The Cierva " Air Horse "

By J S SHAPIRO, DIPL ING , A F R Ae S

As my contribution to this afternoon's proceedings, it is my task to give you a brief account of the Cierva " Air Horse " This machine has the distinction of being the world's largest helicopter undergoing flight testing

Following the recent S B A C exhibition at Farnborough, I have heard many kind and unkind expressions of expert and inexpert opinion, but the lowest common denominator seems to be that it is an " astounding contraption " Faced with this challenge, my purpose this afternoon is somewhat apologetic, namely, to show that it is neither astounding nor a contraption In fact, we, in the Cierva Autogiro Company, have persuaded ourselves that God decreed three rotor helicopters All others are merely attempts by men to cheat His divine laws

The " Air Horse " design arose primarily as an answer to the demand for large loads It was realized that difficulties in helicopter construction increased in proportion to rotor diameter and nothing was therefore more natural than to increase the number of rotors

It is not surprising, however, that three rotors were chosen A body in space is determined by the position of three of its points provided these are not in line The three rotor conception is therefore natural and as such can be traced back to early origins Fig 2 shows a patent drawing from a specification of **Florine** (1921) which covers the torque compensation by rotor tilt in a co-rotating multi-rotor helicopter

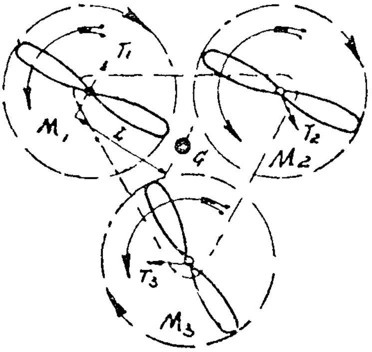
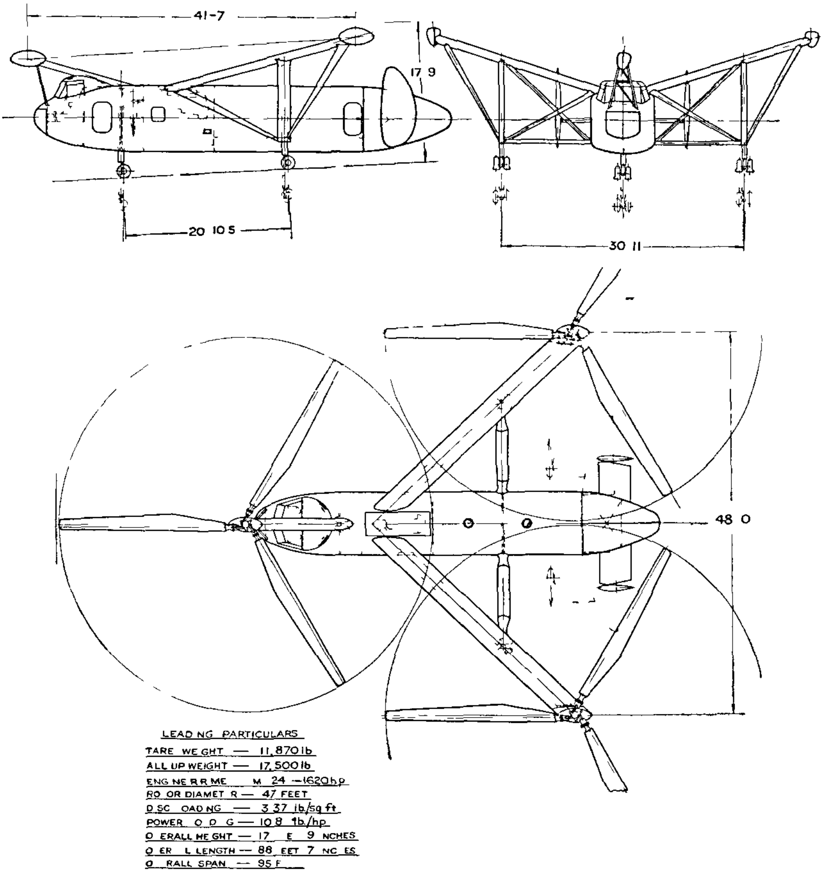


Fig 2 Facsimile

Fig 3
G A of W II
"Air Horse"



DISTINGUISHING FEATURES

Time does not permit me to dwell upon the logical development of the extensive design investigations which gradually led to the specific features of this machine as it has finally emerged These distinguishing features, in combination, render a novel conception Contrary to FLORINE'S proposals, the "Air Horse" rotors have freely flapping blades, but in common with FLORINE'S ideas, the rotors rotate in the same direction and torque reaction is counteracted by horizontal thrust components These are obtained through a built-in tilt of the rotors mainly in the lateral sense

This machine is further characterized by a single rotor being placed forward, in the normal direction of flight, with the remaining two rotors, in side by side formation, behind It is controlled about its pitching and rolling axes by means of lift couples obtained through differential application of collective pitch to the three rotors in an obvious manner For the purpose of control about the yawing axis cyclic pitch variation in the fore and aft phase is applied differentially to the side by side rotors The result of this is a virtual fore and aft tilt of the rotor discs, thereby establishing horizontal thrust components with a yawing couple between them

