The Fairey Gyrodyne

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A lecture presented to The Helicopter Association of Great Britain on Saturday, July 10th, 1948, at Heston Aerodrome, Middlesex

H A MARSH, A F C, A F R Ae S, IN THE CHAIR

INTRODUCTION BY THE CHAIRMAN

HESTON, SATURDAY, 10TH JULY, 1948

Ladies and Gentlemen,

I am sure you will agree that it is quite unnecessary for me to introduce DR BENNETT formally He has previously lectured before the Helicopter Association, to say nothing of numerous lectures to learned Societies both at home and abroad I also feel quite certain that most of you are familiar with his background in the rotary wing field of aviation

On behalf of all Association Members and their guests, I should like to thank the Directors of the Fairey Aviation Company for their kindness and hospitality to us today, and also thank those members of the Fairey Company Helicopter Division whose work has made this visit possible

Finally, on behalf of the Association, may I congratulate the Fairey Aviation Company again, together with all those responsible, for the excellent show in their recent successful attempt to raise the Helicopter world speed record Personally, I feel that given the right conditions they are quite capable of increasing this record still further

DR J A J BENNETT

MR CHAIRMAN, LADIES AND GENTLEMEN I should like to say on behalf of my colleagues of the Fairey Aviation Co and myself that it is both a pleasure and an honour to have you here this afternoon, especially as this is the first meeting of the Association at which a helicopter has been available for demonstration It is perhaps appropriate that this helicopter is one of

British configuration and construction, and in fact is the only one existing in which also a British power unit is installed I should mention at the outset that full credit should be given to the Fairey Company for their firm belief in the gyrodyne principle from the beginning and for having sufficient faith in their own judgment to sponsor it entirely as a private venture

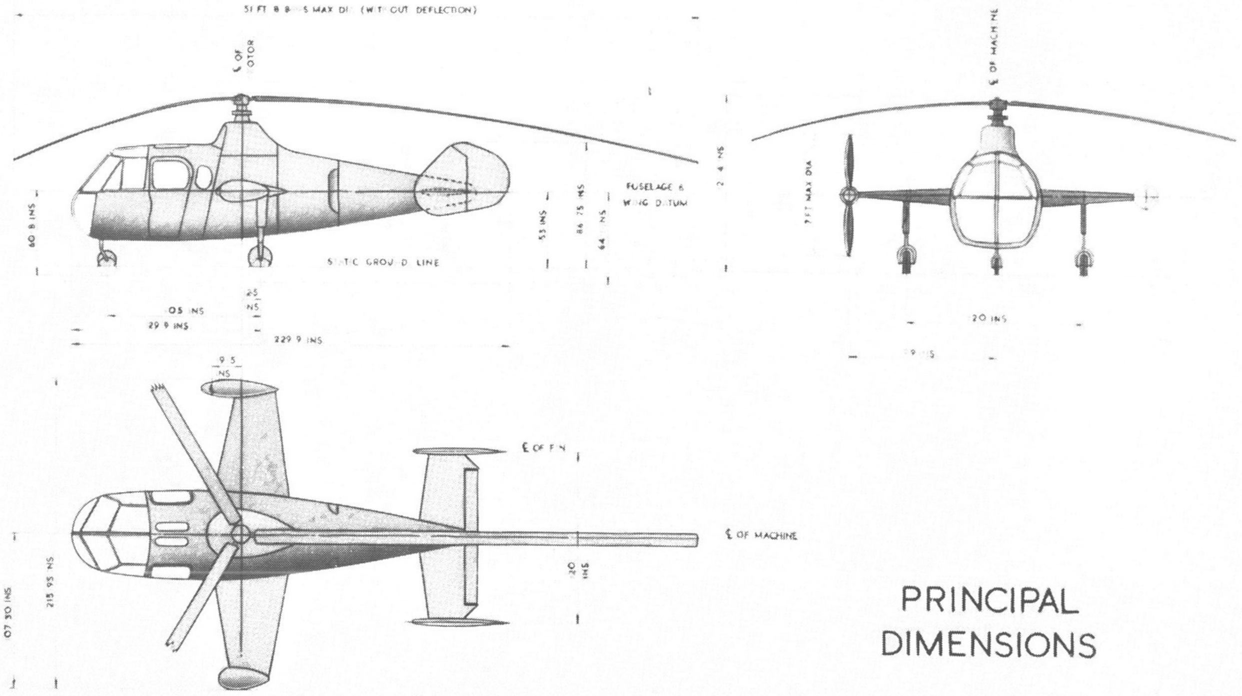
The conception of the gyrodyne originated in this country shortly before the War, to fulfil a Naval requirement for a rotary-wing aircraft capable of operating from the deck of a ship It is true that the possibilities of the gyrodyne gained immediate recognition by the award of a contract from the Air Ministry, but the War intervened and it was not untill 1946 that the development of the gyrodyne really commenced During the intervening period the helicopter became a fully-fledged flying machine incorporating certain features of the gyrodyne, *viz*, the aerodynamic asymmetry of a single lifting rotor in torque balance with a single non-lifting airscrew, the variation of power distribution between branch transmission systems, and lastly the direct control from foot pedals of the collective pitch of the non-lifting airscrew for effecting control of the aircraft in yaw All of these gyrodyne features have become standard practice in helicopter design

