Helicopter Operations—Some Problems and Prospects

By N E ROWE, C B E , B Sc , A C G I , D I C ,
F R Ae S

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H A MARSH, A F C , A F R Ae S , *in the Chair*

INTRODUCTION BY THE CHAIRMAN

Ladies and Gentlemen

The Paper we are about to hear this afternoon is obviously of very great importance to manufacturers and potential operators, and no less to all of us who have the interest of helicopters at heart It is quite reasonable to suppose that the more we know of the problems of operation, the more likely we are to produce the right type of helicopter for the job

It would be difficult to think of anyone better qualified to give this paper than our lecturer to-day, and we are very much honoured that so eminent a gentleman should do so MR ROWE is a Fellow and a Vice-President of the Royal Aeronautical Society, has had a varied and distinguished aeronautical scientific career, and was Director General of Technical Development at the Ministry of Aircraft Production in 1945 His present appointment is that of Controller of Long Term Research and Development with British European Airways Corporation, in which capacity he is intimately concerned with the problems of helicopter operation, both present and future

He is also Chairman of the recently appointed Airlines' Aircraft Requirements and Contracts Committee, whose job it is to co-ordinate the requirements of the three Corporations under the new ordering procedure

It is not too much to say that the practical experience which has been and is being gained by B E A Helicopter Unit will be of immense value to all future operators

I will now ask MR ROWE to read his paper

MR N E ROWE

Mr Chairman, Ladies and Gentlemen

This afternoon I shall attempt to deal with questions in a comparatively new field and, whilst conscious of the honour the Helicopter Association have done me in asking me to give this lecture, I am deeply sensible that much that I say must be necessarily somewhat speculative and hence open to challenge and criticism This may be not a bad thing, we can do with vigorous and constructive criticism in all phases of scientific and engineering thought and development, this is certainly true of the present phase of helicopter development as a new vehicle of transport I intend to confine my attention to operation of the helicopter for conveyance of passengers and goods on scheduled services That excludes very many of the operational uses for which it is so well fitted, but my own view is that the important developments in this country will be connected with transport, and we should therefore bend our attention to the relevant problems which are likely to arise

This approach leads, quite naturally, to a division of the subject into three parts Firstly, a statement and discussion of operational requirements, secondly, a consideration of the major problems arising therefrom, and thirdly, a broad assessment of operational prospects Thus the paper has been cast in this form, although it will be understood that the subject matter of each part is inter-related in the closest way with the others

PART I

STATEMENT AND DISCUSSION OF OPERATING REQUIREMENTS

Perhaps the most direct way of getting to grips with my subject is to outline the basic operational requirements which must be met if this new vehicle is to be used effectively In this way we can expect to focus attention on the main and subsidiary problems in the air and on the ground Before doing this there are matters of a general nature to which I should draw attention

We all know the characteristics of the helicopter which offer such potential advantages in operation—its ability to fly slowly and to hover, to use small and restricted areas for take-off and alighting and to move direct from point to point in three dimensions But we also recognise that it is a comparatively short range vehicle up to, say, 250 miles, in fact, it is at such ranges that it offers its most effective contribution to existing means of transport in this country At longer ranges the advantages tend more and more to the fixed wing aircraft, which is able to make increasingly effective use of its much greater cruising speed

Short range operation introduces a number of most significant factors Firstly, it demands a very high standard of regularity and punctuality This, of course, is because the journey time is short, serious late running or cancellation of a trip which takes, say, one hour (double or more by alternative transport) is likely to have serious immediate effects of inconvenience and personal disorganisation, more perhaps than delay of a day in an air trip to America or Australia Unless the means of transport for such journeys is reliable it will not be accepted as a common agent of communications Secondly, such short stage transits invite the closest comparison with normal means of surface transport in safety, regularity, economy, comfort and convenience Thus, to become effective, helicopter operations in a country like ours must be no more affected by meteorological conditions than is surface transport—this is a fundamental requirement A complementary requirement is that night operations must be as readily performed as operations by day A third most important factor depending on short range operation is the relatively large number of rotor stations needed

Since each must be equipped to the standard needed for regular and punctual operation in all conditions, including night operations, the equipment needed must be simple, cheap and economical in cost and manpower for operation and maintenance

OPERATING REQUIREMENTS

Safety (Fig 1) As a vehicle of transport the helicopter will be used in this country and elsewhere, first, where it can show to best advantage, possibly over water barriers or difficult terrain Here the benefits in time saved and convenience may be considerable, but the journeys will still be " local " and the safety standard will tend to be judged by surface transport rather than air Moreover, the claim of the helicopter, as understood by the public, is that its ability to hover, to move in a vertical direction without forward speed, to operate into and out of small areas, confer elements of safety not available to the fixed wing machine, which relies on forward speed for sustentation Hence the standard of safety expected will be high , it is one of the major problems of operation to ensure this , but basic design is of fundamental importance in this connotation Also the safety of the third party on the ground is equally important

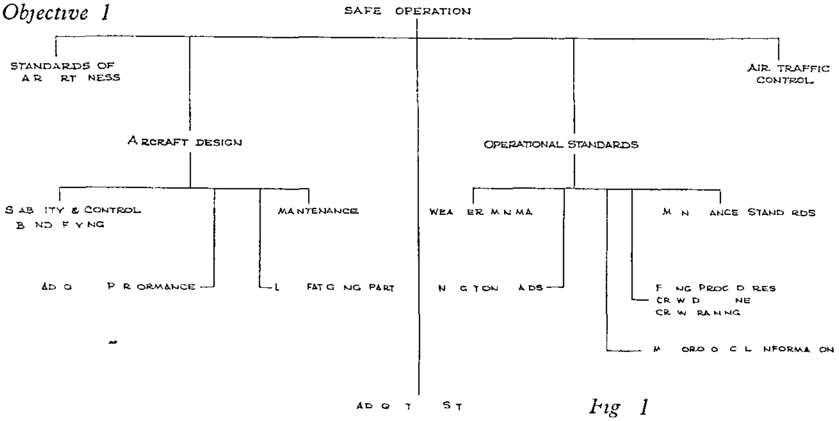

Fig 1

The firm essentials for safe operation are —

(*a*) Good blind and night flying characteristics, especially in regard to stability and control in smooth or rough air and cockpit visibility and layout

(*b*) Satisfactory means of navigation point to point, in I F R conditions, giving accurate information of position at all heights, especially very low ones A very high standard of reliability is needed

(*c*) Satisfactory recognition and let-down aids at alighting points in I F R conditions

(*d*) Good flying characteristics in rough air

(*e*) Adequate performance in regard to the character of the terrain, including the case of engine failure

(*f*) Requisite standard of airworthiness

(*g*) Adequate means of Air Traffic Control

(*h*) Requisite operational standards

(*i*) Effective maintenance of all equipment

Regularity and Punctuality (Fig 2) The standard of regularity and punctuality must be not less than that of existing surface transport travelling over comparable distances in Great Britain The implication is that operations must continue under all except the most difficult meteorological conditions of fog or storm

Objective 2

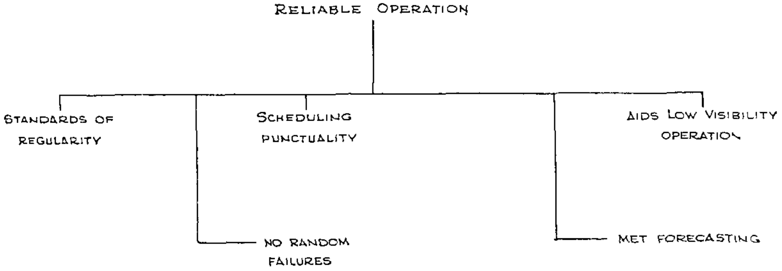

Fig 2

Scheduling to be based on adequate meteorological information and backed by precise navigation and very good flexibility in performance

N B —The relatively low cruising speed of the helicopter (up to 120/130 m p h) is sensitive to winds when maintaining schedule Hence this must be based on the very best information related to local conditions, including variation with height at low heights up to 2,000 ft , and seasonal variations The schedule is profoundly affected by the punctuality standard

Limits of punctuality are to be recognised as a necessary adjunct of scheduling to obtain maximum results with given cruising speeds and at various seasons In general, a standard better than, say ±6 mins on a one hour journey should be met on about 99% of occasions

