British Helicopter Developments*

By

A McCLEMENTS, A R T C , M I Mech E

A paper read by Mr L S Wigdortchik
before the American Helicopter Society Forum,
Washington, in May, 1952

Introduction

When asked to prepare this paper it seemed that two courses were open, namely —

(*a*) the detailed consideration of a few aspects of British helicopter developments, and

(*b*) a more general survey of the British helicopter development field with references from which details of much of our work could be obtained

The latter course was chosen because it was felt to be the more useful as a work of reference and more likely to convey an accurate impression of British activities as a whole

Before and During the War years

To assist in understanding the British helicopter development situation, and because it may be of interest to some not familiar with past events in the United Kingdom, I propose to start this paper by briefly mentioning some important aspects of British developments and activities before and during the war years

In the pre-war era Britain had been making an active contribution to the development of rotary wing aircraft from the time of the formation of the Cierva Autogiro Company in 1926 From then, until the outbreak of hostilities in 1939, we had rotary wing activities such as those of the Cierva Autogiro Company, G & J Weir, and the AR3 Construction Company

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*Note —While much of what this paper contains will not be new to Members of the Helicopter Association of Great Britain, it is reproduced for the purpose of putting on record the background and the broad status of helicopter research and development as it is in this country today It is hoped that other papers of a similar nature will be published in our Journal from time to time for the purpose of placing on record, and keeping Members up-to-date with British Helicopter progress

The paper is reproduced in full, except that many of the figures which appeared in the original have been omitted since they have been published in previous issues of the Journal

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The Cierva Company pioneered the autogiro in Britain Associated with it under licence were foreign companies which included Pitcairn in U S A and Focke in Germany The Cierva Company developed autogiros including the C 19 , the C 30 (which was a marked advance on the C 19 because control, as well as lift, was effected through the medium of the rotor) , and the C 40 with its ability to take-off using the " jump " technique The association of the Cierva Company with foreign Companies was very important It not only assisted us, but in America it made a material contribution to the production by Kellett of numbers of autogiros , in Germany it assisted Focke in building the first really practical helicopter —the Focke-Achelis—which was flying in 1937 At the outbreak of hostilities the A V Roe Company had already produced in Britain about 100 C 30 machines and the Cierva Company five C 40 's Further production of C 40's was not possible when the war started because circumstances were such that the Cierva Company found it necessary to go into temporary retirement

G & J Weir, under licence from Cierva, built their small W 1 autogiro and later their jump take-off W 3 machine Encouraged by the success of the Focke Company, Weir's devoted their attention to helicopter development and built their W 5 helicopter which was the forerunner of their W 6 They were able to devote only a very small effort to the helicopter during the war years, but they did start work on their W 9 helicopter near the end of the war when they took over the Cierva Company

The AR3 Construction Company built the AR3 Gyroplane which flew successfully and embodied cyclic and collective pitch controls among its novel features

Other British Companies also built rotat ng wing aircraft Examples were Westland Aircraft and Kay Gyroplanes

During the war rotating wing development practically ceased in Britain and it was more or less confined to

- (*a*) the Weir Company on their W 9 ,
- (*b*) the application of rotors for the transport of equipment at the Central Landing Establishment (later A F E E) where the Rotachute (Fig 1) and Rotabuggy (Fig 2) were developed , and
- (*c*) the establishment of performance and evaluation techniques at A F E E , using Sikorsky R 4 and R 6 helicopters

Although there was little development going on during the war, we did acquire operational experience both with Cierva type autogiros and Sikorsky R 4 and R 6 helicopters Further, there was British representation in U S A This representation, seeing the potentialities of the Sikorsky XR4, backed the ordering in the U S A of some 250 Sikorsky XR5's These machines were for the British Royal Navy and, while the Royal Navy was never fortunate enough to get them, we like to feel that the order served a very useful purpose in-so-far as it helped to launch helicopter production in America

Summarising, we can say that in 1939 we were in a strong position technically in the field of rotating wing development , we had pioneering