W11 PRINCIPAL DATA

ALL UP WEIGHT	17 500 LB
EMPTY WEIGHT (FREIGHT CARRIER)	11 870 LB

ROTORS

NUMBER	3
DIAMETER	47 FT
NUMBER OF BLADES PER ROTOR	3
NOMINAL SOLIDITY	0 0598
NOMINAL TWIST	11° 45′
NOMINAL TAPER	2 584 1
BLADE PROFILE	NACA 23015
NOMINAL RPM	219 5

ENGINE

1 ROLLS ROYCE MERLIN MK 24

SUPERCHARGER SINGLE STAGE TWO SPEED

GEAR RATIOS 8 15 1 AND 9 49 1

	BOOST	RPM	ICAN SEA LEVEL HP
MAX POWER (5 MIN)	+18	2850	1620
CLIMB POWER (1 HOUR)	+12	2850	1290
MAX CONTINUOUS POWER	+9	2850	1120

PERFORMANCE

MAX RATE OF VERTICAL CLIMB ICAN SEA LEVEL CONDITIONS = 900 FT/MIN

LEVEL FLIGHT SPEED FOR MAX CONTINUOUS POWER ICAN SEA LEVEL CONDITIONS - 125 MPH

FIG 4

Finally, the machine is fitted with an undercarriage having a stroke of five feet and is thereby enabled to absorb the shock of very high rates of descent

DESCRIPTION

Of all the design details of this machine, I have to restrict myself this afternoon to the essence of the control system The hub control mechanism terminates in the actuating sprockets of which the lower, causing axial displacement of a hub control spider, varies the collective pitch of the blades, and the upper, by tilting the hub control spider, imposes upon the blades a cyclic pitch variation of fixed azimuth

Each collective pitch sprocket of a rotor is connected through a cable transmission to one extremity of a stationary spider in the fuselage and each of the cyclic pitch sprockets is actuated through a similar transmission by the displacement of the extremities of another stationary spider The two stationary spiders are the heart of the " control exchange " mechanism, and are shown in Fig 5 in diagrammatic form Axial and tilting movements of the " exchange " spiders combine to control the actuating sprockets in the hub The pilot's control organs are linked with the " exchange " spiders so as to produce the correct combinations of common and differential increments of collective and cyclic pitch control This linkage is assisted by hydraulic jacks supplied by Messrs Lockheed under the trade name of " Servodyne "

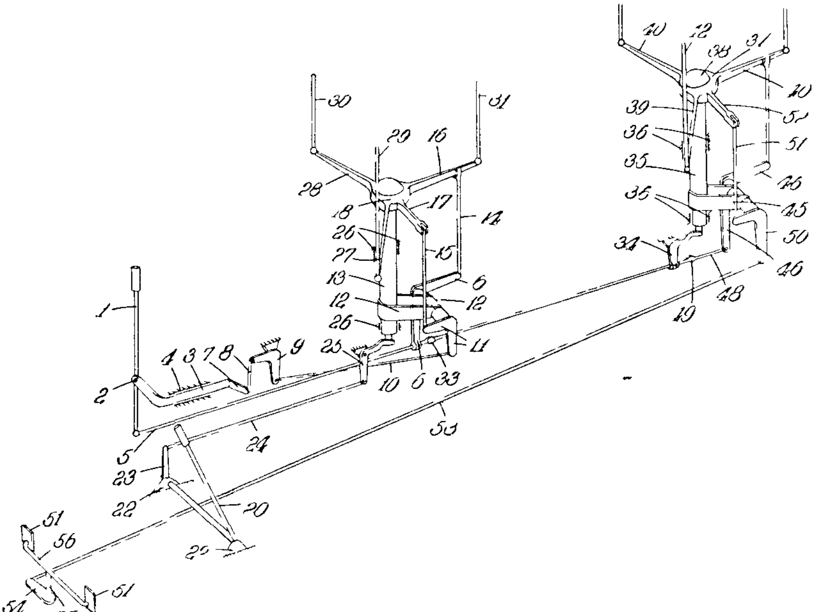


FIG 5

Basic control functions, consist of the following Raising and lowering the " collective exchange " spider by means of the pitch lever produces common collective pitch change The pilot's control column communicates tilting motion about the pitching and/or rolling axes to the " collective exchange " spider which causes differential variation of collective pitch (and lift) between the rotors

Finally, the rudder pedals impose a tilting motion on the " cyclic exchange " spider about its rolling axis which causes the tip path planes of the two rear rotors to be differentially tilted in the fore and aft sense thereby producing a couple between the opposing horizontal thrust components

DEVELOPMENT OF CONTROLS

With controls connected as described so far, the machine is fully controllable, but to extend its range of forward speeds and to improve its flying qualities further control connections are being gradually introduced which are considered in order of importance