Where the gyrodyne differs in principle from the standard form of helicopter is in the azimuth location of the non-lifting airscrew At first sight this might appear to be a matter of minor importance, any position in azimuth from zero to 360° being as good as any other, the choice being determined merely by a desire to mount the non-lifting airscrew as far as possible from the axis of the lifting rotor, thereby keeping the power absorbed by the non-lifting airscrew at a minimum, and the power applied to the lifting rotor at a maximum The gyrodyne, on the contrary, aims at keeping the rotor power as low as possible and utilises the remainder for the useful purpose of forward propulsion Although part of this remainder is used normally for torque balance in hovering flight, the whole of the remainder is available always as a reserve for vertical climb under abnormal circumstances A slow rotation of the fuselage in vertical climb can effect a considerable change in power distribution between the propeller and the rotor Consequently, vertical climb can be temporarily boosted whenever necessary

What is a " Gyrodyne "

According to the British Standard Glossary of Aeronautical Terms, aircraft are classified into two separate categories, " aerodynes " and " aerostats," an aerodyne being a heavier-than-air aircraft A gyrodyne, therefore, is a kind of gyratory aerodyne In other words, a gyrodyne is a form of helicopter in which the rotating wings are basically the sole means of sustentation but not necessarily of propulsion, the main objective being to keep the power transmitted to the rotor as low as possible and thereby provide greater safety in operation It so happens that the steps taken in the design of this form of helicopter to enhance its safety result also in a higher top speed, though speed is considered of secondary importance to safety The higher the forward speed, the less proportion of the total power is delivered to the rotor Hence the main transmission is not so highly stressed at top speed as at slower speeds, thus ensuring a higher factor of safety

A further safety feature of the present gyrodyne is its low-pitch operation under all conditions of flight and, with its relatively low disc loading, it



PRINCIPAL DIMENSIONS

Early flight trials at Heston

possesses well-proven qualities of the gyroplane which the helicopter should seek to retain It is regrettable that present-day helicopters should have sacrificed safety to such a degree that the Parliamentary Secretary of the Ministry of Civil Aviation was obliged recently to refer to the matter in the House of Commons While we do not entirely agree with the statement made on that occasion, the high-pitch operation of helicopters is a definite source of danger, but it should not be assumed that all helicopters are necessarily dangerous The gyrodyne, by keeping rotor power, disc loading and pitch as low as possible, increases the margin of safety