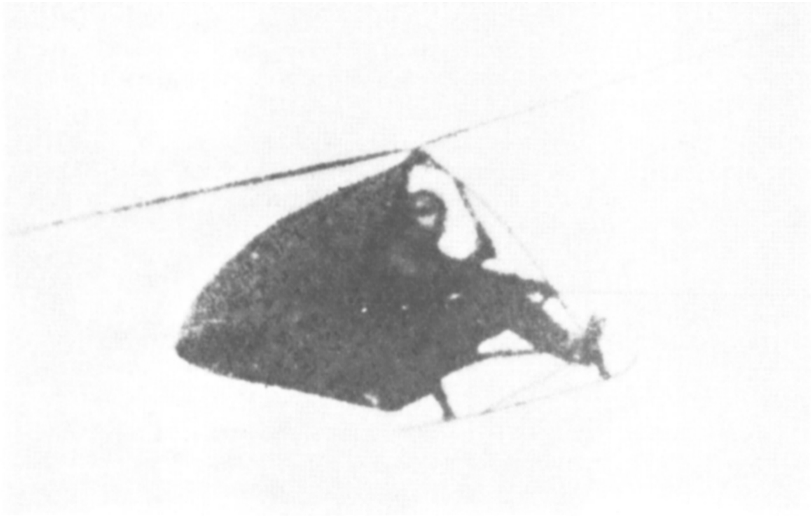

Fig 1. The Rotachute

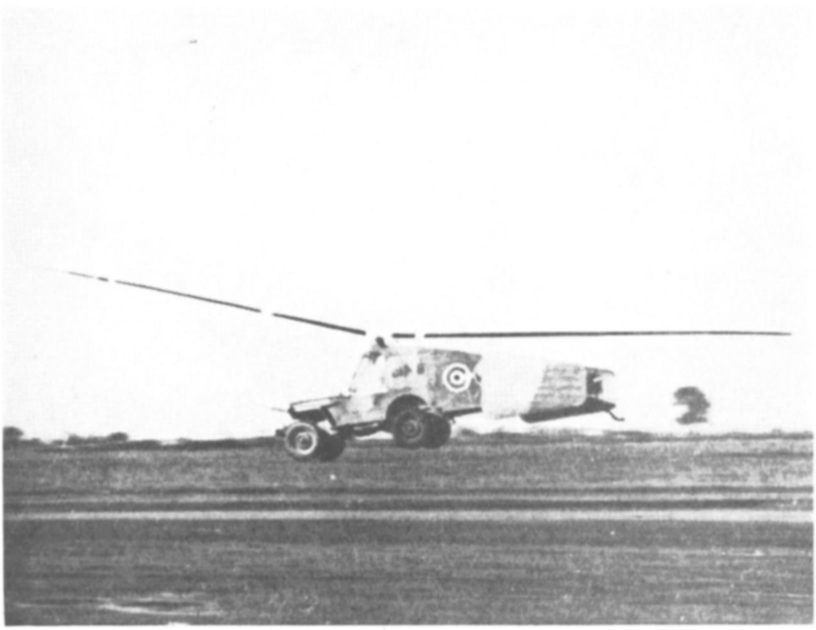

Fig 2 The Rotabuggy

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and operational experience with aircraft utilising autorotative rotors and, as a result of the efforts of G & J Weir, we had some development and flying experience with the helicopter The war years, however, were for us fallow in-as-far-as we had not the opportunity of making progress in the helicopter design field

For this reason, and because circumstances since the end of the war have not been ripe for the placing of worth-while production orders, I believe we in Britain are not nearly so far advanced in helicopter development as we would otherwise have been

Main British Organisations

As soon as circumstances permitted after the war Britain resolved to continue rotary wing research and development with the object of again taking a leading position

To encourage this goal, Government orders were placed for prototypes of three types of research helicopters, and firms—notably the Fairey and Westland Companies—entered the rotary wing business on a private venture basis Since the end of the war progress has been made and the following main bodies have entered or continued in the broad helicopter development field

- (*a*) five firms Messrs Bristol, Faireys, Percivals, Saunders-Roe and Westlands ,
- (*b*) the Ministry of Civil Aviation Inter-Departmental Helicopter Committee ,
- (*c*) two operating bodies British European Airways and Pest Control ,
- (*d*) two Government Establishments Royal Aircraft Establishment and Aircraft and Armament Experimental Establishment ,
- (*e*) the Helicopter Association of Great Britain , and
- (*f*) the Air Registration Board

We shall now briefly consider the activities of certain of these organisations

Activities of Main British Organisations

Helicopter Design Firms

Bristol Aeroplane Co , Ltd A basic philosophy has persisted throughout this Company's developments which may be summed-up by saying that it has always aimed at expanded development by a step-by-step process, starting with a configuration which had already been proved and a size about which their designer had knowledge This trend will be apparent throughout the following projects

Bristol 171[1,2] (Fig 3) This project, design initiated in 1945, aimed at producing a commercial helicopter of proved configuration and known size, but refined in such respects as

- (*a*) the rotor, which was designed for high translation speed and high rotational energy content ,

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Fig 3 The Bristol 171

Fig 4 The Bristol 173

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(*b*) the fuselage, which was designed to give good aerodynamic characteristics ,

(*c*) the rotor attitude datum which was arranged to provide a substantially horizontal fuselage during cruising conditions ,

(*d*) the control system, which was arranged to give low control forces ,

(*e*) mechanical detail to which special attention was paid in the interest of long " life "

Prototype 171's were built to Ministry of Supply contract as research machines This type is now in production The basic machine is the 171 Mk 3, which has the following leading particulars —

Design Weight	5,200 lb
Rotor Diameter	48 6 7
Engine (Type and Power)	Leonides 23 HMV 550 h p
Disp Load	1,230 lb
Number of Seats	4—5
Cruising Speed (maximum)	106 m p h
Maximum Speed	126 m p h
Vertical Rate of Climb	380 ft /min
Best Rate of Climb	695 ft /min at 52 m p h
Hovering Ceiling	6,650 ft
Service Ceiling	16,900 ft

NOTE —Maker's design figures I C A N Conds

Military variants have been developed from the Mk 3 Further technical development will continue and an important detailed improvement will be in the fitment of metal blades

Bristol 173 (Fig 4) In 1946 the Company, considering their next development stage, planned their 173, which was to be a machine of about double the A U W of the 171 The basic thinking behind their choice of configuration was as follows

(*a*) the rotor and as much of the transmission as possible would be the same as on the 171 This meant that multi-rotors would be employed, but they would be developed rotors and economical from the weight view-point because they would be relatively small ,

(*b*) two rotors of equal size and rotating at the same speed would be chosen and therefore a narrowed vibration frequency spectrum obtained, compared with the 171 configuration ,

(*c*) the rotors would be arranged in tandem, thereby effecting the maximum structural weight saving, minimum body drag and the facility for utilising multi-engines in the fuselage under the rotors

The first prototype 173 has flown and it is now undergoing ground running and flight development The second prototype will fly soon

Bristol 173 Developments The 173 will be further developed and in its final form it will probably be a machine with stub wings, retractable undercarriage and two 750 h p engines

Leading particulars of the 173 as designed in 1946, and the machine in its probable final form are