In forward flight at any appreciable speed it becomes essential to reduce or suppress the flapping of the blades To this end all rotors must receive cyclic pitch control in the same sense and roughly of equal magnitude This task is carried out by imposing an axial displacement on the " cyclic exchange " spider whenever fore and aft movement of the control column takes place The interlinkage is adjusted for suppression of flapping in level flight Nearly complete suppression of flapping is easily performed by a linear interlinkage This interlinkage is made possible by a definite relation between stick position and forward speed such that the stick is maintained in a position further forward for increased speed Reference will be made later to this feature, which is illustrated in Fig 6 (Based on " variable dihedral " as explained below)

Directional trim is provided for use in forward flight by means of orientable fins under the control of a trimmer wheel operated by the pilot This serves to avoid holding off the rudder pedals during long stretches of level flight

The stability characteristics of a three rotor helicopter are greatly influenced by the amount of " dihedral " between the rotor discs Effective dihedral is determined not by the mechanical axes but by the virtual axes, normal to the plane referred to which no cyclic pitch change takes place It has been found that negative dihedral contributes to dynamic stability in hovering whilst " stick fixed " stability in forward flight requires positive dihedral This conflict can be resolved through the introduction of variable dihedral by means of a gradual fore and aft tilt of the " cyclic exchange " spider thereby producing virtual differential tilt between the front rotor, on the one hand, and the two rear rotors on the other Dihedral variation will also be interlinked with fore and aft movement of the control column (Fig 6)

It is intended to provide an interlinkage between the common pitch lever and the directional controls so as to ensure yawing equilibrium throughout the range of rotor r p m in flight

It will be appreciated that whilst most of the specific features of the " Air Horse " are based on well known principles the number of possible combinations is very large and the selected combination has been evolved through a long process of elimination

CLAIMS

The " Air Horse," by virtue of its configuration and distinguishing features enjoys many inherent advantages some of which are as follow

Control and Stability The control of the aircraft in roll and pitch is extremely powerful in the sense that only a small fraction of available control range is required to obtain angular accelerations above those common in present-day helicopters Furthermore, control couples are nearly " pure " and not associated with horizontal forces until the aircraft has actually changed its attitude in response to the application of control Both features are due to the fundamental method of multipoint control and cannot be equalled in a single rotor helicopter

In the three rotor machine the basic control functions of pitching and rolling are produced by increments of lift and not by the lift itself An increment of lift can always be obtained by blade pitch variation even when the lift itself is going through zero It can be said, therefore, that basic control functions are operative in three rotor machines under all conditions of flight, without exception

The direct significance of stability concepts in helicopters is as yet uncertain, but in some respects a three rotor (or tandem) helicopter is more similar to the fixed wing aircraft than the single rotor helicopter Static stability in the " original " sense is influenced by the horizontal position of the centre of gravity relative to the geometric centre of the lifting surfaces though the vertical C G distance has a great de-stabilizing influence in a helicopter but not necessarily in fixed wing aircraft There is, however, one fundamental difference between the " Air Horse " and a fixed wing aircraft The " stick fixed stability " in the three rotor helicopter depends almost entirely on the longitudinal dihedral between the front rotor and the rear rotor pair The two " stabilities," therefore, are independent In the " Air Horse " both are positive *throughout the speed range*

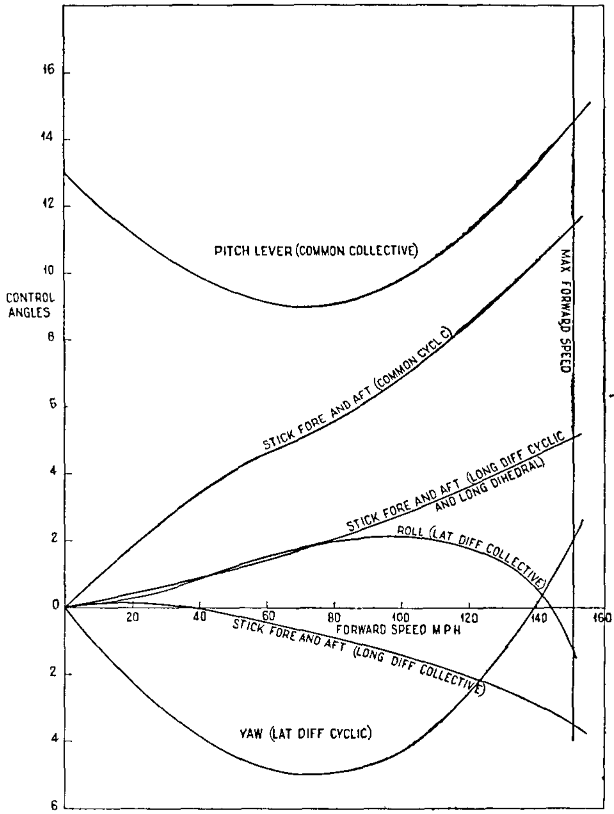


FIG 6

"AIR HORSE"

LEVEL FLIGHT

CONTROL

CHARACTERISTICS

$\delta M/\delta \alpha$ is made negative (conventionally denoting positive stability) by placing the centre of gravity forward of the geometric centre of the rotors by 8% of the distance between the front rotor and the line joining the rear rotors This amount covers the de-stabilizing influence of interference between front and rear rotors in forward flight as well as the de-stabilizing effect of the vertical distance between the C G of the aircraft and the plane of the rotors, the latter being approximately three times as severe as the former It is assumed that the instability of the fuselage body is fully balanced by its own tail plane No other form of helicopter shows any promise of attaining negative $\delta M/\delta_\alpha$ over the whole speed range Usually an unstable region exists at low speed