The Gyrodyne Principle

Attempts have been made in the past to discover a method of propulsion for helicopters so that the tip-path plane should remain horizontal in level flight Probably the nearest approach to the gyrodyne was an arrangement described by OEHMICHEN in which translational flight was effected by differential variation of the thrust of a group of propellers The use of a single propeller was discarded, however, because the machine would be unable to hover owing to the unbalanced thrust of the propeller The gyrodyne does not attempt to keep the tip-path plane horizontal under all conditions of flight, nor to maintain constant power distribution between rotor and propeller The single outboard propeller maintains torque balance, not only with varying rotor torque, but at zero forward speed, in which case the tip-path plane is inclined backwards so that the forward thrust of the propeller is balanced by the backward component of the rotor thrust

Translational speed is achieved by decreasing this backward inclination of the tip-path plane and not until a fairly high forward speed has been attained does the tip-path plane assume a horizontal attitude Beyond this forward speed, of course, the tip-path plane has a slight forward inclination In other words, the normal operating condition of the gyrodyne is with both the fuselage and the tip-path plane substantially level

Periodic blade-tip stall

At one time it was thought that the better propulsive efficiency of a driven sustaining rotor compared with that of a propeller would result in a higher top speed for the helicopter than for the gyroplane In this respect the helicopter has not come up to expectations A bugbear of the helicopter, affecting its propulsive efficiency in forward flight, has been the periodic blade-tip stall This shortcoming is minimised in the gyrodyne

Perhaps this point is best explained by considering the axial component of flow through the rotor disc, *i e*, the flow of air in a direction perpendicular to the tip-path plane The autorotative rotor of the gyroplane is inclined at a positive angle of incidence with respect to the flight path and the rotor is kept rotating by the axial component of flow which, in this case, is directed upward relatively to the tip-path plane A change in axial flow does not alter the blade angle of attack equally from root to tip, but affects the root portion of the blade most Hence, an increase in axial flow merely extends the periodic stall at the blade root and the operation of the rotor remains fairly smooth, though, of course, if too great a proportion of the blade becomes stalled, the vibration from the rotor may be excessive

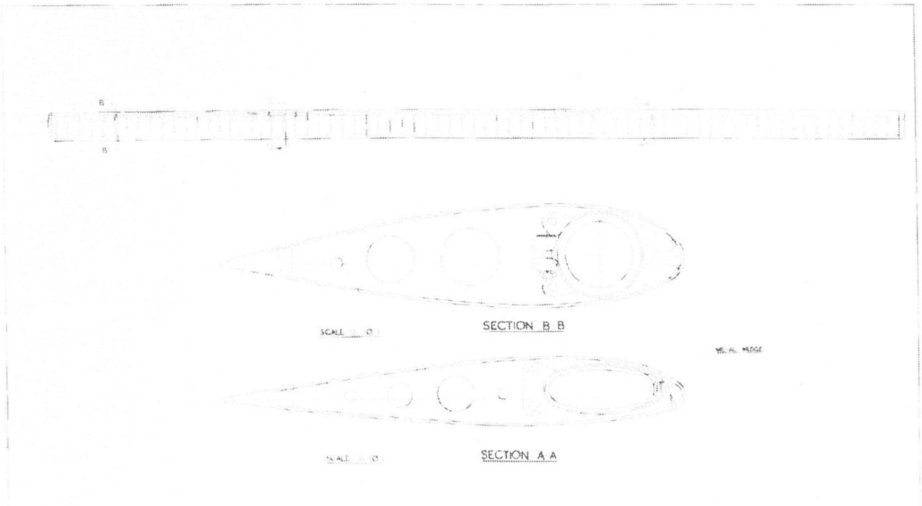
Basic Limitation of Forwardly-Inclined Rotor

The periodic blade-root stall of the autorotative rotor, however, is relatively innocuous in comparison with the blade-tip stall occurring when the rotor thrust of the helicopter is inclined forwardly for propulsion The rotor disc then makes a negative angle of incidence with respect to the flight path, as a result of which the axial flow through the rotor increases with forward speed To compensate for the reduced angle of attack caused by the increased axial flow, the blade angle has to be increased and at a high forward speed it is generally greater than the maximum value at which the rotor would autorotate in power-off flight Hence, in the event of power failure the blade angle must be quickly decreased to prevent the blades from losing their kinetic energy and stalling, though, on the other hand, a sudden large reduction in pitch may be extremely dangerous