Objective 3

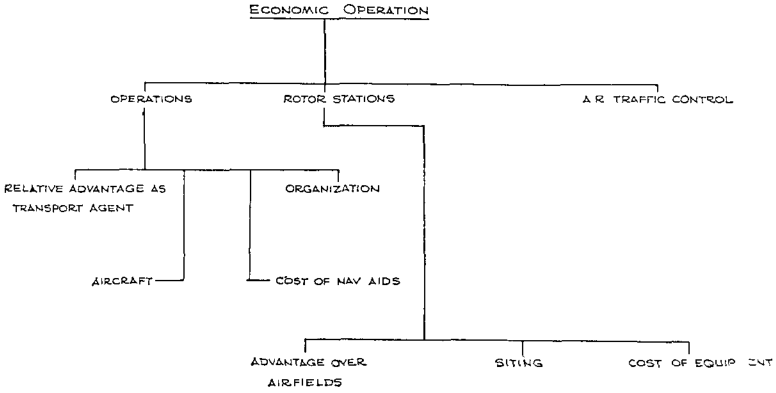

Fig 3

Economy (Fig 3) Fares must be comparable with alternative means of transport when proper account is made of the factors of convenience and comfort In general, convenience in this context means time-saving especially that which may lead to a more effective use of a business man's time It also includes the avoidance of journeys by surface transport involving inconvenient times of starting and finishing a day and train changes The avoidance of a rail-ship transfer and of a rough sea journey are good examples of increased convenience and comfort which travellers will be prepared to pay for

This requirement demands very good basic economy in the rotorcraft, involving the following factors —

(*a*) Low capital charge, depending on a long aircraft life (say, ten years) with reasonably low first cost For this we need aircraft with advanced technical features and of a size likely to serve the needs over the period named The first cost will depend on the numbers produced—we must choose a type likely to have wide application leading to a high demand, and hence a good production rate

(*b*) First class reliability, to ensure the standard of regularity needed with the minimum number of aircraft in the fleet for a given route system

(*c*) Economical maintenance, based on long life of major components and those which are inaccessible and on freedom from random failures

(*d*) High annual transport capacity for given first cost This depends on the product of utilisation (a matter for the user given good reliability and maintenance) and block speed and payload, *i e* , $U \times V_b \times W_p$ where $U =$ annual utilisation in hours, $V_b =$ block speed in m p h , $W_p =$ payload in tons

A short stage operation carries with it the implication of a large number of rotorstations Hence these must be kept simple, cheap and easily maintained and serviced , this includes the ground aids for take-off, approach and alighting by day and night Ideally, the rotorstations should involve the minimum of adaptation of existing facilities Large cities should have a number for traffic in various directions This might well be far cheaper and safer than the complex system of Air Traffic Control which would be needed if one or two main rotorstations became congested with traffic The aim must be simplicity and cheapness , roof tops seem to offer a ready solution, but the whole matter needs careful study, keeping in mind the essential needs of regular operation in all except the most severe meteorological conditions and basic economy

For maximum operating economy the means of point to point navigation should be such as to give complete tactical freedom in operating a route system at all heights It must also be economical on the ground and in the air The standard of reliability should be such that no airborne standby is needed, since it is essential to keep to the minimum the weight of airborne equipment

Convenience and Comfort (Fig 4) Choice of routes to give maximum advantage Our minimum aim should be to save one hour on a 100 mile journey compared with the best surface transport, taking full account of surface times to rotorstation or railway station This implies rotorstations near to city centre , also the study of helicopter movements into and away from busy airports, since an important application of scheduled services may be transport from the main international airport to a provincial centre No scheduled helicopter services city centre to airport are envisaged, although "taxi" services may well develop

Frequencies correctly related to journey times As a general rule it can be said that frequency is ideally inversely proportional to journey time, *i e*, the shorter the time the higher should be the frequency of the schedule

Objective 4

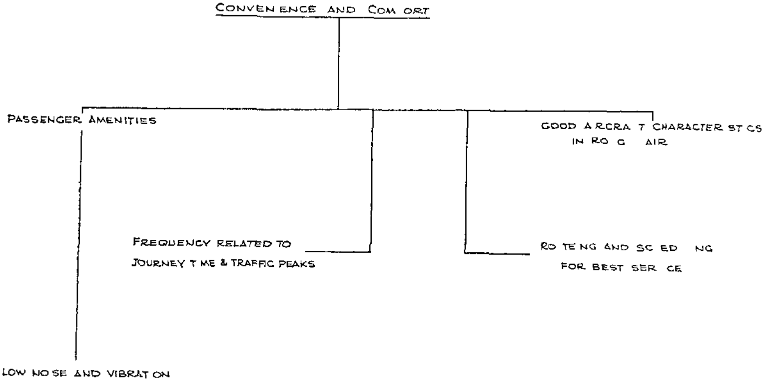

Fig 4

Frequency has a strong bearing on requirements and economics in deciding on the size of aircraft needed, and in obtaining the annual utilisation needed for economical running

Services in the Scottish Islands and Highlands seem a natural application Such operations must not be run with single-engined aircraft, the same applies to regular operations into heavily built-up areas Hence, in Great Britain, our minimum requirement for regular scheduled air transport operations is a twin-engined machine

The standard of comfort should be what is acceptable for a short journey, bearing in mind that this will often be the alternative to a much longer and more tedious and difficult journey, and that the weight for furnishings and amenities must be kept to a minimum External noise must be reduced so far as possible consistent with efficiency, and operating arrangements of rotorcraft, rotorstations, etc, should correspond to surface transport practice as nearly as possible in such matters as ticketing, booking and boarding

COMMENTS ON OPERATING REQUIREMENTS

Safety and Regularity In his Wilbur Wright Lecture of 1943, DR EDWARD WARNER observes "Regularity and Safety obviously have an inverse relationship" He was then discussing the problems of transport by fixed wing aircraft, but I think that what he says is equally true of transport by helicopter He was referring in the main to irregularities caused by poor meteorological conditions, including icing The datum meteorological conditions as affecting safety may be very different between the two types of aircraft For example, forward visibility equal to or less than one mile when flying at 1,000 ft or less would entail I F R flying on a fixed wing aircraft, but would not interfere at all with the helicopter flying at the same height Moreover, the helicopter pilot will continue to fly in complete safety at much lower meteorological visibilities than are possible with fixed wing aircraft, because he does not rely on speed for sustentation and generally flies at lower heights Clearly much depends on the terrain over which the route passes, *e g* , of the total irregularity due to weather of the B E A dummy mail operation in Dorset in February/March of 1948, which amounted only to 3% , 2% was due to low clouds on high ground over which the route passed and 1% due to sea fog Many times visibility was down to quarter mile locally without hampering the operation It is noted that this operation was limited to contact flying only

But the meteorological conditions in the worst months of the year in these islands are so poor that the 100% regularity, which is the aiming point, will be obtained with safety only by obtaining complete solutions to the problems of blind flying and navigation, blind approach and landing by day and night The frequency of irregularity shown in Fig 5 takes account of low cloud and low visibility It is of interest that the visibility is rather better in central London (Air Ministry roof) than on the outskirts, as judged from the records of Northolt, Hornchurch and Hendon The study of meteorological conditions in East Anglia, which was made in connection with B E A operations there, showed rather worse conditions, particularly at night It must be emphasised that over hilly country low cloud is likely to be much more troublesome than in low lying areas B E A experience in Dorset bears this out In my view, successful use of the helicopter for regular transport operations in Great Britain rests on successfully solving these problems The B E A Helicopter Experimental Unit has had these targets before it from its inception , the results of the work already done, in which we have received the greatest help and co-operation from all concerned, show that there is good prospect of realising our objectives in a reasonable time

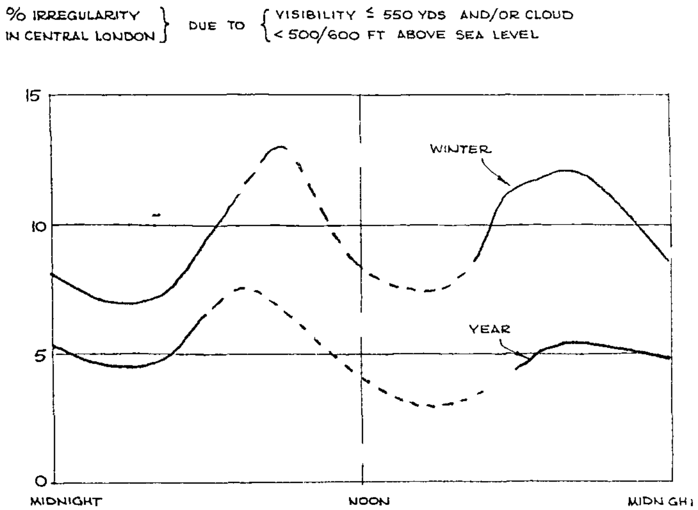

Fig 5 Effect of low visibility and low cloud on regularity

A brief statement of the present position will doubtless be of interest The Unit has now (the 30th November, 1948) completed 87 hours of night and blind flying, of which 4-5 hours has been cloud flying by day The longest continuous time in cloud is 20 minutes, but this can be increased with practice Pilots report that the strain of flying the S 51 blind is high, much higher than a comparable fixed wing aircraft The instruments used, and their grouping, is shown in Fig 6 All are standard except the Artificial Horizon, which has adjustable pitch and roll datum lines