Stick fixed stability is achieved by positive dihedral (or variable dihedral becoming positive in the upper range of forward speed) This stability is illustrated in Fig 6 giving the position of controls over the speed range in level flight

Dynamic stability has been investigated mainly in hovering It is well known today that dynamic instability in hovering is mainly caused by the existence of a moment derivative with regard to horizontal translational motion In a three rotor machine having a (virtual) negative dihedral, this derivative can be suppressed and even changes sign Under such conditions dynamic stability is obtained as shown in Fig 7 representing graphs of the stability parameters over the dihedral angle The graphs refer to longitudinal motion but apply to lateral motion as well I am indebted for these graphs to Dr Sissingh who very kindly confirmed and improved upon our own calculations

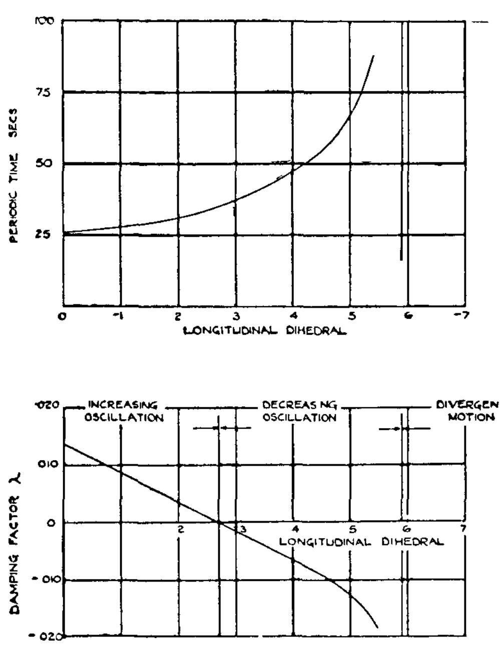


Fig 7—Longitudinal stability in hovering flight at sea-level (C G position 59 per cent aft of front rotor)

Undercarriage As a consequence of the geometry of the three rotor helicopter, it is possible to provide the undercarriage with relatively large track and wheel base without any weight penalty The importance of this feature will be apparent when it is recalled that the majority of accidents to rotating wing aircraft in the past have been due to overturning on the ground and could have been avoided by increasing the track of the undercarriage

In the " Air Horse " the legs are so spaced in relation to the radii of gyration of the machine that non-symmetrical landings are only slightly more severe than symmetrical landings

Layout The Lay-out of the machine provides unobstructed entry into the main load compartment Further, on single rotor machines, the fore and aft limits of the centre of gravity are rigidly prescribed not so much from the point of view of static stability which is, in any case, problematical and depends mainly on the vertical position of C G but from the point of view of control range In the " Air Horse," due to the extremely powerful pitching control, such a restriction does not apply in practice and no difficulty will be experienced in flying with the centre of gravity as far as two feet off the mean position in either direction This fact greatly facilitates the loading procedure and is likely to be especially appreciated in freight carrying machines

Due to the absence of a tail rotor and the elevation of the main rotors, the " Air Horse " is completely free from the usual hazards to personnel on the ground

CRITICISMS

Having enumerated some of the principal advantages of the three rotor configuration, we now have to turn to criticisms likely to be advanced against this form of helicopter and examine their justification It is natural to question the complexity of a three rotor machine with its multiplication of blade articulations, transmission elements and controls Furthermore it is expected that the weight penalty as well as the drag penalty of the outriggers and long travel undercarriage legs will have to be justified on performance grounds in spite of the numerous other advantages of the configuration

No definite answer to such criticisms can be provided without first choosing a suitable criterion derived from a distinct approach to helicopter operation It is my intention in this paper to underline the quantitative approach and to choose the point of view of the commercial operator selling the use of " helicopter communications " In this way, from the great number and variety of considerations applicable to the evaluation of a helicopter, those expressible in economic terms can be selected and correlated under the guidance of the over-riding aim " to provide helicopter transport services at low cost in terms of pence per ton mile or passenger mile at a speed leaving a substantial margin compared with ground transport and accompanied by the highest possible safety "

Once commercial operation is considered, the criticism of complication loses its significance as an independent yard-stick in evaluating the helicopter or any other piece of equipment From this point of view, to be significant, complication must be expressible in terms of first cost and/or maintenance

As regards first cost, it is believed that the multiplication of components carries with it the tendency to cheapen manufacture by increasing numbers We are all aware of numerous examples in technical development where multiplication of components has no specific effect on first cost I only need to mention multi-cylinder engines or ball-bearings

As regards maintenance, final judgement will have to await practical experience, but it is believed that the advantage of accessibility obtainable in a three rotor machine of the size of the " Air Horse " and the reduction in the relative cost of spares through interchangeability, outweigh the disadvantages of multiplication

We are left, therefore, with the problem of evaluating the "Air Horse" from the point of view of performance expressed in terms of transport economics The evaluation will be divided into two main chapters dealing with the relatively independent features , three rotor configuration and long travel undercarriage

ECONOMICS OF THE THREE ROTOR CONFIGURATION

We formulate our first problem in the following terms are the advantages of the three rotor helicopter accompanied by a weight and drag penalty leading to increased cost of helicopter transport ?