The effect of the increased axial flow on smoothness of operation of the rotor is more marked than in the gyroplane because, in the helicopter with the rotor forwardly inclined, the axial flow is downward and an increase in axial flow affects the tip portion of the blade least Consequently, when the mean collective pitch is increased to compensate for the increased axial flow, the blade angle at the tip is excessive and the blade tip approaches the stall cyclically at high translational speeds, especially as the angle of attack on the retreating blade is already high due to blade flapping or cyclic feathering resulting from the aerodynamic dissymmetry of forward flight The helicopter rotor, therefore, becomes rough in operation at high pitch in forward flight, though it may be quite smooth at the same forward speed in auto-rotative flight

Advantages of low pitch

It may be argued that there is no need for the helicopter to travel fast , there are plenty of uses awaiting slow-speed machines for some time to come But even if one neglects the possibilities of increased speed offered by the gyrodyne principle, the smoothness associated with low-pitch operation is in itself a desirable attribute It is unnecessary to exceed the maximum



ROTOR BLADE CONSTRUCTION

autorotative blade angle to compensate for an increased axial flow resulting from a forward inclination of the rotor. In other words, the propulsive powered-rotor departs too far from the satisfactory condition of operation of the autorotative rotor, and the relatively non-propulsive powered-rotor of the gyrodyne avoids the limitations of the two extremes.

Automatic pitch variation

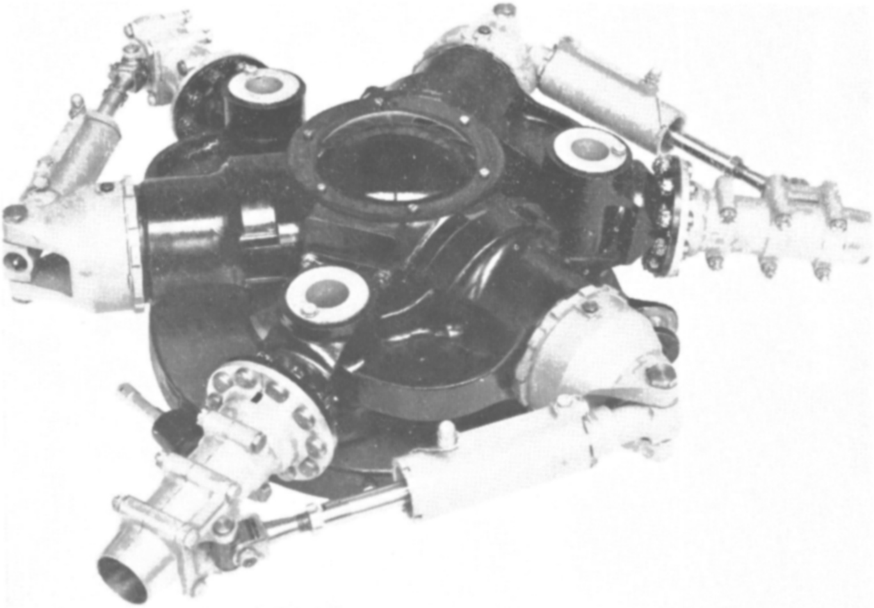
Apart from the novelty of the gyrodyne configuration, the Fairey prototype incorporates a number of novel features, with regard to which patents are pending in a number of countries. Blade torsional bearings are eliminated entirely, and collective pitch change is effected automatically about the flapping and drag articulations. There are no flight controls other than stick, throttle and foot pedals. At the request of the Ministry of Supply, however, an alternative hub arrangement has been designed incorporating an over-riding collective-pitch control mainly for trim purposes at altitude and this will be evaluated later under a Government contract.

Tilting-head control

The present machine is controlled by a tilting-head arrangement which eliminates the multiple levers and bearings of the conventional cyclic-pitch method, although the alternative hub for the Ministry of Supply is provided with cyclic-pitch as well as collective-pitch control. It should be of interest to compare the operation of the two alternative systems on the same aircraft.