	Basic Machine	Developed Machine
Design Weight	10,600 lb	13,500 lb
Rotor Diameter	48 6 7″	48 6 7
Engine (Type and Power)	Leonides 25HMV	Leonides Maior
Disp Load	3,180 lb	4,570 lb
Number of Seats	10	15
Cruising Speed (max)	125 m p h	160 m p h
Maximum Speed	158 m p h	
Vertical Rate of Climb	1,150 ft /min	
Hovering Ceiling	6,950 ft	
Service Ceiling	17,600 ft	

NOTE —Maker's design figures , I C A N Conds

Bristol 181 The Company has this machine under consideration with a view to meeting a Civil requirement (to which I will refer later) It will be similar in configuration to the fully developed 173, with rotors of approximately 173 size, but operated at much higher disc loading The machine will have capacity for about 45 seats, its A U W will be in the region of 40,000 lbs , and its power will not be less than 4,000 h p

Bristol Test Tower At the outset of their helicopter developments the Bristol Company appreciated the need for a means for developing and conducting research on rotors independently of the helicopter as a whole Accordingly, they designed and built the test tower shown in Fig 5 in 1946

The following brief particulars of the tower may be of interest

Distance between ground and centre of rotor	50 ft

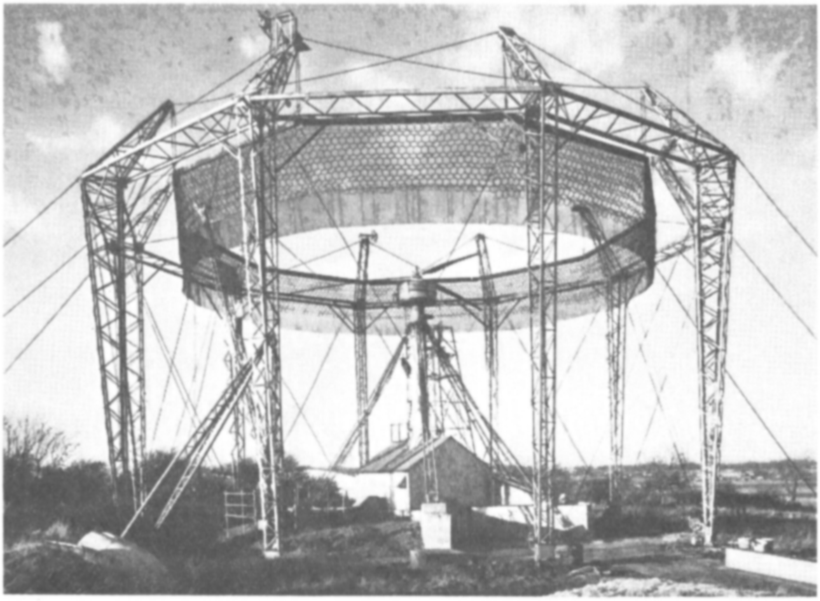

Fig 5 Test Tower

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Maximum rotor diameter	70 ft
Maximum rotor thrust	15,000 lbs
Drive	Electric motor
Supports	Guy ropes of variable tensions thus enabling the whirling frequency to be varied at will
Instrumentation	Measurement of thrust, r p m torque, wind velocity and direction catered for Means provided for strain gauging and recording of blade motion about hinges
Developments	Means of applying cyclic pitch control being added , also means of simulating blade loads associated with forward flight (by placing local obstructions under the rotor)

The tower is more or less in continuous use and it has proved invaluable as a research and development tool Example of the uses to which it has been put are the determination of rotor parameters, blade snatch tests, routine acceptance tests of blades and hubs, and the determination of methods of reproducing blade loading equally damaging from the fatigue aspect as that encountered in translational flight

Fairey Aviation Co , Ltd

One of the main aims of this Company's developments has been to take advantage of available engine power to achieve high cruising speeds by overcoming the limitations characteristic of the two extremes of the helicopter and the gyroplane

Fairey Gyrodyne Towards the above end the Company built on a private-venture basis two research prototypes of the Gyrodyne A fundamental feature of the Gyrodyne was that the tip path plane of the rotor was maintained nearly level in cruising flight This was achieved by arranging the torque compensating propeller such that it provided the required thrust for forward flight, while balancing the residual torque from the limited power applied to the rotor

The first two prototype Gyrodynes flew successfully and their leading particulars have already been published [3 4,5]

The first machine was destroyed in 1949 on account of a mechanical failure, but, prior to this accident, the Company claimed that they had made the case for the Gyrodyne principle, namely that it was capable of extending the speed range of the helicopter by minimising the tendency of the powered rotor to operate close to the periodic blade-tip stall, thus limiting vibration due to the dissymetry of translational flight They demonstrated that the machine was capable of high speeds by establishing an International Speed Record for helicopters on the 28th June, 1948 (Official speed achieved was 124 3 m p h)

Further Developments of the Gyrodyne Principle Two factors play an important part in projected development of the Gyrodyne principle, viz

(*a*) the use of a fixed wing in conjunction with the rotor, and
(*b*) turbine engines

The firm's arguments for developing the Gyrodyne principle run on the following lines

Fixed Wings A feature of the Gyrodyne was its use of small fixed wings With the low pitch operation of the rotor, and the relatively low rotor power, there was no need to carry a major portion of the load on the fixed wings, but rotors of higher power and disc loading can take advantage of this feature By allowing the fixed wings to unload the rotor progressively with increasing forward speed, the rotor, operating at less lift, can be reduced in pitch with the result that vibration need not be a barrier to higher cruising speeds This approach at overcoming the vibration normally associated with high speed, because of the approach of the stall over the working portion of the retreating blade, can be exploited fully in the gyrodyne principle This follows since propulsive thrust is not dependent on forward inclination of the tip path plane (which inclination could only be accentuated by the unloading of the rotor in the orthodox arrangement in which forward thrust is obtained by this means)

