weight is 13,500 lb)

5 A Single Rotor with Auxiliary Tail Rotor

As has been pointed out, the autogiro provided a major contribution to the development of the helicopter The autogiro possesses all the characteristics required by the helicopter and, indeed, in its final form of which the Cierva type C 40 and Hafner's Gyroplane are examples, it was in fact a helicopter for several seconds during take-off For vertical take-off in these types, the rotor was over revved with the blades at a small angle, then the blade angle was suddenly increased and the aircraft jumped in true helicopter style After the initial jump the blade angles were returned to the autorotative setting and the aircraft continued in flight as a normal autogiro

It is not a matter for surprise, therefore, that the helicopters which so far have given the greatest success have been those like the Sikorsky, which have a single articulated rotor with an auxiliary rotor at the tail to provide torque balance

This configuration is not new, since in 1925 von Baumhauer in Holland constructed a helicopter of this type but he used rigid blades and although the aircraft was able to rise some few feet and to hover for periods up to 5 minutes, it never achieved really practical results

Oemichen's third helicopter built in 1928 used a similar arrangement, though, in his case, he provided two lateral auxiliary propellers, one at the nose and one at the tail on opposite sides so as to obtain yawing couple rather than a moment

(a) *Sikorsky* It was left for Sikorsky to develop this type into a really practical helicopter and to create, not only in America but throughout the world, an enormous interest in the problems connectd with the helicopter

In 1909 Sikorsky had designed a helicopter without any success and he turned to the conventional aeroplane, for which he is very well known In 1938, however, he returned to the study of the helicopter His first type had a single articulated rotor with three variable pitch rotors at the tail, one turning in the vertical plane was to balance torque reaction, and the two others turning in horizontal planes were for longitudinal and lateral control   This type was entirely satisfactory and it broke all existing world records   In spite of this success, it was in fact only a flying laboratory, and during development the two horizontal auxiliary rotors were replaced by a single rotor for longitudinal control, and cyclic pitch control was introduced for lateral control   This change brought about such a great improvement in the flying characteristics of the aircraft, particularly in its control, that in the the final form cyclic pitch control was used for both longitudinal and lateral control   By the end of the war Sikorsky had built three different types in addition to the laboratory aircraft, known as R 4, R 5 and R 6, of which the two latter were put into full scale production

The R 4, which is probably the best known of all helicopters today   is a 2-seater with an engine developing 185 h p   Its normal flying weight is about 2 600 lb   including a useful load of 550 lb   Its maximum speed is 82 miles per hour and its cruising speed 70 m p h   The diameter of the main rotor is 38 ft   This aircraft, which is largely experimental, is under powered and it can only hover at a height comparable with its rotor diameter, i e , within the ground cushion   In translation, however, its ceiling is of the order of 9,000 ft

R 6 —This is only a refined version of the R 4   Its characteristics are —

Engine, 240 h p
Normal weight, 2,650 lb
Useful load, 585 lb
Max speed, 94 m p h
Cruising speed, 80 m p h
Main rotor dia , 38 ft
Max ceiling in translation, 15,000 ft

R 5 —This is a bigger aircraft, the first one ever to be designed to fulfil an operational function, i e , to carry hydrostatic bombs for operation against submarines, and as a means of protecting convoys   Its characteristics are —

Engine, 450 h p
Normal weight, 4,950 lb
Useful load, 1,100 lb
Endurance, 4 hrs
Max speed, 106 m p h
Cruising speed, 90 m p h
Hovering ceiling, 2,000 ft
Max ceiling in translation, 14,500 ft
Main rotor dia , 48 ft

Later Sikorsky modified the R 5 installing a bigger engine developing 500 h p   and with a cabin accommodating six passengers   In this case, he returned to his original idea of a second horizontal tail rotor for longitudinal control   He did this, not only to improve longitudinal control and stability, but also to give a means of trimming the aircraft for variations in c g   position   It is understood that Sikorsky has abandoned this type and instead is building a straightforward civil version of the R 5   i e   with normal cyclic pitch control and a single tail rotor for torque balance   It is this type, known as the S 51 which has recently been awarded the American Civil Airworthiness Certificate