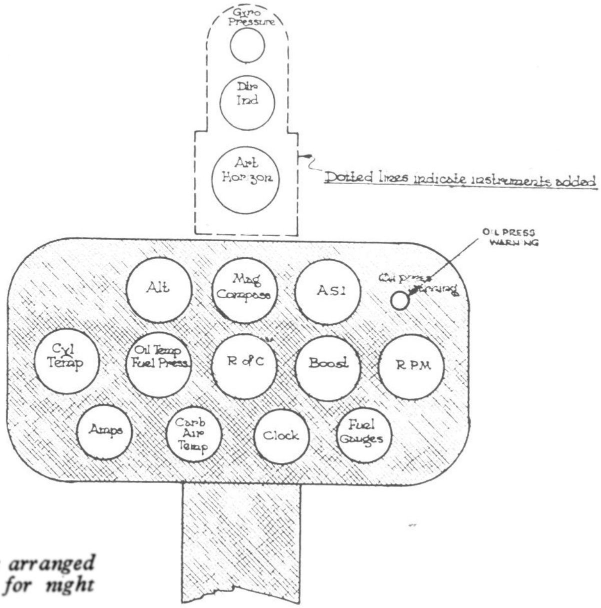

Fig 6 Instruments as arranged in experimental S 51 for night flying trials

This arrangement is a temporary one, a better panel now being tried is shown in Fig 7 An experimental scheduled night operation was completed in the five weeks ending on the 23rd September, 1948, consisting of the return flight Peterborough-Downham Market (58 miles total) made on four successive nights each week commencing on Mondays 100% regularity was obtained The recognition aid was an occulting beacon shown in Fig 8, made up of five standard sodium runway lights arranged to give a two second cycle of one second on, quarter second off, half second on, quarter second off, etc For this it was necessary at this stage to use 60-watt instead of 140-watt lamps R A E have since suggested a means of operating the 140-watt lamp in this way Wind direction and illumination for landing was given by the "Wiggimac" shown in Fig 9 This illuminates at low intensity an area about 100 ft in diameter, the circumference is marked by a band of white on the ground and the pilot can land without dazzle The wind direction is shown by a shadow bar and approach light This piece of equipment is quite satisfactory An adaptation of the standard S B A /V H F equipment was used for point to point navigation, but this is not satisfactory The Decca Track Guide (referred to later) will, we hope, when available, become our standard means of navigation In the meantime restricted operations can be done using D F and beacon systems Further development of recognition beacons is also in hand

Punctuality and Wind Allowance The remarks in the paragraph headed " Regularity and Punctuality " need a little amplification The point I wish to bring out is the manner in which the scheduled block speed is affected by recognising limits of punctuality Journey times are much influenced by wind speed at the present level of helicopter cruising speeds

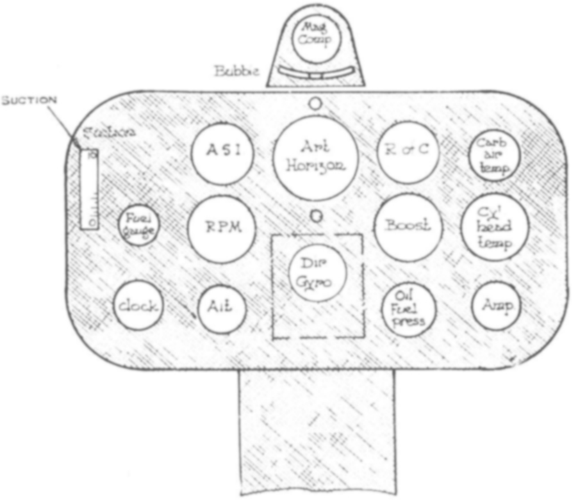

Fig 7 Suggested good arrangement of instruments in S 51 pilot's cockpit to facilitate I F R flying

In planning a schedule, the most reliable information of average winds over the routes is used Such information is in the form of frequencies of winds of a given strength Clearly, if there are to be no tolerances in punctuality, the schedule must be based on the highest adverse winds even though these occur extremely rarely For example, on a direct route of 100 miles an adverse wind component of 50 m p h may occur on the average once per year Hence a helicopter with a maximum cruising speed of 100 m p h would have to be scheduled at about two hours for the journey, whereas, if it was allowed to be 20 minutes late on this occasion, the scheduled block

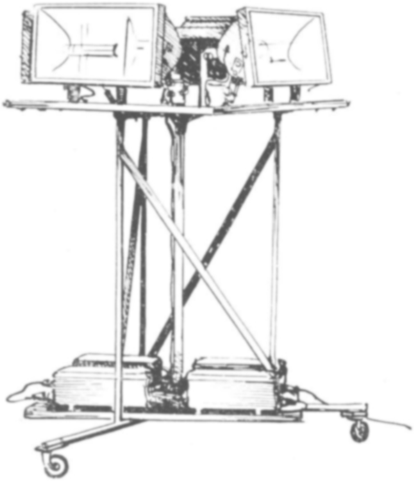

Fig 8 B E A Helicopter Unit

Flashing sodium beacon installation at Downham Market speed could be increased from 50 m p h to 60 m p h, with resultant benefit in every way, especially in the costs/mile which would be reduced by 17%

The results of the study of winds in East Anglia, which was made when planning the schedule for the mail operation run during June, July, August

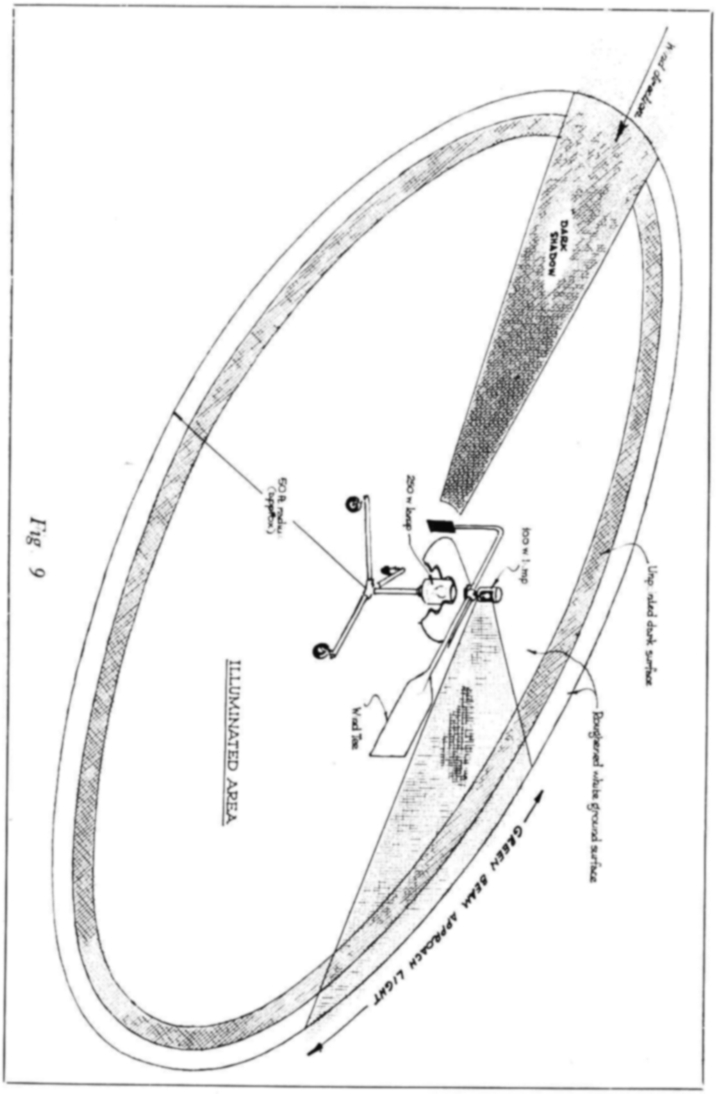

Fig 9

and September, 1948, are of interest here (see Figs 10 and 11) Fig 10 shows the average year-round frequency of equivalent headwinds along the route from Peterborough to Lowestoft, via King's Lynn, Wells, Cromer, etc, and Norwich, *i e*, winds from an easterly direction These winds may