Turbine Engines The advent of the gas turbine engine means that greatly increased power can be made available at the expense only of increased fuel consumption Fuel consumption is relatively unimportant in view of the fact that rotary wing aircraft are normally short duration machines

Turbo-propeller engines can be utilised directly in helicopters and they are particularly attractive when used in a Gyrodyne application because they generate a convenient means of variation in the ratio of rotor/propeller power It will be appreciated that such a variation leads to the possibility of a machine in which—

(*a*) all power can be applied to the rotor—the helicopter ,
(*b*) power can be divided between the rotor and propellers—the Gyrodyne , and
(*c*) all power can be applied to the propellers—the autogiro

The Fairey Rotodyne is such a machine and Fig 6 illustrates one application of its development

The Cierva Autogiro Co and Saunders-Roe Ltd

In 1946 the Cierva Autogiro Company came out of retirement and gave

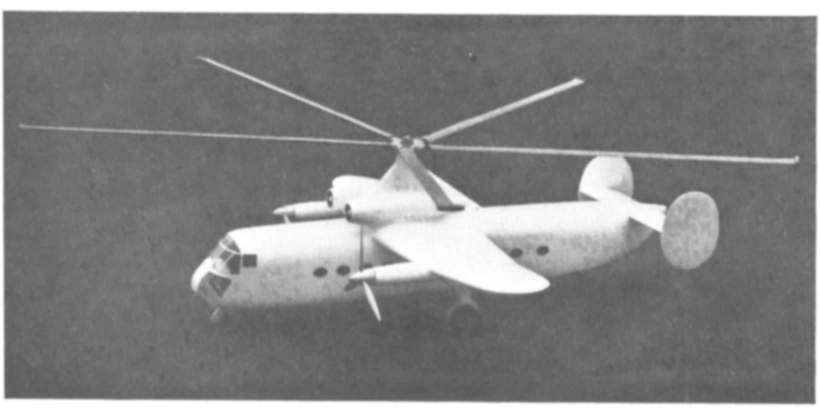


Fig 6 The Fairey Rotodyne

thought to the design of a large helicopter They selected a three-rotor configuration and the main factors which influenced their choice were —

(*a*) The problems of the large rotor were unknown Hence, only by selecting the multi-rotor configuration could a machine be produced with rotors of " known " size

(*b*) The three-rotor configuration would be attractive in-as-far-as

i stability would be good and control powerful ,

ii the influence of the ground cushion would extend to a considerable height ,

iii the method of torque compensation would result in a favourable balance between structure and all-up weights ,

iv the lay-out could be made attractive in respect of cabin space, loading facilities, C G range and accessibility to engine and transmission

It was appreciated that there were unknowns associated with a machine of the type proposed—notably mechanical complexity, structural complication and vibration , however, a need was foreseen for a large machine in the aerial crane and crop dusting roles Accordingly, the Ministry of Supply supported the design and construction of two research machines (flying shells) for the purpose of investigating such problems as those associated with control, stability, autorotation, vibration, the co-relation of actual and predicted performance and overall practicability

The first prototype[6] (known as the Air Horse) flew in December, 1948 Development continued and, prior to its destruction in June, 1950, it had been flown at full design weight (17,500 lb) and demonstrated that control was adequate to enable all normal manoeuvres to be carried out with precision from 0-90 m p h , also, autorotational flight had been shown to be quite feasible at a rate of descent of 900 ft /min

The first prototype was destroyed because of a fatigue failure in the swashplate driving scissor linkage This fact, together with new helicopter test requirements delayed further research on the configuration

Since the accident, Saunders-Roe Ltd has taken over the contract and, to assess fully the factors which initially determined the configuration, research and development work is proceeding on the second prototype To give the maximum degree of insurance against further mechanical failure, the aircraft is undergoing a comprehensive strain gauge analysis

If it were decided at some future date to proceed with the three-rotor configuration on a production basis, it is possible that a large twin-engined machine would be chosen

Leading particulars of the W 11 (Air Horse) are

Design Weight	17,500 lb
Disposable Load	5,267 lb
Rotors (Number and Diameter)	3 × 47 ft
Engine (Type and Power)	Merlin 24 1,620 h p
Maximum Speed (Design)	149 m p h
Speed at Maximum Cruising Power	100 m p h
Best Rate of Climb	1,440 ft /min
Vertical Rate of Climb	320 ft /min at 2,000 ft
Hovering Ceiling	4,200 ft
Operational Ceiling (200 ft /min Rate of Climb)	14,900 ft

NOTE —Maker's design figures , I C A N Conds

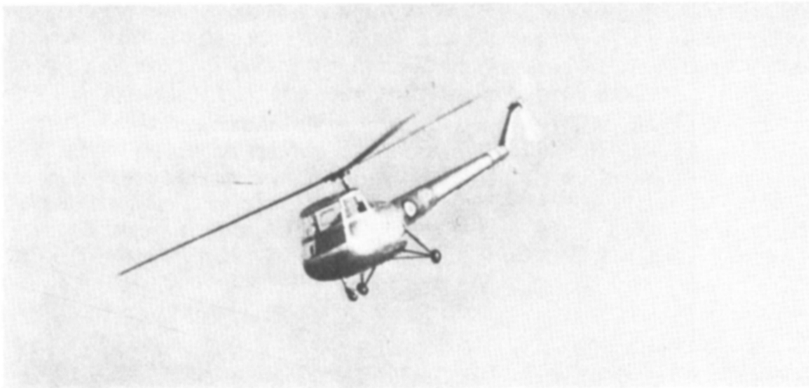


Fig 7 The Skeeter

Concurrently with the Air Horse development, the Cierva Company designed and built their two-seater Skeeter helicopter (Fig 7) Development of this machine is now being undertaken by Saunders-Roe Ltd , and prototypes ordered by the Ministry of Supply are flying It seems likely that Saunders-Roe Ltd will put the Skeeter into production Leading particulars are