We are mainly concerned with examining the three rotor configuration in comparison with others However, it is essential to ensure that other things are equal Among other things we include the remaining principal factors determining the economics of helicopters, that is Size , Choice of parameters, and Detail design

It will at once be obvious that we cannot replace a theoretical evaluation, however uncertain and based on inspired guessing, by a direct comparison of existing types simply because no such types are available of equal size, equal approach to optimum parameters, or equal stage of design development

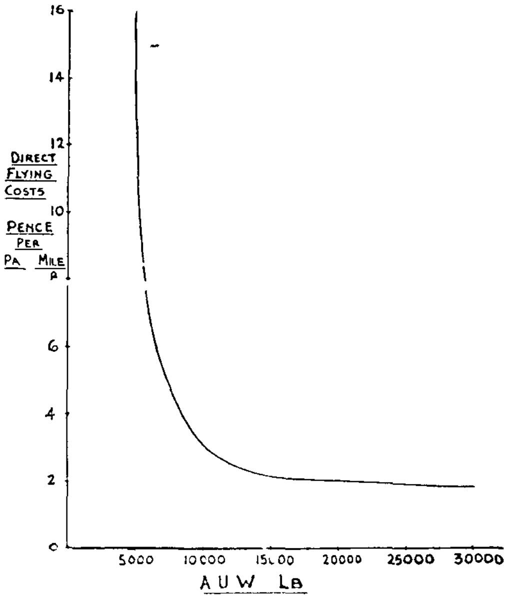


FIG 8

Direct flying cost v A U W
Passenger carrying helicopters
Stage length = 100 miles approx
Load factor = 100 per cent
Utilisation = 2,400 hrs /year

Referring to the chosen criterion of economic efficiency, we can narrow it down by first examining the conditions of safety and speed Some of the advantages of the three rotor configuration enumerated above are concerned with safety In addition it is thought likely that, except for special duties, the twin engined version will be the only one employed for civil transport

All helicopters under development today are inherently capable of substantially identical cruising speeds of about 115 m p h and the " Air Horse " promises to attain this speed with economical cruising power

Consequently that speed can be eliminated as a factor in comparing the economic efficiency of helicopters, and we are left, therefore, with a cost comparison alone

Effect of Size Fig 8 illustrates the fact that up to the size of the " Air Horse " and beyond, the effect of size on cost is predominant This graph is based on existing helicopters, but includes the twin-engined " Air Horse " Fig 9 applied to three rotor machines only shows that size has a far less pronounced effect on the percentage of disposable load Such a conclusion is roughly in accord with fixed wing experience in the range of sizes considered here and represents the balance of several opposing tendencies The effect of size on the cost of transport is due to cost items, such as crew remuneration, which are predominant in small sizes

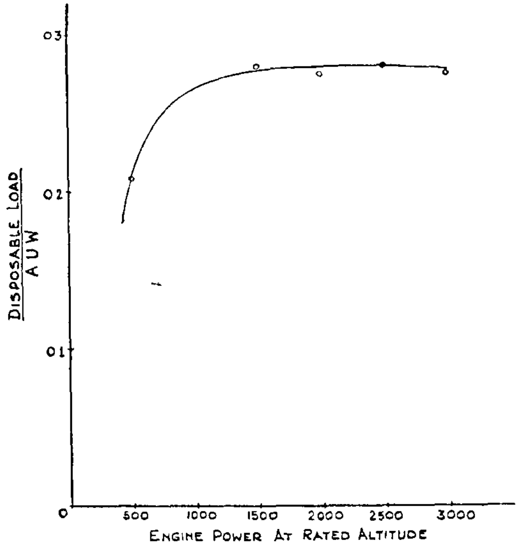


FIG 9

Disposal load/A U W

v Power at rated altitude

3 rotor helicopter, tapered, twisted blades tip speed$=$550 ft /sec

Optimum disc loading

Minimum solidity

Minimum U/c travel

Effect of Configuration It is most profitable to restrict our approach and to compare multi-rotor helicopters having different numbers of rotors In this limited field, at least, the comparison expresses real trends Such an evaluation extends to all out-rigger machines from side by side twin rotors to three and four rotor configurations It is based on the assumed laws by which weights of different components alter with basic physical magnitudes of the helicopter to which we shall return later Fig 10 shows that a very considerable improvement results from increasing the number of rotors from two to three Further possible improvement is limited and may no longer justify the additional complication