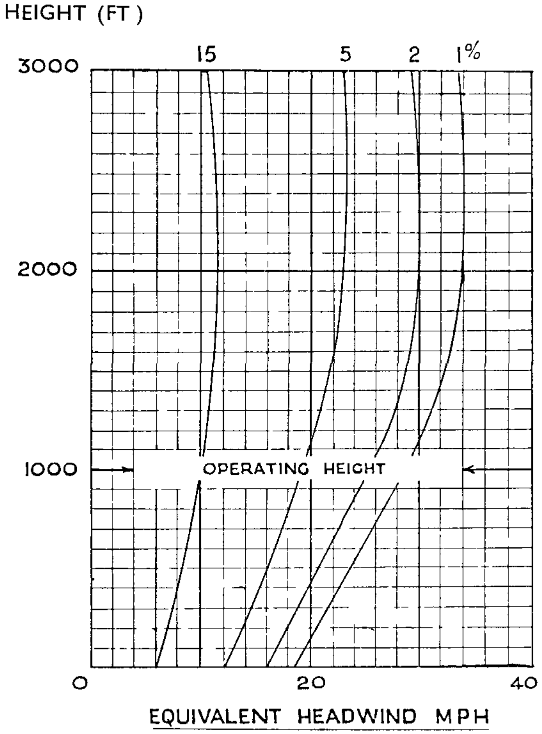

Fig 10 Occasions when equivalent headwind exceeds stated value

be used to estimate scheduled block speeds for varying standards of punctuality at the terminus Fig 11 shows the results obtained It needs a little explanation The ringed points at the lower ends of the curves show the scheduled speed allowing a given unpunctuality, marked on the curves, on about 1% occasions throughout the year If the scheduled speed is raised then the percentage frequency of lateness greater than the standard of unpunctuality rises as shown For example, the actual schedule used in the operations was based on a mean block speed of 64 5 m p h , estimated to give punctual running-on all except about 0 75% occasions throughout the year If we allow a wider margin of unpunctuality, we find that the mean block speed may be increased to 72 5 m p h for unpunctuality on 5% of occasions or 75 m p h for 10% unpunctuality The lower of these speeds corresponds to rather more than 10% increase in block speed, a most significant improvement in economy The explanation of this effect is, of course, that the higher the scheduled mean block speed, the less margin of cruising speed is available to cope with strong winds

The principles should be —

(*a*) to keep to advertised times of departure

(*b*) to have seasonal schedules on the routes most influenced by wind

(*c*) to schedule so that a tolerance of +10% on scheduled elapsed time is exceeded on only 1% of occasions in any scheduling period This would correspond roughly to punctuality on 95%of occasions

(*d*) accept early arrivals except as affecting Air Traffic Control, and Size of Rotorstation

Fig 12 gives data relevant to seasonal scheduling and shows also the variation of wind with height, an important factor in planning helicopter operations Since we had analysed the effects of winds in East Anglia, we combined these results with wind data available for Leuchars in south-east

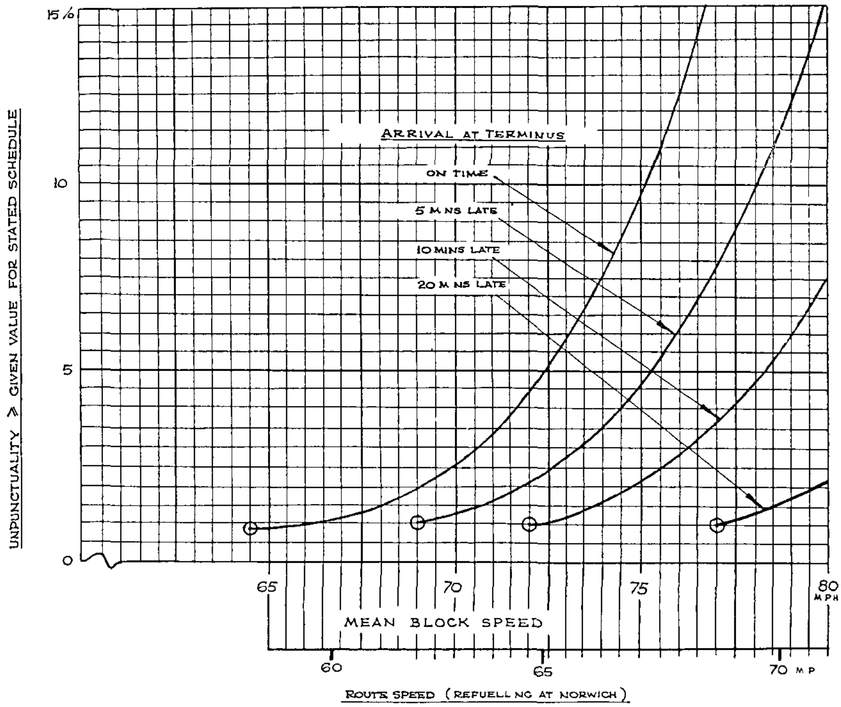

Fig 11 Effect of scheduled speed on punctuality for outward (West-East journey) in East Anglian day mail service (average 17 miles)

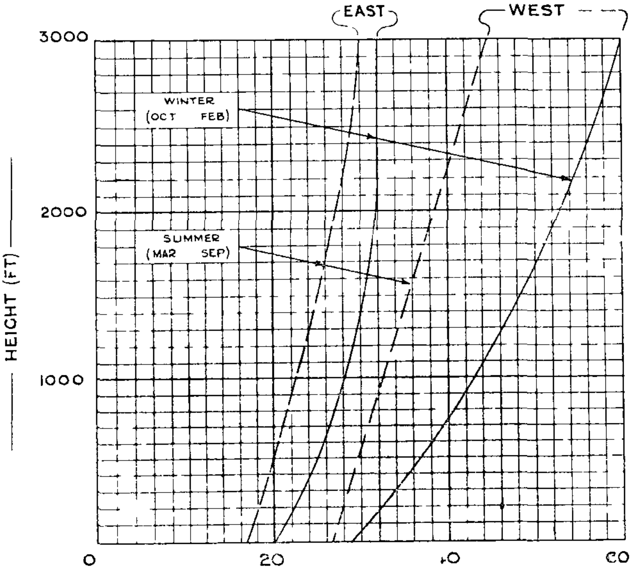

Fig 12 Effect of height, season and route direction on equivalent headwind exceeded on 1% occasions (mean of S E England and Leuchars)

Equivalent headwind MPH exceeded on 1% occasions for route in stated directions

Scotland The curves show the mean of the equivalent headwinds in easterly and westerly directions, for winter and summer, exceeded on only 1% of occasions These are the results on which scheduling would be based The advantage of seasonal scheduling is at once apparent, especially for east to west routes Block speed in summer could be increased over the winter value by about 9 m p h for operations at 1,000 ft and by 12 m p h at 1,500 ft , *i e* , by about 10% A smaller increase is possible for routes in the opposite direction, but in any case a higher block speed is possible because high winds are less strong in this direction Block speeds which would be feasible are —

Winter	92	m p h	to west	106	m p h	to east
Summer	101	m p h	to west	111	m p h	to east

These are based on occasional use of maximum continuous power, which is assumed to give a cruising speed of 130 m p h at 1,000 ft

The increase of wind with height, a natural phenomenon, is well illustrated As a point of interest, it is noted that in deriving these results, a method has been used which takes account of components of high winds in the general easterly or westerly directions, so that the results are reasonably representative over the westerly and easterly quadrants N W to S W and N E to S E

PART II

MAJOR OPERATING PROBLEMS ARISING OUT OF THE OPERATIONAL REQUIREMENTS

Helicopter Operations and Air Traffic Control This contains the problems of *area control* and *local control*, and the overriding conditions of *simplicity* and minimum interference with existing controls for other air traffic

The essence of the fixed wing traffic control problem at airports is the conversion of random arrivals into a regular sequence of approaches and landings This may always involve some degree of stacking since the fixed wing depends on forward speed for sustentation and must circuit to remain in the neighbourhood of a given point, whilst waiting to land Moreover, airports are rare and expensive, and hence must be used to maximum capacity—at present, this results in the rate of arrival being greater than the rate of acceptance for landing in I F R conditions, and hence extensive stacking and a big air traffic control problem

The differences introduced in helicopter operation are of a fundamental kind —

(*a*) Rotorstations will be numerous and comparatively *inexpensive*
(*b*) Journeys are short, hence the degree of randomness is greatly reduced, since timekeeping should be good given that the scheduling is soundly based on the available data on frequencies of high winds
(*c*) The helicopter does not depend on forward motion for sustentation , if in doubt speed can be reduced to zero
(*d*) A means of accurate navigation, point to point, is likely to be available , this can be the basis of a scheduling system by which risk of collision can be eliminated

The essential features for helicopter air traffic control of the simplest kind are a means of point to point navigation of high accuracy in terms of time and means of rotorstation recognition and safe let-down in conditions of low visibility Two-way communication with aircraft is, of course, a further essential In other words, reliance is placed on accuracy in time and place Schedules would have to be worked out to preserve adequate spacing of aircraft in all winds and local arrangements would be made to ensure this , there is a great advantage in the sector principle discussed later, since all aircraft in a given sector will be affected by wind in the same general way Emergencies would be dealt with by the two-way communication system from nodal points