(b) *Bell*   Another interesting American design of the same general configuration is the Bell which has several important characteristics   Contrary to almost all other helicopters, this type has a single rotor of 2 blades only, the blades being rigid This type of rotor suffers from severe vibration In the Bell type this is not permitted to reach the fuselage and passengers, since the rotor and power unit are mounted on flexible rubber mountings The rotor is mounted universally on a pylon and, as the method of cyclic pitch control is used, the hub tilts with application of control The special characteristic of the rotor is the means adopted for stabilising This consists of a weighted rod at right angles to the blades and mounted on a horizontal axis This rod is connected to the cyclic pitch control mechanism and, acting as a gyroscope, controls the attitude of the rotor in spite of any inclination of its axis while at the same time, the cyclic pitch control can still incline the rotor for control purposes at the will of the pilot The control and stability of the Bell helicopter are reported to be very good indeed A small 2-seater of this configuration is being put into production and has obtained an American Certificate of Airworthiness and a bigger type weighing 4,800 lb with an engine developing 450 h p , accommodating a pilot and four passengers, is also undergoing flight trials Information on this aircraft is not complete, but it would appear that with a bigger rotor considerable vibration troubles are being experienced

(c) *Hafner* Many years ago, Hafner constructed a helicopter with very little success From flight trials on this aircraft, he appreciated the control problems facing the helicopter designer and he turned to the autogiro as the simplest rotating wing type on which to develop his ideas He arrived at his well known Gyroplane which used cyclic pitch control and gave extremely good performance He has now returned to the helicopter and is designing a 4-seater with an engine of 450 h p Its most interesting characteristic perhaps is that, as in his Gyroplane, the blades are mounted on a group of torsional rods which not only give a frictionless feathering hinge, but also give a torsional restoring moment which stabilises the blade

(d) A variant of this general type has been proposed by Dr Bennett, in which the auxiliary tail rotor is arranged to autorotate in the downwash from the main rotor In this way, perhaps, we might eliminate the power loss which is associated with the tail rotor of the Sikorsky configuration

6 Single Rotor with Off-Set Tractor Propeller

This type is a variation of the general Sikorsky configuration which has been proposed by Dr Bennett In this arrangement the propeller which is used to balance torque reaction, is mounted as a tractor on a stub wing at the side of the aircraft Power for balancing torque reaction in cruising flight is thus reduced and the torque correcting propeller also contributes tractive forces for translational flight The efficiency of the aircraft in flight is thus improved and the price paid is that the power for compensating torque reaction is increased during hovering As the proportion of the total flight which is spent in hovering is relatively small this loss of power is of little account

As this type of helicopter is half-way between the autogiro and the true helicopter, it has been given the name 'Gyrodyne' The main points in favour of this configuration are —

(a) Because it uses the torque correcting thrust for forward propulsion, it eliminates the power losses inevitably associated with all other methods of torque balance

(b) The rotor disc is little if ever forwardly inclined, even at top speed, and there is thus no need to increase the blade angles to compensate for the reduced angle of attack which is caused by the axial flow through the rotor This has two very definite advantages

  (i) The blade angles are always within the autorotational regime, so that autorotation is automatic in the event of power unit failure

  (ii) It eliminates the possibility of blade tip stalling and the dissymmetry associated with a tilt of the tip path plane so that while a true helicopter becomes progressively rougher and less efficient with increasing speed, the Gyrodyne remains as smooth and as efficient as the autogiro under all flight conditions

It can be disclosed that a 4-seater Gyrodyne is at present under construction but it is not permissible to give details

7 A Single Rotor with Surfaces in the Downwash from the Main Rotor

About 1938 Hafner was designing a helicopter with a rotor of low solidity and high rotational speed, in which the fuselage was of twisted aerofoil shape in order to provide torque balance Owing to war conditions, this type was not completed