This graph cannot, of course, cover single rotor, tandem, intermeshed,

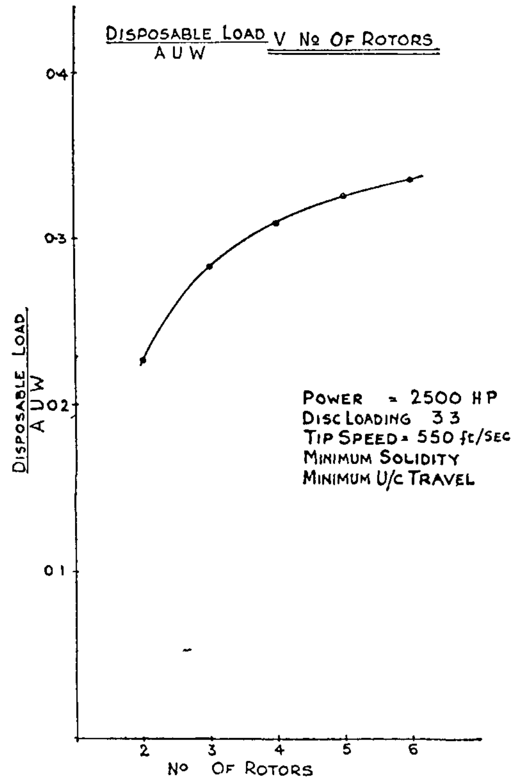


Fig 10

or co-axial configurations which are the present practical competitors of outrigger lay-outs In each case, if we take the side by side outrigger system as a basis, there will be items causing weight reduction as well as items causing weight increase My point is that the best alternative system which I personally believe to be the tandem machine, is only marginally better than the side by side twin and therefore probably inferior to the three rotor machine

Other performance aspects are more easily dealt with It can be stated with some assurance that the gliding angle of the three rotor machine as a whole is of the same order as that of the better single rotor machines This is due partly to the utilisation of the rear outrigger booms to produce lift in forward flight and partly to the effect of size

Effect of Design Parameters I cannot here deal with the subject exhaustively but, in outline, our approach consists of the following steps, each one containing somewhat bold and debatable assumptions, but which in combination are plausible and consistent

(1) Definition of permissible All Up Weight

(2) Determination of truly independent parameters

(3) Subdivision of component weights into groups depending on individual parameters and their combinations

Briefly All Up Weight is limited to that which can be lifted vertically at a rate of 6 ft /sec by maximum engine power without wind or ground interference under the worst atmospheric condition in which the machine is expected to operate To avoid a " multiplication of pessimisms " average individual efficiencies are chosen and a total allowance of 4% power loss is made to cover all errors

There are four major design parameters once the configuration is settled and the power unit chosen

(*a*) Disc loading (*c*) Blade solidity

(*b*) Tip speed (*d*) Undercarriage stroke

Of these (*c*) and (*d*) prove on investigation to be dependent upon others

Fig 11 illustrates the effect of disc loading on the percentage of disposable load for a given power It is seen that the effect of disc loading flattens out and remains stationary over a considerable region Disc loadings of the two Air Horse types are near the maximum I would like to make it clear that these graphs represent a comprehensive approach In all cases, for instance, solidity is automatically adjusted to avoid tip stall and U/C stroke is automatically increased to absorb the energy of unaided vertical descent without power

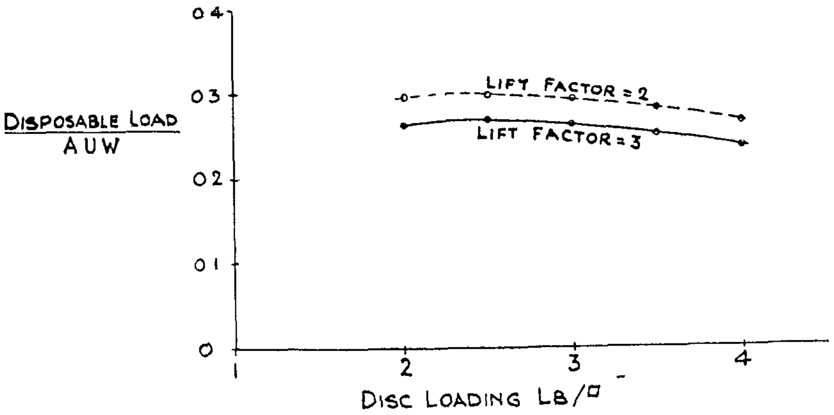


Fig 11 —Variation of Disp Load with Disc loading
A U W
Engine Power 1000 H P Top speed 500 ft /sec
Minimun solidity Minimum U/c Travel

In contrast to disc loading graphs, those showing the percentage of disposable load over the representative tip speed (Fig 12) have no optimum We have to re-emphasize that rotor solidity is adjusted for each tip speed to a value determined by tip stall in forward flight

The Figure includes a graph of the kinetic energy of the rotors It is seen that the effect of decreasing solidity nearly offsets that of increasing tip speed and the kinetic energy increases very slightly with increasing tip speed

Effect of Detail Design A novel configuration presents new problems requiring time and experience for their solution It calls for caution but it also offers new opportunities to the designer In particular, larger size contributes to the possibility of greater refinement and the lay-out of the " Air Horse " facilitates attention to ease of maintenance The three-fold repetition of many components makes every improvement in the design of such components *three times* more effective