Design Weight	2,100 lb
Disposable Load	620 lb
Rotor Diameter	32 ft
Engine (Type and Power)	Bombardier 702, 180 h p
Number of Seats	2
Maximum Speed	100 m p h
Cruising Speed (maximum)	95 m p h
Vertical Rate of Climb	200 ft /min
Best Rate of Climb	1,050 ft /min
Hovering Ceiling	1,280 ft
Operational Ceiling (200 ft /min Rate of Climb)	12,000 ft

NOTE —Makers design figures , I C A N Conds

In addition to continuing with the development of the Air Horse and Skeeter, Saunders-Roe Ltd are engaged in project investigations of helicopters of novel type

Westland Aircraft Ltd

This Company gained some experience of rotary wing aircraft in the 1930's when they manufactured a two-seater Autogiro, in conjunction with the French engineer Lepere, and later when they manufactured a five-seater Autogiro under licence from the Cierva Company

In the post-war period, wishing to enter the Helicopter field, they concluded a Licence Agreement with the Sikorsky Division of United Aircraft covering the manufacture of a British version of the Sikorsky S 51 helicopter As a result Westland S 51's are available for the Civil market with either Alvis Leonides or Pratt & Whitney Wasp Junior engines, and various Marks are in service with the Royal Air Force and the Royal Navy Several specialised versions of the aircraft have also been supplied for a variety of uses, including crop-spraying

The Westland S 51 helicopters have been flown and extensively demonstrated throughout the United Kingdom and various parts of Europe as far afield as Switzerland, Spain and Italy, and it is interesting to note that the Company operated experimentally the first scheduled passenger service outside the United States when they carried passengers regularly from London to Birmingham throughout the period of the British Industries Fair in 1950, using Westland S 51's

About forty Westland S 51's have so far been delivered and these aircraft are now in service in Italy, Egypt, the Belgian Congo, Malaya and Thailand, and others will shortly be delivered for use in Norwegian whaling operations and in French Indo-China The Company is now commencing deliveries from a new and considerably larger production batch The majority of new machines will go to the Royal Navy and the Royal Air Force, bringing the number of these aircraft in use up to quite a significant total

In the closing months of 1950 Westlands negotiated a Licence with United Aircraft covering the construction of a British version of the Sikorsky S 55 helicopter, and at the same time they purchased a Sikorsky-built S 55 which has since aroused great interest among our Military and Civil Aviation authorities Westlands are building an initial batch of ten S 55 helicopters as a private venture and the first of these is expected to fly some time during the coming summer

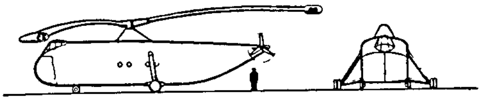
Initially the Westland S 55 will be powered by the Wasp 1340 engine , later it is hoped that a new Alvis engine will become available having weight and power characteristics which will enhance the performance of the type

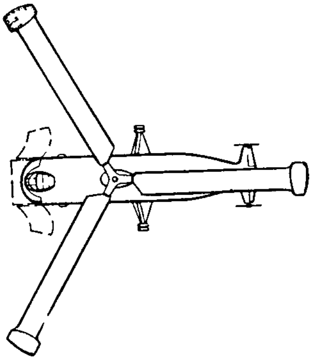
Westlands are very appreciative of the assistance they have received from Sikorsky and undoubtedly they would like to continue the present cordial relationship in the future At the same time, their design effort has grown steadily and the Company now has a considerable body of knowledge and experience on which to base their plans for the future Their thoughts for the future are interesting and, in the field of large transport machines, they are no doubt reflected in Fitzwilliams' recent lecture[7] to the Helicopter Association in which he dealt with a family of " Giant " helicopters (Fig 8)

Towards the attainment of high operating speeds of an order generally thought to be possible only with compound or convertible type of rotary wing aircraft, the Company is interested in the combination of four-bladed rotors and second harmonic feathering The proposed (W 81) illustrated in Fig 9 employs these features and is listed as having a cruising speed of 190 m p h

Civil Operational Development

In Britain users are conscious of the potentialities of the helicopter in the Civil field They think that in the British Isles, with centres of population relatively close together, and with many routes necessitating





Main Rotor Diameter	104 ft
Length of Fuselage	64 ft
Height to C/L Rotor Hub	18 ft
Depth of Fuselage	11 ft 9 ins
Width of Fuselage	12 ft 6 ins
Volume of Main Cabin	4 400 cu ft
Size of Door Opening	7 6 deep 12 0 wide
Max Tankage	2 000 galls
Max Seating Capacity	102 Troops
Normal A U Weight	53 000 lb
Overload A U Weight	60 000 lb