8 A Single Rotor with Jet Reaction at the Tail

An example of this type of helicopter is one designed by Mr C G Pullin and constructed by the Cierva Autogiro Co, which is now undergoing its trials Quite apart from the jet reaction at the tail, this type is of interest because control is obtained by tilting the entire hub which is mounted on a spherical joint of the "constant velocity" type, and that the articulations are of the type with two inter-coupled hinges so arranged that any tendency of the blades to flap is converted into pitch change This arrangement was proposed in order to get a rotor which would be automatically stable in gusts

9 A Single Torqueless Rotor

The most attractive single rotor helicopter, because of its mechanical simplicity, would be one with jet reaction motors at the tips of the blade, because, in that case, there would be no torque reaction and no need for any torque balancing device which inevitably involves some loss of power It is also advantageous in that it eliminates clutches, free wheels, gearing and transmissions, and so reduces the bare weight of the aircraft

One of the first to realise the advantage of this type was Monsieur Isacco, but, in the absence of jet reaction devices, he was forced to use reciprocating engines with propellers mounted on the blades In his type, each blade was essentially a small monoplane with its own aerodynamic controls and power units mounted universally on a hub and so constrained to move in a circular path Isacco called this type the 'Helicogyre'

The first aircraft which he constructed was a single seater with a 2-bladed rotor 41 ft diameter, each blade carrying a small engine developing 30 h p I had the great pleasure of personally carrying out flight tests on this aircraft and I can say that, weighing 1,320 lbs , it was just capable of hovering close to the ground I was not able to attempt free flight in the open, but my tests were made in a large airship shed, and with quite a small forward velocity I was able to get the aircraft airborne, when it proved to b stable and controllable Isacco, in point of fact, never intended this type to be a true helicopter, i e capable of hovering, but rather postulated that it should always have a small forward speed which, of course, greatly increases lift efficiency and, for this reason and with the same underlying idea as in the Gyrodyne, he fitted a forward tractor engine and propeller, so that the rotor axis should always remain vertical

Another aircraft of this type was built in Great Britain in 1929 this time with a 49 ft diameter rotor with four blades each with an engine of 40 h p The total weight was 2,420 lb and it proved to be just capable of supporting itself close to the ground Its trials, unfortunately, had to be terminated because the engines would not run for more than a few minutes because of difficulties of lubrication and carburation, due to the intense centrifugal field in which they were operating

One has to admit, I think, that Isacco was in advance of his time and that if he had had satisfactory power units, his type could have flown satisfactorily

Nagler-Rolz During the war Nagler and Rolz in Austria built a baby helicopter of this same general type It had a 2-bladed rotor 13 ft diameter each blade carrying an 8 h p engine The gross weight including 220 lb for pilot and fuel, was 312 lb The designed forward speed was 50 m p h and the estimated vertical climb 480 ft per min

During the war many inventors have tried to use jet reaction, but the only aircraft within my knowledge which has flown successfully is the Doblhoff, also constructed in Austria The principle employed here was to drive a compressor from a normal reciprocating engine The compressed air was mixed with petrol vapour and the gases ducted to the blade tips where they were burned in combustion chambers This aircraft had undergone some 25 hrs testing in hovering flight and made a few flights in translation up to some 20 m p h The main disadvantage was that the fuel consumption was prohibitively high Until it was found possible by development to bring down the fuel consumption to a more reasonable level, it was Doblhoff's intention to fit a propulsive screw which could be clutched in as required The jet would then only be used for landing and take-off as a helicopter, the aircraft being flown as an autogiro in cruising flight

10 **Oscillating Rotors**

A method of driving rotors which would be free from the usual torque reaction was suggested some years ago by Count Korwin He proposed a pair of articulated rotors mounted co-axially and in which the two rotors were oscillated along their axes The claim was made that not only would this provide a drive for the rotors, but that the flapping of the rotors would give an increased contribution to lift This, of course, is not true, and the method is not likely to be practicable though it is of interest as showing another method for a torqueless drive

In proposing a vote of thanks for this Inaugural Lecture, The Chairman, Mr H A Marsh, felt all would agree that it was a very good beginning to the Association's activities The Sikorsky film was then shown