Summarizing, we can conclude that the " Air Horse " constitutes a most important advance in economic efficiency on account of its size made possible by multiplication of rotors, that the three rotor configuration compares favourably with the best known alternatives and its numerous advantages are not bought at a sacrifice in economics, that the " Air Horse " represents a choice of design parameters approaching the optimum in all but tip speed, and that, for its potentialities to be fully applied in detail design, type development will be pursued promising to reach really high standards in the twin-engined version

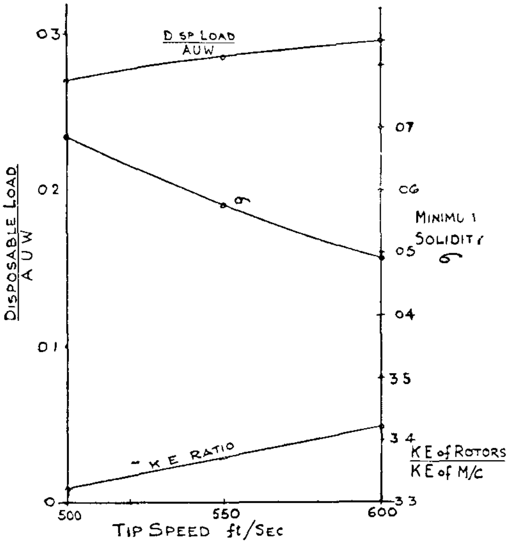


FIG 12

The effect of tip speed
Power = 2,500 h p
Disc loading = 3 3
Minimum U/c travel

ECONOMICS OF THE LONG TRAVEL UNDERCARRIAGE

The " Air Horse " undercarriage has a travel of five feet which enables the machine to carry out an emergency landing in vertical descent without power and without relying on the kinetic energy of the rotors The rate of vertical descent is estimated at 41 feet per second and the energy absorption is, therefore, approximately 12 times that corresponding to minimum ARB requirements

In providing a high absorption undercarriage the Company were guided by the following considerations —

(*a*) That safety features independent of the pilot's skill are likely to be far more effective than those depending on a rather precise manoeuvre requiring great presence of mind and experienced judgement

(*b*) That loss of power is experienced often immediately after take off when there is no time for the pilot to carry out the required landing manoeuvre In fact, to reduce, if not escape, the danger at small heights over the ground, it is necessary to follow a take off and landing technique which, apart from using maximum r p m , includes inclined climb as well as taking account of the prevailing wind Such procedures militate against the main advantage of the helicopter, namely all weather operation from strictly confined spaces It is visualised that the helicopter, to do justice to its principal function and to simplify landing facilities and navigation, has to be able to take off and land truly vertically and to be independent of wind direction These considerations apply more particularly under conditions of poor or zero visibility Imagine the advantage of knowing that you can hit the deck at a vertical rate of 20 m p h without the slightest inconvenience !

(*c*) To substitute effectively kinetic energy for undercarriage absorption capacity it is necessary to provide enough of it at take off and landing

A full analysis of energy transformation in vertical descent is complicated, but for the purposes of our argument, it is enough to state that in *practice* (that is allowing for a normal degree of error on the part of the pilot) the available kinetic energy in the rotor must be a multiple of the kinetic energy of the machine in vertical descent Some published data lead to the conclusion that the factor ought to be about 5 for adequate safety

Referring again to Fig 12 we observe that without special attention to this matter we may expect, in a well designed three rotor machine, a factor of 3 varying only little with tip speed

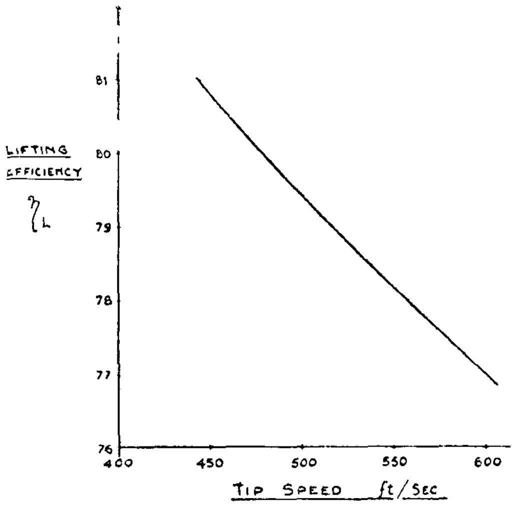


FIG 13

Lifting efficiency *v* tip speed tapered twisted blade

Disc loading = 3 5lb /sq ft

Normal solidity = 0 05

To obtain the missing 66% of available energy we can either increase tip speed by 30% *keeping the same blades* or increase blade inertia by 66% with constant tip speed The former procedure will reduce the lifting efficiency by as much as 4% as can be seen from Fig 13 giving lifting efficiency over tip speed at constant solidity The latter solution will add 4% to the structural weight

On the other hand, the weight sacrifice for long travel amounts to barely 3% of All Up Weight which is less than the useful weight increase obtained by enabling the machine to take off, hover and land at optimum blade angle