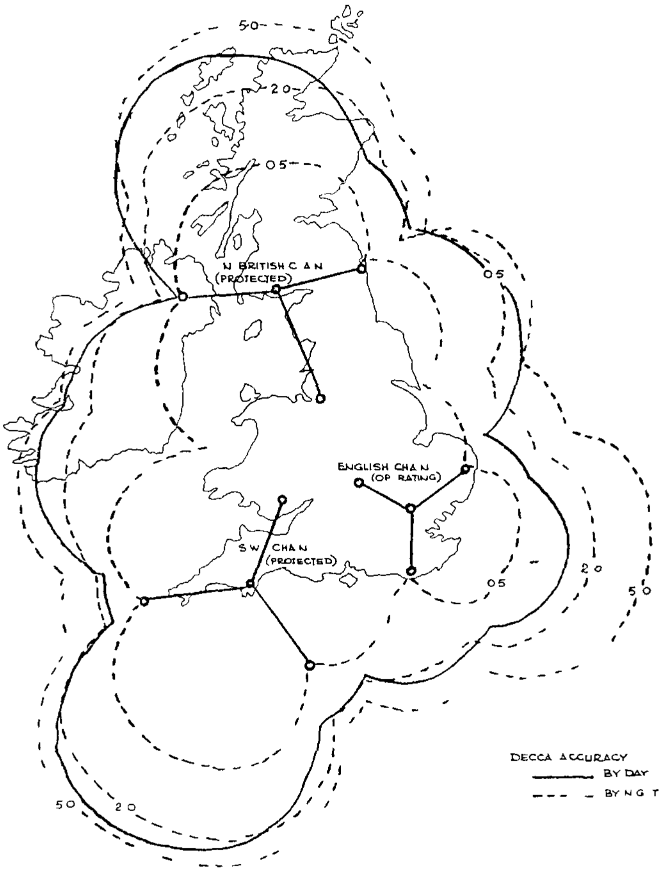

Fig 13

We think we have the basic means of accurate navigation in the Decca Track Guide System This gives the pilot left/right indications in relation to a pre-determined track and records distance flown along the track The instruments use the information available from the Decca

Marine Navigation System, which gives low level coverage over most of Great Britain

The great advantages of this system are that it does not require special ground stations , it gives the low level coverage essential for helicopter navigation , and it presents navigating information to the pilot in a simple form This last point is of great importance since we expect helicopter pilots to do their own navigation in commercial operations , also the flying of the helicopter under blind conditions may demand high concentration from the pilot This is certainly true of the S 51, but we may confidently expect improvement in new types

The means of rotorstation recognition and subsequently the let-down and alighting under blind conditions are problems for which we have not yet the solutions They are linked with the accuracy of the point to point navigation, since if the accuracy was high enough the recognition aid might also be the let-down aid The accuracy of the Decca system depends on azimuthal position in relation to the ground stations, but much more critically on distance from stations Fig 13 shows the root mean square error which will be exceeded with a 5% probability by day and by night This accuracy *might* be sufficient to permit the use of a light as a means of let-down in many localities where the incidence of cloud on the ground is rare Fig 14 illustrates this point Using data in Ref 1, the lowest meteorological visibility by day and night is plotted against the distance at which a 10,000 c p light source is just visible These latter can be interpreted as the ideal limiting accuracy of a navigational system under stated conditions of low visibility For example, by night a limiting meteorological visibility of 350 nautical yards requires a navigational accuracy of 0 5 nautical mile or less By day, the same visibility requires a higher accuracy of the order of 0 3 nautical mile It is fortunate that the accuracy of Decca is so much better by day than by night, as shown in Fig 13 This would have the great advantage of the avoidance of a special radio or radar aid at *each* alighting point with the accompanying loss of economy in capital, maintenance and operational charges But it is important to emphasise that such an aid will be required where low cloud and/or industrial haze is persistent and its development should be pressed forward now

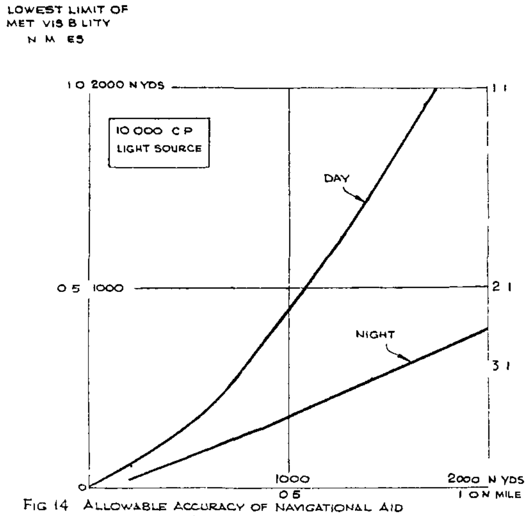

FIG 14 ALLOWABLE ACCURACY OF NAVIGATIONAL AID
REF R A E MEMO EL 1185

Fig 14

Minimum Distance between Rotorstations It is necessary to consider the influence of the accuracy of the point to point navigational aid on another basic factor affecting both safety and economy, *viz* , the minimum allowable distance between rotorstations Its influence on safety is obvious The influence on economy in the sense of the operational value of the helicopter for passenger transport in this country needs a little explanation

The primary consideration is the avoidance of the need for a complex system of air traffic control This at once suggests the idea of dispersal to reduce rate of aircraft movement at a given traffic centre It is envisaged that a number of rotorstations will be used instead of a single main station

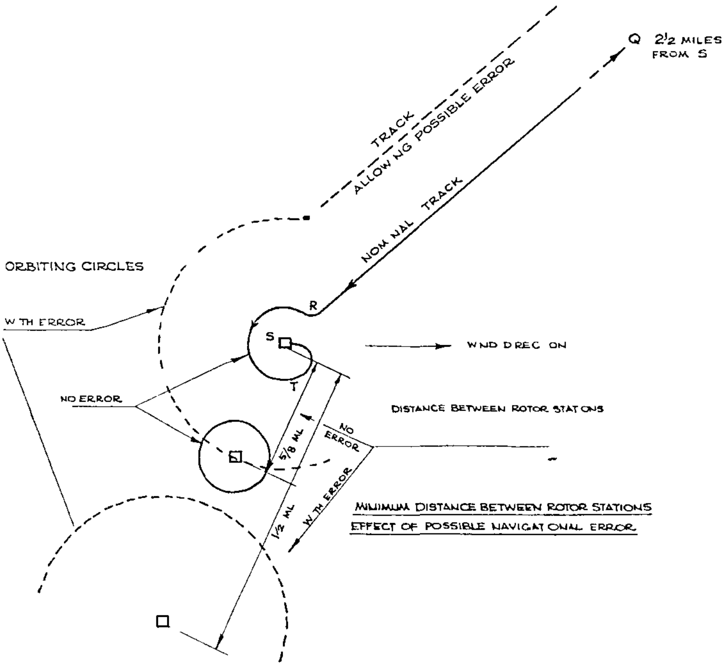

Fig 15

Each will handle the traffic from a sector, the angle of the sector depending on the density of traffic in that general direction Then the mean distance of the stations from the city centre will depend on the minimum safe distance between any pair The farther they are forced out from the centre the less convenient they become for passenger traffic, with the consequent effect this may have on operating revenues The following brief outline of possible let-down and take-off procedures shows how the accuracy of navigation affects this minimum safe distance These ideas are given for illustration , they can be only tentative at this stage

In the sectors, traffic follows pre-determined Decca tracks which result in a " keep right " convention within five miles of the rotorstation At the five mile point, marked on the mileage indicator, the pilot would report to ground and obtain wind strength and direction, etc At " Q " (Fig 15), say $2\frac{1}{2}$ miles from the rotorstation " S," a light is shown in the cockpit, and the pilot starts to reduce speed and adjust height so that when the light goes out at " R," $\frac{1}{4}$ mile from " S," he is flying at 50 m p h at 500 ft At this point he should have full knowledge of the position of " S " from the recognition aid (lights or otherwise) He initiates a procedure turn at " R," still flying at 500 ft , to bring him to the down wind side of " S," previously known to him as a compass bearing During this turn, he circuits at constant distance from " S," using information from the recognition aid for this purpose The let-down commences at " T," the flight path being adjusted to keep the final angle of approach at about 45°, as determined approximately by lighting aids Precise adjustment into wind is made during the final straight approach

The influence of navigational error (Decca plus pilot) on the radius of the procedure turn is shown in the diagram The effect of a lateral error of $\frac{1}{2}$ mile and a track error of $\frac{1}{8}$ mile will nearly treble the nominal value and increase the minimum distance between rotorstations from two-thirds of a mile to $1\frac{1}{2}$ miles This difference would well increase distance of stations from city centre from, say, $\frac{1}{2}$ mile to 1 mile, a significant change However, I should mention that much better accuracy may be obtained by " line flying," *i e* , flying along one of the lattice lines of the Decca grid This may be adopted as standard means of remote approach, say, from 5 miles, thus avoiding the difficulty referred to above

The suggested take-off procedure is to ascend vertically to 100 ft , climb at best rate of climb to 250 ft , and at this height circuit left-hand until on course, when the climb would be continued to reach the permitted height at the 5 mile point The radius of procedure turn would be about one-sixth of a mile in still air

The aim of these procedures is to keep the radius of procedure turn to as low a value as possible whilst, at the same time, ensuring physical separation during the take-off and landing manoeuvres, although it must be noted that the scheduling will be such that normally such manoeuvres are not taking place at the same time at a given rotorstation