JET TRANSPORT HELICOPTER

6 ARMSTRONG SIDDELEY ADDER GAS TURBINES

By courtesy of "Flight

Fig 8 "Giant" Helicopter

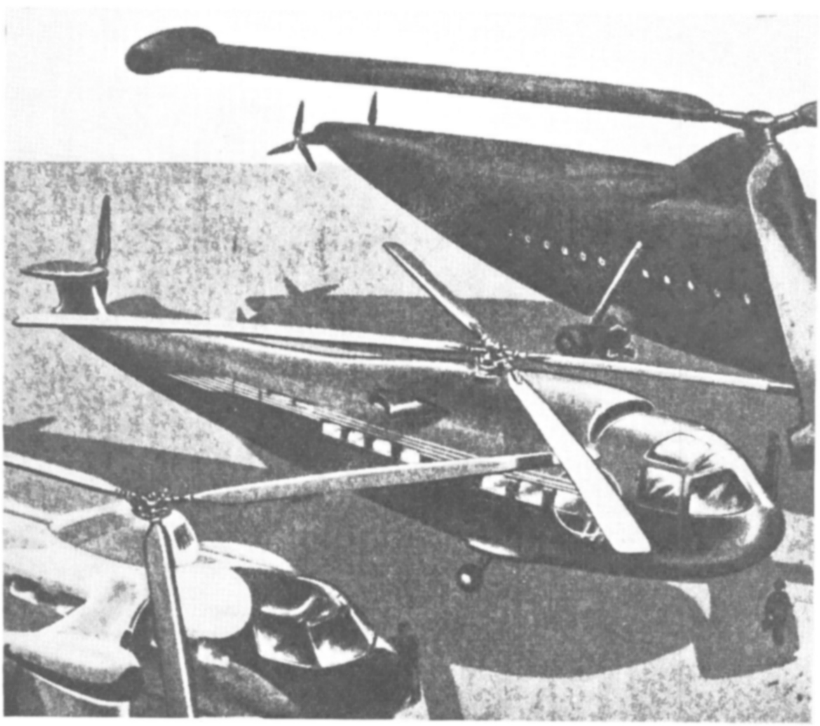


Fig 9 W 81

water crossings, they have an ideal opportunity of exploiting the helicopter in the Civil transport role Anticipating this full exploitation, the approach has been to explore operational aspects in advance of the availability of operational equipment This approach has merit because it utilises " waiting time " to provide information necessary to enable the correct type of helicopter and ground equipment to be developed , it will also result in the speedy integration of transport helicopters into the main air transport network when they are operated in numbers

In the Civil transport role there are two main pioneering bodies, viz

(*a*) The Ministry of Civil Aviation Inter-Departmental Helicopter Committee, and

(*b*) The British European Airways Helicopter Unit

The M C A Inter-Departmental Helicopter Committee

This Committee was set up in 1948 by the Minister of Civil Aviation to consider, in relation to present and likely future developments of the helicopter,

(*a*) the prospects of its future commerc al use on internal air services in the United Kingdom and other fields of potential use ,

(*b*) the related programmes of development of the helicopter, and experimental work on equipment required to achieve the necessary regularity of successful commercial operation

In general, the Committee approached that part of its task which referred to the prospects of the helicopter's use on internal services in the United Kingdom under the following main headings

(i) the present status of helicopter development ,
(ii) the operational characteristics of the helicopter ,
(iii) the ground organisation and navigational aids required for helicopter services ,
(iv) the economics of helicopter transport services ,
(v) the field of operation of helicopter transport services , and
(vi) general conclusions and matters for immediate action

The first report of the Committee[8] (confined to the above aspects) is available to the public so I will confine further reference to it to mentioning some of its conclusions These are

(i) the helicopter must be regarded as a coming medium of commercial transport, suitable for distances up to 300 miles ,
(ii) a 20-passenger helicopter should be fully economic for commercial use on scheduled services ,
(iii) a fleet of 50, 20+ type passenger helicopters can be absorbed progressively into commercial use on our internal transport services this number may increase ,
(iv) among the requirements to be satisfied in any helicopter to be introduced into schedule services in this country are included
   (*a*) multi engines with adequate performance with one engine inoperative,
   (*b*) increased payloads and cruising speeds (related to present designs),
   (*c*) simplicity in operation , one-crew operation , minimum demands in relation to landing area and navigational aids,
   (*d*) rotor blade folding rapid and easy

The above conclusions (and the others in the report) are based on operational research over a number of years and they reflect the official Civil outlook The work of the Committee continues and it will no doubt report later on the other aspects of its deliberations

The British European Airway's Helicopter Unit

With the object of assessing the operational future of the helicopter in Britain, its technical and commercial problems, and limitations, the B E A Helicopter Unit was formed in 1947 to acquire sufficient experience to frame requirements for designs which could exploit fully the potentialities visualised ahead

The Unit's policy has consistently been to initiate and undertake operations which would demonstrate the capabilities and potentialities of the helicopter, enlarge its operational experience and steadily build up the standards and technique of operation in as many aspects as possible The equipment available consisted of three S 51's and two Bell 47 machines

The work of the Unit has been reported fairly fully[9] so I will confine myself to a few general observations about its activities, viz

(*a*) The following regular experimental services have been operated (excluding the Birmingham/London passenger service which has recently terminated)

Experimental Service	*Total Distance Miles*	*Total Load Carried* lbs	*Scheduled Number of Stops*	*Regularity*
Dorset/Somerset Dummy Mail, Jan -March, 1948	6,750	N/A	570	96%
East Anglian Day Mail, June-Sept , 1949	26,943	28,613	1,334	98 4%
Peterborough-Norwich Night Mail, Oct , 1949-April, 1950	14,807	96,228	283	77 1%
Cardiff-Wrexham-Liverpool Passenger Service, June 1950-Sept , 1950	56,542	118,400	506	96 5%