Cyclic-pitch control has so far been preferred for helicopters, and control by tilting of the hub axis for rotors which are autorotative in flight, mainly for reasons of mechanical simplicity in either case, but also in the case of the helicopter because cyclic-pitch control allows the tip-path plane to remain nearly perpendicular to the hub axis, which is important for the purpose of minimising vibration. As the gyrodyne rotor normally operates neither in the non-powered condition of the autorotative rotor nor in the fully-powered condition of the propulsive rotor, but somewhere about half-way between these two extremes, it is appropriate that the control should conform to neither of the two conventional forms but should combine certain features of both. It resembles the tilting-hub method, but in the gyrodyne the hub axis, *i.e.*, the axis of the main bearings, is not tilted. Instead, the rotor head—the hub member to which the blades are attached—is tilted with respect to the hub axis, and in forward flight the forward inclination of the head balances the backward inclination of the tip-path plane with respect to the head so that the tip-path plane remains substantially at right angles to the hub axis, giving effectively the same result as cyclic-pitch control.

The three flapping hinges all intersect on the axis of rotation and are inclined to the blade axes at about 60° when operating at zero torque. In response to torque, this angle increases progressively and attains a value of about 70° at full torque. The automatic change in blade angle is associated with the angular displacement of the blade in azimuth and is caused partly by a so-called " alpha one " inclination of the drag hinge and partly by the variation in " delta three ". The combined effect is such that there is an immediate increase in boost whenever the throttle is opened without there being any appreciable change in angular speed of the rotor. The blade articulations, therefore, self-govern the collective pitch quite independently of any over-riding collective-pitch control that may eventually be provided for other purposes.



Rotor Head

Power Plant and Transmission System

The Fairey prototype is powered by an Alvis " Leonides " 9-cylinder, air-cooled radial engine which has a maximum sea-level rating of 515 b h p at 3,000 r p m It is mounted vertically inside the fuselage and cooled by a fan driven at engine speed The cooling air is drawn in through openings in front of the rotor pylon and discharged through ducts in the tail unit Ducts are also provided to deflect air through the oil cooler and the engine-driven generator

The installation of the power plant and transmission consists of four self-contained units , first, the engine, its mounting and cooling system , second, the main gearbox providing the first stage reduction gears for the rotor and propeller drives, and incorporating the clutch and the freewheel , third, the top gear-box housing a double epicyclic gear which provides the final gear reduction between the engine and the rotor, with a rotor brake mounted above it , and fourth, at the outer extremity of the starboard wing, a gear-box carrying the propeller reduction and pitch-changing gear

The engine is coupled to the main gear-box by a splined shaft carrying a multi-bush universal coupling at each end, the fan being mounted on to the coupling nearer the engine This arrangement allows the engine and fan to float on the rubber mountings provided for the engine and covers mal-alignment between the engine and the main gear-box

Main Gear-Box

The main gear-box which is mounted on four rubber bushes, carries the clutch, the vertical shaft drive, the side propeller drive, the freewheel, the Lockheed pump drive, the oil pump for the main and top gear-boxes and the engine and rotor tachometer drives The propeller is positively geared to the engine and is unaffected by clutch operation The vertical shaft is driven by bevel gears and the propeller by a smaller pair of bevels A central shaft running at engine speed carries the clutch casing and the clutch plates are splined to an extension on the driving bevel A " Lucas " actuator is provided for controlling the rate of clutch engagement, thus limiting the maximum starting torque and ensuring that the rotor blades can not be damaged by a sudden engagement of the clutch The freewheel is located above the main bevel and, to ensure that the rotor tachometer and hydraulic pump are driven when the rotor is freewheeling, the drives for these services are located above the freewheel