Traffic control *en route* rests on height separation by quadrantal rules or otherwise, combined with Decca track flying to good schedules kept all along the route by reference to watch and mileage indicator Since stages are short, altimeters can be checked frequently and the error in height-keeping will be small Bearing in mind also the flying qualities of the aircraft, a 500 ft vertical separation should be adequate E T A will be estimable accurately, a very great advantage in avoiding difficulties in air traffic control

ECONOMY

This undoubtedly is the major problem to be solved before the helicopter can play its *full* part in the pattern of transport It must be considered in general terms since here we are dealing with a new vehicle of transport for which all the organisation and operating conditions have yet to be created By this I mean that we should take not only the operating economy but the balance of economy as a whole to a country such as this, in setting out to provide a great improvement in transport facilities in Great Britain For example, the evolution could so easily be crippled if rotorstations were allowed to become highly specialised, expensive places, in terms of first cost, running and maintenance, or if the growth of the helicopter system was allowed to develop so that a highly complex system of air traffic control was needed Taking the problem as a whole, the following aspects in particular need consideration —

(*a*) Cost of operations
(*b*) Capital and running costs of rotorstations (Their siting is also important since a more costly site may be so much more conveniently situated as to promote more traffic)
(*c*) Capital and running costs of all navigational aids
(*d*) Cost of air traffic control

And, on the credit side —

(*e*) the value to the community as a whole of the improved transport facilities provided in terms of the general stimulation of commerce and trade, time saved to individuals, convenience and comfort secured, compared with available alternative means of transport

To reach our goal we must provide (*e*) at the minimum cost in terms of (*a*), (*b*), (*c*) and (*d*) The most important of these is most certainly (*a*), since it involves the greatest rate of spending money, but (*b*) is not far behind This is because so many rotorstations will be needed, very often on expensive sites near the centres of great towns and cities As with fixed wing air transport the greatest factor influencing economy in the cost of operations is the efficiency of the aircraft, and it is worth spending a little time considering in what ways we can look for improvement on what we have now

Present Operating Costs The best data available to me, of what we have now, is obtained from analysis of the operating costs of the B E A Experimental Helicopter Unit, which has now been running for rather more than a year, has run two operations, one of about five weeks' duration carrying dummy mail, the other of four months' carrying live mail, and has a total flying time of 1,332 hours (1,019, S 51 , 313, Bell) to the 30th November, 1948, with five aircraft, two Bell 47B and three Sikorsky S 51 The rate of utilisation is low, but allowance can be made for this in extrapolating the data to other conditions Taking the live mail as the most representative operation, the average total operating cost of the S 51 is about £28 per flying hour, made up in the following proportions —

	Per cent
Standing charges	33
Maintenance and repairs	22
Flying operations	23
Station costs, Headquarter's charges	22
Total	100

The high proportion of standing charges may be misleading since it is based on an annual utilisation of only 567 hours, and on a comparatively short aircraft life The effect of increasing the utilisation to 1,200 hours and making the necessary adjustments in the other factors would reduce the standing charges to somewhat less than 25%

Expressed in transport units, the operating cost per capacity ton mile is £1 5s 0d This is based on an average capacity payload (depending on stage distance and wind allowance) of 750 lbs and a route speed of 65 m p h

Means of Reducing Operating Costs A regular scheduled passenger service could not be run economically in this country on charges such as these Can we expect substantial reductions, and in what ways? We are looking for an overall reduction to about one quarter, which shows the order of the problem

The main factors involved are —

(*a*) *Speed* Increased cruising speed is important to diminish affect of adverse winds Note that for a given utilisation in a given route system higher speed implies higher frequency

(*b*) *Size* As in fixed wing aircraft, there is a gain in economy with increasing size Operators have a responsibility to say what is needed, not only immediately, but to last for, say, 8 to 10 years

(*c*) *First Cost*

(*d*) *Utilisation* A matter for organisation by the operator, provided that the builder supplies a reliable product, readily maintainable

(*e*) *Maintenance* The operator can only organise cheap maintenance if the basic qualities have been designed into the machine and fully developed

Further comment must be made on the relative importance of each of these factors, and the prospect of achieving improvements during the immediate and longer term future

Speed Current aircraft in operation cruise at about 85 m p h on 65% take-off power In this country equivalent headwinds along any given direction rise above 30 m p h on about 1% of occasions throughout the year In westerly and south-westerly directions the corresponding figure is nearly 40 m p h Thus one cannot schedule for a block speed much higher than 60 m p h, which is not sufficiently superior to good surface transport Moreover, the irregularities by unpunctuality are likely to be numerous Hence an increase in speed is likely to effect considerable improvement by making regularity much less dependent on wind speed, by providing higher potential revenue from a given annual utilisation, and by making the service more attractive in competition with existing surface transport

I think, during the next few years, we should aim to achieve a cruising speed of 115-120 m p h on 60% take-off power in weak mixture, this would make practical a schedule of 100 miles in the hour as an average, and give savings of time which would be well worth the passenger paying for The prospects of this seem to be bright since the Fairey Gyrodyne has done a record speed of 124 m p h using less than full power What are the prospects of obtaining higher cruising speeds in the longer term, and can the operator use such increased speed if provided? The answer to the second part of the question is "Yes!" provided that no material operational penalties such as decreased reliability, increased vibrations, noise, roughness in gusts, or greatly enhanced cost of operations are involved Clearly there are limitations to forward speed from compressibility and vibrational causes, but we do not yet seem to have run into any trouble of a fundamental kind Hence I should expect cruising speeds to increase by, say, 50-60% during the next decade, in the shorter term then we can look for an increase of 60-70% in block speed, and some years later a further increase to rather more than double the existing block speed

Size This factor can be treated on its merits as a technical matter, but consideration of potential traffic may demand a vehicle much smaller than that which would be most economical judged on technical grounds only The point is that the revenue comes only from the people who travel, hence the size of the vehicle should be the smallest (hence the cheapest in overall running cost) to handle the traffic in an efficient, satisfactory manner, provided that it is large enough to handle increasing traffic economically over a period of years

A rough assessment of the influence of size on operating economics can be made on the following lines —

Operating cost per aircraft per hour is made up of —

Standing charges $\propto$ all-up weight
Maintenance and repairs $\propto$ all-up weight
Flying operations, including crew, fuel and oil, landing charges, *i e* , part constant, part varying roughly with all-up weight
Station costs, Headquarter's charges—A constant for a given area of operations

Thus, operating cost per aircraft hour $= AW + B$, where W is the maximum weight and A and B constants

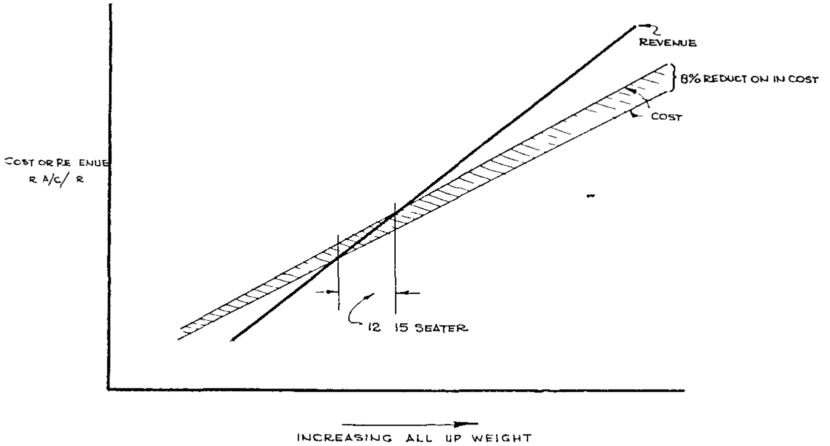

Fig 16 Approximate influence of size on helicopter economics

Revenue per aircraft hour over given stage distances, assuming operating speeds independent of weight, depends on the payload or number of passengers carried per aircraft, *i e* , revenue per aircraft hour $= CN$, where N is the number of passengers carried per aircraft and C a constant An examination of contemporary and projected designs shows a variation of N with W which is practically linear, and of the form N = constant × W — a constant

Fig 16 shows cost and revenue against weight, the revenue based on a fare slightly greater than existing for air transport in Great Britain It must be taken only as a rough approximation, and hence the weight scale is not added, but it demonstrates that for commercial operations on scheduled services we can expect a steady improvement with increasing all-up weight Also there is a minimum size for such operations to break even A tentative conclusion is that this is about a 12-15 seater, but the actual figure will depend entirely on the detailed economics of any specific design, and especially on such factors as first cost and utilisation as affected by maintenance and operational techniques

First Cost Little information is available at present of the probable cost of commercial passenger-carrying helicopters Masefield, in the Fourth Commonwealth and Empire Lecture, given before the Royal Aeronautical Society in September, 1948, suggests a figure of £3 per lb of all-up weight, which is supported by the little practical data available Taking a round figure of 1,000 lb all-up weight per passenger, first cost is of the order of £3,000 per passenger, to be taken as the basis for fixed charges It is increased by cost of spares (say 30%), interest and insurance charges The cost per hour of these fixed charges depends directly on annual utilisation and life of aircraft Taking reasonable values (a total life of 12,000 hours) the cost per hour is about £3 35, which represents 15% of a fare of 8d per mile This is a very high proportion of total cost , its reduction is of great importance to the success of helicopter commercial operation