NOTE —The night mail operation was of historical interest because it was the first occasion in which certification was granted for helicopters to operate for hire and reward under night blind flying conditions Since the machines used had only a single engine, a 500 ft cloud ceiling limitation was imposed to allow visual landings in emergency This factor alone accounted for the major loss of regularity During the service winds were above 25 knots for half the flights, and greater than 35 knots on 6% of the flights Over 80 hours flying were done under completely " blind " conditions (*b*) Experimental work was undertaken by the Unit which included the development of the airborne and ground equipment necessary for the certification of the S 51 for blind and night flying, also of methods of pilot training under synthetic blind conditions

As a result of their past activities, British European Airways have recently been able to issue a specification[10, 11] for a helicopter which they anticipate will be fully economic when employed on regular scheduled operations in the United Kingdom The following details of the specification will show that it embodies a good deal of advanced thinking

Size 30 seats over 100 n /Mile stage (minimum)
36 seats over 100 n /Mile stage (desirable)

It is hoped that development to 35-45 seats over a 200 n /mile stage will be possible

Operational Regularity Direct air service between city centres or other desired points with regularity of at least 95% over the year

Cruising Speed Not less than 120 knots at 2,000 ft

Climb Not less than 600 ft /min at sea level without ground effect and at zero forward speed With critical engine inoperative, rate of climb at best speed not less than 200 ft /min between sea level and 5,000 ft

Handling Positive longitudinal static stability is demanded in a range of climbing, cruising, hovering, single-engine and power-off flight

Operational Features

Indiscriminate loading is required
Blind flying instruments for both pilots are required
Automatic pilot is required
Decca flight log equipment will be fitted for navigation
Rapid means of blade folding and ground handling are required

Maintenance A "sealed" system of maintenance is called for

The B E A specification is at present being studied by the British Industry and the Ministry of Supply Obviously machines of the size of the Bristol 181 and Fairey Rotodyne can be anticipated as being necessary to fulfil this Civil demand

Government Establishments

The two main Establishments engaged on helicopter research and development are the Aircraft and Armament Experimental Establishment, Boscombe Down, and the Royal Aircraft Establishment, Farnborough Much of the helicopter work done at these Establishments has been reported elsewhere, *e g*, [12], and the following information is provided mainly to indicate the type of helicopter work which each Establishment undertakes

Aircraft and Armament Experimental Establishment

This Establishment is responsible for the flight testing of new type helicopters, and for associated research work on flight testing methods and operating techniques for helicopters The research work on flight testing methods is concerned with extending the scope for the tests, improving the techniques used, developing the equipment for measuring performance, and also with adapting and extending helicopter theory for analysis of measured flight test data An example of recent work in the latter field is the preparation of empirical curves for estimating the low speed performance of a helicopter, covering the range between vertical flight, for which an empirical curve is commonly used, and speeds at which the momentum theory is sufficiently accurate Last summer, performance trials were made for the first time in tropical conditions in Africa to investigate the general effects of atmospheric temperature, pressure and humidity on helicopter performance

Helicopter operating techniques are being investigated for both military and civil applications Some work is being done on night and blind flying, and methods of dead reckoning navigation are being developed for military use

A general investigation is being made of the performance of a helicopter after power failure to ensure safety from the point of view of handling, and to determine the height band unsafe in the event of power failure Helicopter take-off and landing techniques are being studied, in particular to determine the space required for safe take-off and landing in restricted areas when the possibility of power failure is admitted

In addition to the above, the Establishment is frequently required to assist in assessing the possibilities of proposed schemes involving rotating wing aircraft and also to test helicopters in special operational roles

Royal Aircraft Establishment

The helicopter activities of this Establishment are mainly of a research nature

Much of the work done during the past few years has been theoretical, concerned mainly with stability and control problems and with blade motion A general approach, using what is now called frequency ratio theory, has shown that the main parameters in oscillating rotor work are the frequency ratio and the specific damping For the long period oscillations of the ordinary helicopter, it has been found that there is no significant difference from the quasi-static theory, but for systems such as the Hiller and Bell, the effect is important In wind tunnel testing, the differences can be very great and oscillation tests on a 12 ft dia rotor in a wind tunnel have been used to illustrate these differences

Full scale testing has been undertaken by the Royal Aircraft Establishment mainly with the Bristol 171 helicopter A flight programme on blade motion and blade stalling has been started, using a camera located on the rotor head in conjunction with suitable markings and tufts on the blades Other items on the flight programme include the testing of an automatic pilot in a Bristol 171

The Helicopter Association of Great Britain

This Association—the British counterpart of the American Helicopter Society—came into being in 1945 with the object of providing a means of collecting, exchanging and promulgating information concerning research, development and achievement in the rotating wing sphere of aeronautics It has always endeavoured to attain a high standard, particularly in the field of technical advance This point will be appreciated by reference to the

Association's Journal in which all lectures and discussions enjoyed by Members are reproduced

The Association's Journal reflects to a large extent British rotating wing developments , hence, I cannot do better than refer to it those who wish to examine in greater detail many of the aspects touched on in this lecture

By way of reference I list lectures[13] already printed in the Journal, additional to those mentioned elsewhere in this paper Regular subscriptions to the Journal and Membership in an appropriate grade are available to all

General Research Work

Helicopter research of general interest (as distinct from that associated with particular projects) is going on in the United Kingdom at firms and Government Establishments In the time available I can only touch on a few current items and refer you to other papers, *e g* , [12 13], for details of some of our past contributions

The items which I will now briefly mention are associated with airworthiness and higher translational speeds