Top Gear-Box

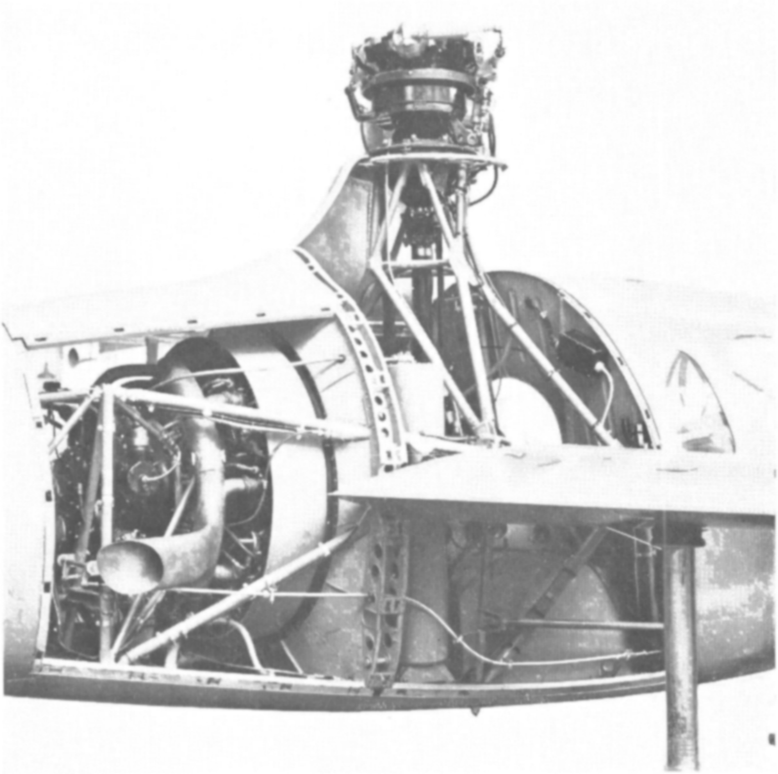
The top gear-box is coupled to the main gear-box by a tubular vertical shaft fitted with a torsional rubber coupling at each end Oil is delivered to the top gear-box by a pump located in the oil sump of the main gear-box and circulates through the top gearing, the freewheel and the gearing in the main gear-box, before returning to the sump Thermocouples are fitted to all gear-boxes The oil cooler is carried in a duct which diverts air from the fan through the cooler

Propeller drive

The propeller shaft, which is in two lengths, is driven from the main gear-box through a torsional rubber coupling embodying a sliding joint A rubber-mounted bearing is located at the centre of the propeller shaft to support the " Hardy Spicer " universal coupling which connects the two lengths of shaft A second " Hardy Spicer " coupling connects the outboard end of the shaft to the propeller gear-box This gear-box carries its own oil pump and oil supply

Rotor Blades

The rotor blades are of steel tubular spar and wooden rib construction and are covered with plywood and fabric The spar is circular in section at the root end, but, over the greater part of its length, it is of oval section, which combines rigidity in torsion with flexibility in vertical bending A root flange integral with the spar enables the blade to be attached to the root fitting without perforation of the tube with its attendant stress concentration Drilling of the spar is avoided also at the rib clips which are attached frictionally over the main portion of the blade and not by bolted or welded joints The rotor blades have been manufactured to very close tolerances and, as a result, have been trouble-free throughout all the tests The hydraulic dampers for damping the blade motion in the plane of rotation, although provided with only a moderate amount of damping, have proved satisfactory in suppressing entirely self-excited instability



Power plant installation

Other design features

The present fuselage is of steel tube construction although a metal monocoque fuselage is being provided for production The pilot's seat is