It is recognised that operators have some responsibility here if they demand standards of equipment, furnishing, etc , in excess of the true requirements These need the most careful study in this new form of transport The rather luxurious standards associated with fixed wing transport must give way to a more austere type of 'bus seating appropriate to the short stages Other features can be fruitfully reviewed Anything which will save first cost without detracting from the essential suitability for operations, in this country, should be eliminated The operator has an even more important part to play in stating his requirements of numbers of passengers and range The right size of vehicle will doubtless attract a wide range of customers, and all users will have the benefit of improved efficiency of production of larger numbers Another factor influenced by the operator's choice is the useful life of aircraft in operations A type, for instance, which is too small will be rapidly out-dated by expanding traffic, and may have to be discarded on economic grounds before its full useful life has matured But, in the matter of first cost, it is the constructor, not the operator, who has the control

Utilisation and Maintenance These two factors are so interrelated that they must be taken together , it is only possible to obtain high utilisation if maintenance is simple and, in particular, reliability is very good

In my view, a revolution is needed in present day methods of maintenance if we are to obtain the high utilisation and cheap maintenance essential to bring the operating costs of helicopters to a commercial level The S 51, of which we have most operating experience, is not difficult to maintain, but on the maintenance schedule laid down the ratio serviceable hours — unserviceable hours is 0 4 The schedule, in common with all such documents, lays down periodic inspections and overhauls, during which dismantling of parts and components is done to varying degrees to enable full inspections to be made We do this sort of thing on all classes of aircraft, not only on helicopters, because we are not sure that something has failed or is in process of failure, and we have to look to find out This process rests essentially on lack of knowledge , it is not only uneconomic but highly unscientific I propose that we should replace it by a system of Sealed Servicing in which parts, components, etc , would not be touched save for normal servicing—lubrication, running adjustments, and so on—until they had completed a pre-determined life, when they should be removed and replaced by a new or overhauled part, equivalent to new This may sound a very ambitious idea, but I am convinced that it holds great possibilities for reducing costs of air operation , moreover, I think the helicopter offers a particularly fruitful field for its application This is because the helicopter is a compact design, mechanical in essence with forces and vibrations susceptible of fairly precise calculation These factors are favourable to the application of a technique of laboratory and rotor tower testing to determine lives of components , such testing would be correlated with results from full scale at all stages and would, where necessary, test numbers of parts to obtain a conservative value of life to be expected in actual operations I suggest research is needed to develop techniques of testing on which we can rely for prediction of lives of all wearing and fatigue stressed parts of helicopters, and hence make a major economy in maintenance

The benefits which will accrue are manifold First and foremost, unserviceable time will be reduced to a minimum allowing operators to obtain very high utilisation from their aircraft in operations Secondly, maintenance charges will be reduced for three reasons —

(i) Maintenance will become a simple routine of servicing plus replacement of parts at life periods Hence labour is reduced to a minimum Fig 17 illustrates this very well It shows the manhours spent in dismantling, overhaul and reassembly and installation of the main rotor head and blades of the S 51 during a 200 hour periodic inspection, keeping the aircraft unserviceable for 9½ days By direct replacement, this period could be reduced to three days and a marked increase of utilisation effected

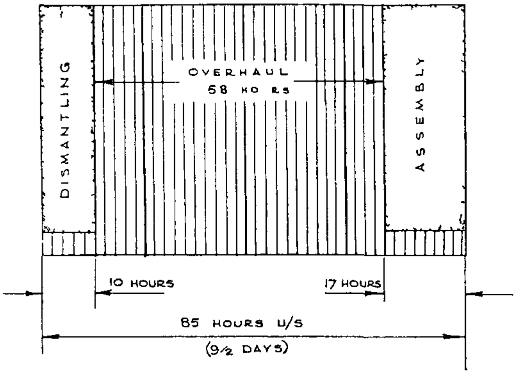

Fig 17 U S aircraft time 200 hr inspection S S I in B E A experimental unit

(ii) A given volume of traffic can be handled with the least number of aeroplanes because of the high utilisation and high reliability implicit in the system

(iii) The cost of spares will be reduced because useless spares will not be purchased and the correct proportions of the spares actually needed will be known

Thirdly, the tests adumbrated will show forth improvements in design or installation needed for maintenance, leading to a further simplification

Here is a problem to be tackled, with the greatest prospect of forwarding the effective use of the helicopter for commercial transport by obtaining a great reduction in operating costs

To return to the effect of utilisation on economy Costs per mile vary inversely as block speed , they also vary with utilisation in a manner which is roughly inversely as (utilisation) n where n is less than 1 On the other hand, revenue/mile is constant for a given route and traffic density Hence it is clear that the lower the value of block speed, the greater the cost/mile, other things being equal, and the greater the difficulty of avoiding financial loss in operations Increase in utilisation is the most direct way of improving matters with a given aircraft This argument applies equally to fixed wing transport, but since the block speed of the helicopter is considerably lower than that of the fixed wing aircraft, taken over a route system, there is the greater need for high utilisation of the former For example, figures common in fixed wing transport are block speed of 160-170 m p h , and utilisation of 1,500-2,000 hours per annum The utilisation required for the helicopter to obtain the same aircraft miles per year is 2,500-3,500, *i e* , our target must be 3,000 hours per annum, or roughly ten hours per day of actual operation To obtain such high utilisation, maintenance must be simple and mechanical reliability very high Clearly, an operation of this sort must depend on an adequate network of ground sites covering the country, placed for the best convenience of the travelling public, so that with the size of aircraft in use, frequency is properly related to demand Thus the great towns would be directly linked by a shuttle service of frequency roughly determined by the ratio travelling day (taken as 14 hours) — journey time, giving 10-14 services each way for places about 100 miles apart Lesser towns would be linked by a circuitous stopping service, frequency again being determined by journey time, reaching a value of 3-4 per day for a total circuit of 300-400 miles This widespread use of the helicopter on scheduled services in this country will take some time to develop, but the point emphasised here is the relation between high utilisation (and hence good economy) and frequency, and the corollary that an adequate number of operating sites is needed in any area in which helicopter services are to be developed Thus we see the connection developing between the economics of the operation itself and the less direct, but wider, field of economics of the provision of rotorstations which is now to be considered

COSTS OF ROTORSTATIONS

This will depend fundamentally on the size required, but will be affected substantially by other factors such as position, whether elevated, complexity of operating essentials such as lighting and other aids, maintenance and servicing Costs and complexity of aids may vary depending on meteorological, terrain and traffic factors , a very busy station may need a different standard of lighting and approach aid , if blind conditions at the time of operation are highly improbable, then it may be justifiable to simplify the ground equipment The overriding objective should be to satisfy the essential needs of a safe, regular operation in the simplest and most economical manner It is my view that an expensive standard of rotorstation may do more to restrict the development of helicopter scheduled transport in this country than any other single thing, because in local affairs, and especially in these times of stringency, projects demanding heavy expenditure of public money are likely to be shelved indefinitely, and if the stations are not available, then regular passenger carrying operations cannot be started, and if they do not become available on the scale and in the locations demanded by the nature of the service, it will not be possible to build up the frequency of service and utilisation which goes with it, essential to exploit the vehicle and to obtain operating economy This is a basic problem to provide what we must have for safe, regular operations in the simplest and most economical manner

SIZE OF SITES

The size required for helicopter operating sites is fundamental to the cost, it is also likely to be a cardinal factor in obtaining a suitable location at a city centre In this connotation " city centre " is taken as an area roughly a mile in diameter round the business or industrial part of the built-up area The time to get from office to rotorstation would then be comparable to that required to reach the railway station

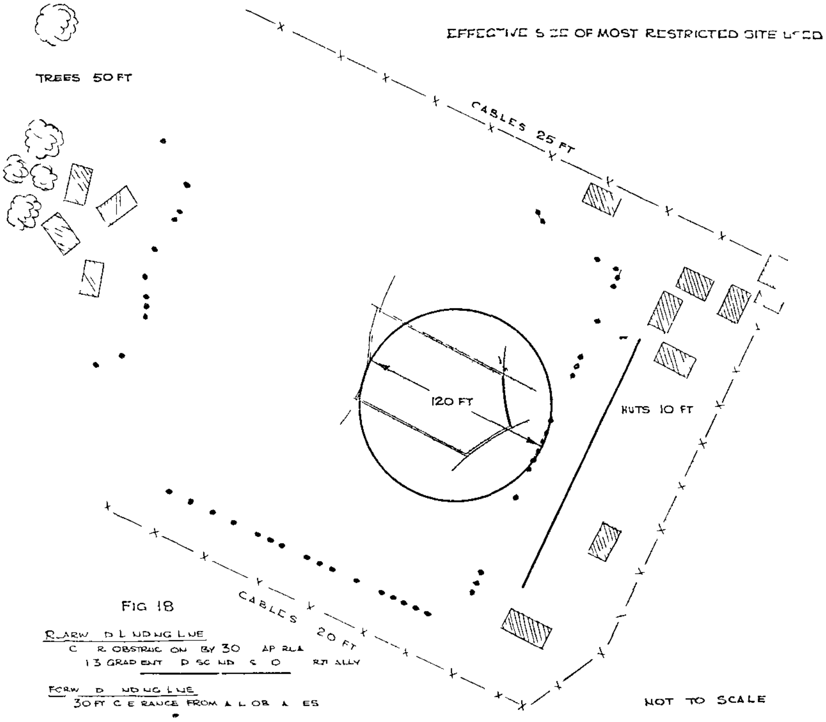

FIG 18

Some idea of minimum size required for a site can be obtained from one of the small areas used by the B E A Helicopter Experimental Unit in their operations in Dorset and East Anglia