AIRWORTHINESS

The consequences of mechanical failure in the helicopter can be disastrous Hence, the official British attitude is to impose additional requirements aimed at reducing the likelihood of accidents from this cause in the future What form these additional requirements should take is not easy to decide, but the aim is to subject the first prototype helicopter of each type to a controlled schedule of testing during which a limited amount of flying will be permitted to enable the fatigue stresses in the primary systems to be measured , thereafter the prototype, or individual systems, will be subjected to sufficient ground running to give subsequent protoytpe and type aircraft reasonable clearance from the danger of fatigue for a stated " life " which might be infinite Obviously such a procedure is only of value if loads can be imposed during ground running which will be equally damaging from the fatigue viewpoint as the flight loads This is an aspect on which we are conducting research on the following lines

Bristol

Stresses in the rotor, control and transmission systems of the 171 have been measured under various flight conditions and methods are being explored of reproducing loads, equally damaging from the fatigue point of view, in these systems under the ground running conditions in the following way, viz

Rotor System By spinning the rotor on a tower and generating periodic blade loads by placing obstructions in the air flow under the rotor

Transmission System (Fig 10) By suspending the helicopter from a gantry and fitting a paddle in place of the rotor The combined aerodynamic and dynamic characteristics of the paddle blades feed into the

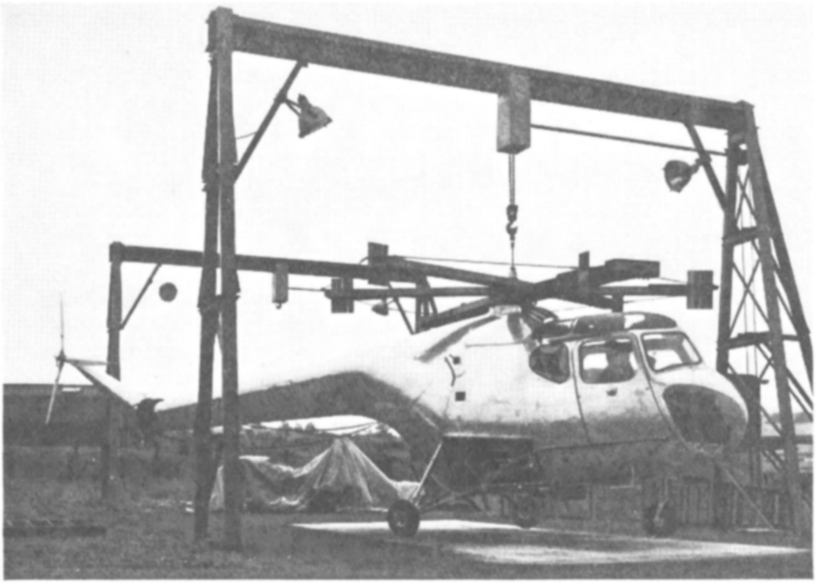


Fig 10 Gantry Transmission System

	Condition	Mean Torque lb /ins	Mean Overall Fluctuation
MAIN SHAFT	Cruise Hover Autorotation Gantry	5000 8000 — 7000	350 350 — 400
TAIL SHAFT (Forward)	Cruise Hover Autorotation Gantry	400 600 200 300	20 20 20 20
TAIL SHAFT (Aft)	Cruise Hover Autorotation Gantry	400 600 200 300	30 35 30 30

TABLE 1

COMPARISONS OF TORQUE FLUCTUATIONS UNDER GANTRY CONDITIONS AND IN FLIGHT transmission system disturbances of a similar magnitude to those generated by the rotor

Control System By testing on individual rigs

Saunders-Roe

The object of the work being undertaken by this Company is to reproduce equivalent flight loads in the three primary systems by running the helicopter (Skeeter) on the ground as a complete unit Periodic control displacement is the method being adopted in an attempt to reproduce the equivalent flight loads

To date more results are available from the Bristol work (Table 1) than from the Saunders-Roe experiments and the indications are that equivalent loads can be introduced to the three primary systems by the Bristol methods Sufficient results are not yet available to indicate the value of the method being explored by Saunders-Roe

This subject will be reported on at a meeting of the Helicopter Association of Great Britain during the 1952/53 session and those interested in its conclusions are referred to the Association's Journals covering that period

Higher Translational Speeds [14]

A body of technical opinion does not anticipate that the improvements in speed to be expected by the development of better blades with higher maximum lift coefficients and improved compressibility characteristics will in themselves satisfy the user demands In any case, such improvements are liable to be offset by increased disc loadings Hence, other means of obtaining higher speeds are being explored and the following two methods in particular

Rotor Wing Combination

The problems of this combination must be faced soon because the future trend will no doubt depend on this application Towards this end, we hope to fit a variable incidence wing to a Bristol 171 for research investigations at the Royal Aircraft Establishment The main object of this work is to provide general information of the stability and control problems likely to arise

Use of Second Harmonic Control

The aim here is to delay stalling of the retreating blade by a redistribution of lift over the disc such that loading is reduced over the lateral sectors and increased over the fore and aft sectors It can be shown that such redistribution can be obtained by the introduction of second order cyclic feathering Both the Westland Company and the Royal Aircraft Establishment are showing interest in this possibility and it seems probable that flight experiments will be carried out in the near future

Concluding Remarks

In this paper I have tried to give a broad outline of British helicopter developments I hope the information it contains, together with the references quoted, will convey a fairly complete picture of the British situation

The British approach has been to use the resources available to acquire knowledge In this I hope we have succeeded and I believe that when the user demand does come the British Industry will not be found wanting

In closing, I would like to thank the American Helicopter Society for giving me the opportunity of presenting this paper I would also like to thank the British firms, and my many friends engaged on British helicopter development, for allowing me to use much of the information the paper contains , also the Chief Scientist, British Ministry of Supply, for permitting me to present it Finally, I am indebted to Mr L S Wigdortchik for undertaking to read the paper on my behalf

The opinions expressed are entirely my own

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