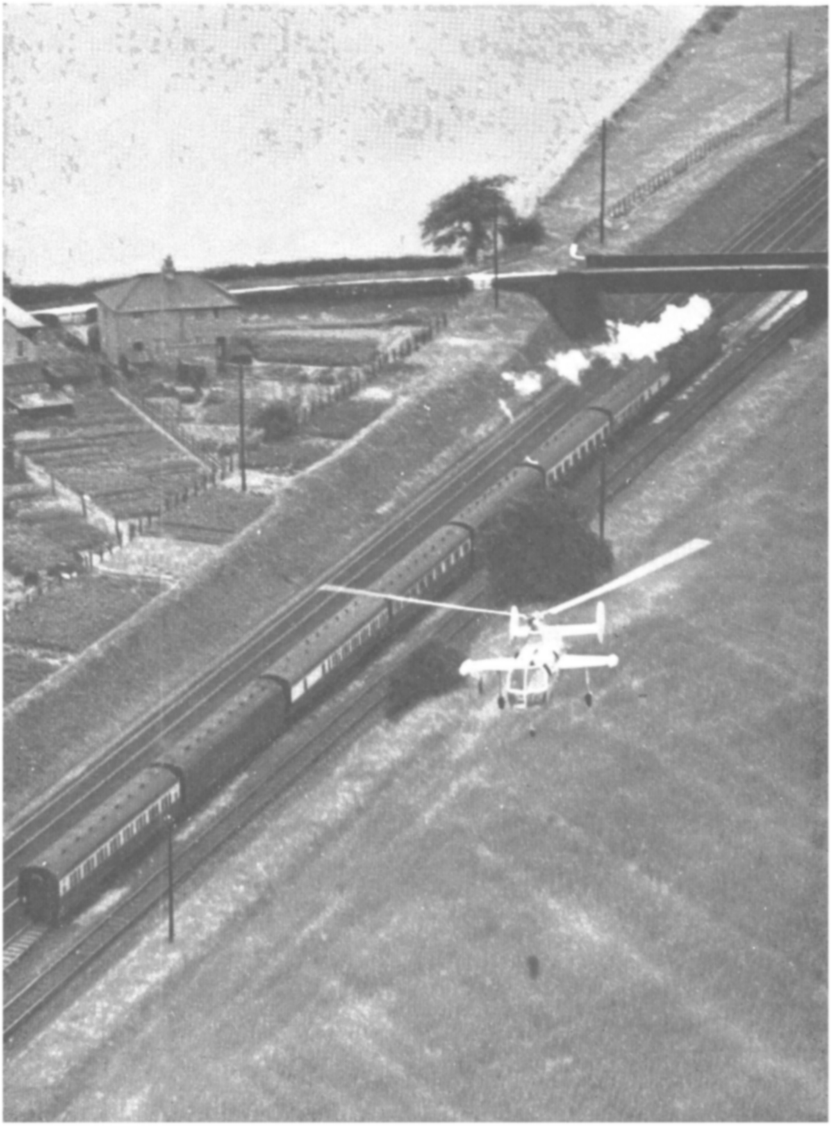


Photo Charles E Brown

Great Britain establishes new International Helicopter Speed Record

The Fairey Gyrodyne, piloted [by Basil Arkell, on a 3 kilometre course at White Waltham, over which the new speed record of 124 3 miles per hour was established on the port side at the nose end of the cabin and to his right an occasional seat with dual control may be installed The back seat is designed to take three passengers The rear portion of the fuselage carries a tailplane and outboard fins which are required for stability purposes in forward flight The stub wings are merely fairings for the structure supporting the outboard propeller and the main legs of the tricycle undercarriage

The flight controls are, as in the conventional aeroplane, stick, throttle and foot pedals The stick controls the angular displacement of the head through hydraulic jacks, which completely eliminate stick shake, though the initial few hours of flight were performed with reversible controls The operation of the collective pitch of the propeller by the foot pedals is also arranged hydraulically Centralising springs are provided in all controls

Performance

The flight trials of the prototype are being conducted at a gross weight equal to that of the production aircraft, which including pilot, 3 passengers, 150 lbs luggage and 47 gallons of fuel, is approximately 4,800 lbs The empty weight of 3,600 lbs is apportioned as follows —

Rotor blades	8%
Power plant and transmission	47%
Structure	30%
Fixed equipment	15%

The rotor diameter being 52 ft, the corresponding disc loading is 2 25 and as the solidity is relatively low, being only 1% per blade, the blade loading has a relatively high value of 75 0 At 3,000 engine r p m the rotor speed is 227 r p m, giving a tip speed of 619 ft/sec and a thrust coefficient of 0 082 (based on blade loading)