OPERATORS' REQUIREMENTS

Though this contribution to the discussion was broadly intended to represent the constructor's reply to requests expressed earlier by operators, we have until now concentrated on the description and evaluation of a type already in existence We can now turn to the operator's problems but will have to restrict ourselves to brief remarks

We have to classify requests made by operators into several categories

(*a*) Many of the features which distinguish the " Air Horse " either inherently or incidentally, directly meet some of the points raised by the lecturers and have, in fact, been introduced in response to such requests

(*b*) To be honest, every designer has to admit that many troubles experienced by operators arise not from inherent difficulties but merely from lack of foresight No purpose is served by covering up lack of attention, and the remedy for such faults lies in better appreciation of the problems by the operators themselves, and better co-operation between operators and designers This discussion must be especially welcomed from this aspect Specifically, it cannot be denied that in helicopters some, though not all, vibration troubles fall into this category especially those arising from avoidable unbalance and resonant response to periodic impulses which, in themselves, are not intolerable

(*c*) Operators must realise that some of the requirements put forward by them are conflicting Most improvements have to be paid for with money or weight, or both To do justice to such conflicting requirements it is essential for the designer to be given some guidance of a quantitative nature as to the relative value of the different requirements It is admitted that such information may be extremely crude at this early stage of practical experience My point is that crude information is better than none

(*d*) Finally, there are requirements to which the designer is fully alive but which constitute real technical problems requiring systematic research and development, for their solution

Progress will be determined by the effort invested in research and we all hope such research will receive assistance and sponsorship on a scale commensurate with the promise of the great benefits which the public expects from further developments of helicopters

POTENTIALITIES OF THE " AIR HORSE " IN CIVIL AIR TRANSPORT

The present achievement is characterized by a percentage of disposable load of 32% in the freighter version corresponding to 27% in the passenger version Although this figure may drop somewhat owing to additional operational equipment, we recall that it approaches the figure of 28% given for the " Ambassador " which is a highly developed, conventional, fixed wing aircraft It cannot be stressed too strongly that such an achievement in a completely novel configuration means that the potentialities of the type are very much greater The policy of our Company is to pursue development along the line of increased all-up-weight with the twin-engine installation, preserving many of the existing components Experience with the " Air Horse " research prototype will enable us to depart from the caution with which such a novel conception had to be approached It is confidently expected that the twin-engined " Air Horse " will have a disposable load percentage of 30% in the passenger version and 35% in the freighter version, with full operating equipment of approximately 800 lb

Present estimates of direct cost for the twin-engined " Air Horse " are of the order of 1 9 pence per passenger mile for 100% load factor, and a stage length of 100 miles

The load factor in helicopter transport must be considered without prejudice from fixed wing experience It will be greatly influenced by tariff policy and by the frequency of the service and must at present remain highly speculative However, even if we assume a load factor of 65% the direct cost per passenger mile becomes 2 66 pence

All that can be said at present about overhead expenses is that they must be inherently lower than those of fixed wing aircraft due to the basic features of the helicopter which requires only a fraction of the ground installations and facilities essential for fixed wing operation I believe that overhead expenses of 33% are a generous allowance which can eventually be reduced to 25% or even 20% We thus arrive at an economical fare of less than 3 5 pence per passenger mile I visualize the single fare between London and Birmingham to be 28/- compared with the present single first-class rail fare of 37/9 On the basis of a cruising speed of 116 m p h the scheduled block time of the journey would be 59 minutes Similarly, a single fare between the centre of London and the centre of Paris would be exactly £3 and the journey would take two hours and two minutes

Few people would disagree with me in expecting that if these figures can be obtained, and I believe them to be quite within our grasp in three to four years, a vast volume of traffic will be carried by helicopter services over routes such as those mentioned above and I am confidently looking forward to the day when from a helicopter station in the centre of London, twin engined " Air Horses " will rise every 20 minutes and carry 30 passengers to Paris, or Brussels, or Birmingham, or Manchester

Acknowledgments

Whilst other contributors to this discussion share the distinction of leading the design teams responsible for their machines, I was merely given the honour of representing the team of the Cierva Autogiro Co , I have to pay very special tribute to the pioneer of successful helicopter flight in the United Kingdom, our Chief Designer and Managing Director, Mr C G Pullin, and my colleagues, the Deputy Chief Designer, Mr H Bolas, the Chief Mechanical Engineer, Mr K Watson, and the Chief Test Pilot, Mr H A Marsh, as well as to the able and devoted staff of the Company who have made the design and construction of the " Air Horse " possible

When the achievement of the " Air Horse " is judged as the latest link in an unbroken line of development, the Rotary Aircraft World owes a great debt to our President, Mr J G Weir, for his pioneering devotion for the last twenty-five years

The continued sponsorship given by the Ministry of Supply to our work deserves the profound gratitude of all rotating wing enthusiasts and we all know to what degree this sponsorship has been inspired by and personified in Captain R N Liptrot, Director of Research and Development

Finally, let me express our thanks to all our friends, whether at the R A E , Farnborough, or among our Suppliers and Sub-contractors, who, by showing their enthusiasm and doing a little more than priority justified or duty demanded made this achievement possible at a difficult time