The first flight of the gyrodyne entirely free from ground restrictions was accomplished successfully on December 7, 1947, after a period of preliminary ground testing, during which the engine was run for 85 hours and the rotor for 56 hours At 4,800 lbs gross weight and 190 rotor h p the blades have sustained in hovering flight at a few feet from the ground a load of 25 lbs per rotor h p which allows an ample margin of power for vertical climb even assuming that the power applied at the rotor hub is only 50% of the brake horse-power developed The present gyrodyne therefore, differs, little in vertical performance from the best existing helicopter and, without making any definite claim at this stage in regard to climb (at the best climbing speed) and in regard to maximum speed in level flight, the gyrodyne appears in both respects to be markedly superior to present helicopters Moreover, this improvement in performance is effected without departing appreciably from the low disc loading and low pitch advantages which contributed basically to the remarkable record of safety achieved by rotary-wing aircraft in the pre-war era

Mr O L L Fitzwilliams' Vote of Thanks to Dr Bennett

Mr Chairman, Ladies and Gentlemen,

I have accepted with pleasure our Chairman's invitation to propose a vote of thanks to Dr Bennett and, to start with, I would call your attention to the large attendance at this lecture In view of today s counter attractions at Gatwick this excellent turn-out is both an encouraging sign of the keenness of the Association's members and a tribute to the high regard we all have for Dr Bennett

I would also like to add my congratulations on the Gyrodyne's successful establishment of a new speed record For passenger operation there is no doubt that high cruising speed is becoming an increasingly important aim in helicopter design, but in spite of the Gyrodyne's success we have little cause for complacency Indeed it is curious to reflect that whereas today we have a helicopter speed record standing at 124 m p h , some 13 years ago the Pitcairn PCA-2 was being flight tested at speeds up to 160 m p h and at tip speed ratios far in excess of any employed today Certainly this speed was registered in dives but it is well beyond the permissible diving speed of most present-day helicopters , moreover the tip speed ratios achieved would today correspond to a speed of the order of 200 m p h

The Gyrodyne configuration therefore demands the most careful attention, not only because of its many interesting technical features but also because it represents the considered judgment of the man who is our chief link with the very extensive experience accumulated in the development and operation of the Cierva Autogiros I believe that, for future designs, there are a number of important lessons to be learned from the Gyrodyne and it progress will certainly be followed with the greatest interest

For instance, the use of auxiliary airscrews for horizontal propulsion is of course by no means a novelty in the design of helicopters but the Gyrodyne calls our attention to this arrangement in a manner and at a time which is of peculiar significance since we are now approaching the 150 m p h or so speed beyond which horizontal propulsion by tilting the main rotor is not expected to be practicable However, helicopter speeds (and especially cruising speeds) are likely to remain well below this figure for some time to come and it would therefore be most unwise to jump to the conclusion that there is at present anything wrong with the many other single and multi-rotor projects which obtain their forward propulsion by tilting the main rotors

In respect of safety too I feel that Dr Bennett would be the first to agree that the attention which he has drawn to this aspect of the Gyrodyne s performance should be understood not as a reflection on other helicopter configurations but as an indication of the degree of safety which is obtainable with rotary-wing aircraft in general In the course of his lecture Dr Bennett recalled the statement, recently made in Parliament, that helicopters are not as yet considered sufficiently safe for passenger services and, as we have with us today a number of eminent representatives of the Aeronautical Press, I feel it is only proper, on behalf of all of us who are connected with helicopter development, to register our disagreement with that statement

So far as I am aware there are no valid reasons for supposing that a helicopter carrying a Certificate of Airworthiness is in any way less safe than a similarly qualified fixed-wing aircraft, whereas the helicopter's flight characteristics are such that there are a number of reasons for supposing the contrary If some people consider that present-day helicopters are unsafe for the transport of passengers over water or into and out of our large cities, this is not at all because they are helicopters, and even less because they are any particular kind of helicopter, but simply because at present they all happen to be single-engined

Finally I would like to add my congratulations to the many already received by Dr Bennett and his colleagues on their considerable technical achievement, and to say that I have the greatest pleasure, on behalf of our Association, in thanking him for his excellent paper and its admirable delivery