The inner area on the map shown in Fig 18 is the space into which the pilot can land in still air assuming he clears obstacles in the approach by thirty feet, and allows adequate sideways clearance The approach path is taken at 20° to the horizontal Pilots had no difficulty in getting into or out of this area under the conditions of visual approach and landing , hence they do not necessarily represent minima

The diagram makes clear how the size of a site within obstructions may be influenced by the angle of the flight paths into and out of the site The greater the angle, within limits, the smaller the landing area In Fig 19

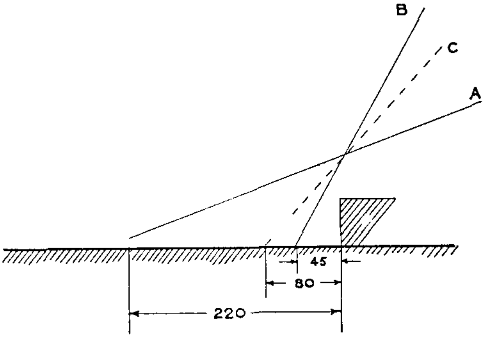

Fig 19 Size of landing site as affected by angle of approach path

A represents the approach paths of the S 51, *B* an approach at 60° to the horizontal clearing the 40 ft obstruction by 45 ft There is a limiting distance from the obstruction given by $\frac{D}{2} + C$, where

D = diameter of circle circumscribing the helicopter
C = a reasonable clearance

However, other considerations—possibility of engine failure, pilot's view, handling qualities at low speeds—make it desirable to limit the angle to a value of, say, 45°, shown by *C* in Fig 18 This will give the minimum size of site in most cases It will also allow of the selection of sites which would be otherwise inadmissible for all weather operation, because of tall obstacles remote from the site, but which might interfere with the approach path Hence the use of a steeper approach path than now current with the S 51 will make it easier to obtain sites in built-up areas

The elevated site without nearby obstructions may be much smaller than the ground site , it may also be much easier to provide near the city centre It can possibly be " built-in " to new buildings which will be erected on many bomb damage sites in good locations For example, the new G P O building at Mount Pleasant is planned for helicopter roof-top operation The area required will depend on a number of factors —

(*a*) Rate of traffic movement
(*b*) Possibility of need for concurrent alighting and positioning for take-offs
(*c*) Size of aircraft to be handled
(*d*) Need for parking space
(*e*) Operational facilities—navigation aids, passenger handling

The whole design of such sites is intimately interconnected with the foreseen pattern of helicopter services, and the problem of air traffic control , in particular, the siting will depend on accuracy of *en route* navigation, let down and take-off procedures, as discussed earlier

The concurrent landing and positioning for take-off probably can be avoided by the sector scheme, but the need for parking, say, two aircraft at a busy site would remain It will be clearly a marked economy in space if blades can be folded in such cases The folding must be simple in itself, so devised as to involve the minimum employment of manpower It will have incidental advantages in reducing risk of accidental damage, in avoiding damage from high winds, and in providing means of securing blades against wind forces Parking areas in elevated sites may be constructed to a lower standard of strength than that required for the actual alighting area

Returning again to the problem of size Assuming that the whole alighting area will be always available for the approaching aircraft, that there are no obstructions immediately adjacent to the site, and that we must cater for aircraft circumscribed by a circle of 100 ft diameter Then, allowing for errors of wind and pilotage, the area should probably be of the order of 120 ft by 120 ft as a minimum Additional space for aircraft parking would depend on the plan shape with blades folded, but would possibly be of the order of 60 ft Thus the area of an elevated rotorstation capable of handling a fairly large helicopter (about 25 seater) is by no means excessive However, from preliminary enquiries made it seems that such sites could be provided only if the need is foreseen in the early stages of design of buildings, so that adequate structural provision can be made This implies long term planning of a difficult kind since we have so few data to guide design An attempt has been made to assess cost, generous assumptions have been made on numbers of staff required, on ground rents, costs of ground aids, and so on The resulting charge per landing is £10, assuming a low utilisation of sixteen landings per day, *i e*, one per hour, and that *all costs* are supported by the operation, a condition very different from fixed wing transport At a more reasonable utilisation of four per hour, for which the staffing is adequate, the charge would be £2 10s 0d per landing

PART III

OPERATIONAL PROSPECTS

What are the prospects of operation, *i e*, economic operation as a vehicle of transport on regular scheduled services in this country? We have examined the operating requirements and the nature of the problems thrown up by them, in my judgment, the most intractable at this time is that of economy in the overall sense embracing the vehicle, the provision of rotorstations, navigational and other operating aids Of these the vehicle is quite the most important, with rotorstations a good second Bearing in mind the broad characteristics of the aircraft needed, as mentioned earlier, I think there is good prospect of commencing operations about four years hence This would imply an overall period of growth from a practical flying machine to a sound vehicle of regular air transport of the order of 10-15 years, giving due credit to autogiro developments which have had such a strong influence on certain fundamental features of helicopter design This compares very well with a similar advance in fixed wing transport, in fact, it is surprisingly short, but we must remember the great improvements in engines, the results of which we now enjoy and which have undoubtedly materially shortened the development period of the helicopter Hence the history of development of fixed wing transport is reasonably reassuring in the forecast made I think the greatest doubt is the development of suitable power plants Our future strength in this country is likely to be in the development of the internal combustion turbine engine I suggest that we must quickly begin to apply these to the helicopter development The ranges are short, hence fuel economy will have less influence on operating economy than we expect in fixed wing aircraft, and to compensate for it we should have a lighter installation of power plant as compared with reciprocating engines, with possibly much greater reserves of power for emergency use

The provision of rotorstations must be made in advance of the operations When well-sited they must be in the heart of built-up areas of great towns and cities Hence long term planning is involved and steps should be taken to reserve areas and building sites in the rebuilding plans which are now being considered and initiated for many large urban areas In addition, a comprehensive study is needed of the structural layout and siting problems of rotorstations, with special reference to operational needs and the minimum of capital outlay In my view the prospect of having the rotorstations we shall need some years hence, in the most favourable sites, is likely to be small unless action is taken now on broad and liberal lines Such action depends to a degree on the investigation into the accuracy of the Decca Track Guide System of navigation, to be initiated early in 1949, but preliminary action could, and should, be started now

What, finally, is the potential use for this new vehicle of transport in these islands ? I think it is not possible to make any precise calculation at this time, but one can build up some sort of picture from the broad basis that it is the only means of transport which brings to the realm of practical politics a direct point to point link between all our major towns and cities Examples of what this may mean in economy of time are shown in the following table, giving train/helicopter times The helicopter block speed is taken as 100 m p h for 100 miles, and is reduced for shorter distances

DIFFERENCES TRAIN/HELICOPTER TIMES IN HOURS

TRAIN TIME/HELICOPTER TIME DIFFERENCE

DIRECT MILEAGE

Destination / *Starting Point*	Manchester	Glasgow	Newcastle	Leeds	Barrow	Hull	Nottingham	Edinburgh
Manchester	—	5 8 1 8 4 0 180	4 1/1 1 3 0 110	1 3 0 4 0 9 38	3 3/0 6 2 7 56	3 7/0 8 2 9 80	2 7 0 6 2 1 58	6 0 1 7 4 3 173
Glasgow	5 8/1 8 4 0 180	—	4 9/1 2 3 7 120	5 2/1 8 3 4 180	6 5 1 3 5 2 130	9 0 2 1 6 9 210	10 1 2 2 7 9 230	1 1/0 45 0 65 42
Sheffield	1 7 0 4 1 3 32	6 8 2 0 4 8 200	2 9 1 1 1 8 110	1 1/0 35 0 75 30	4 6 0 85 3 75 83	20 0 0 55 1 45 53	1 2 0 4 0 8 32	6 5/1 9 4 6 190
Edinburgh	6 0 1 7 4 3 173	1 1/0 45 0 65 42	3 8/0 8 3 0 80	5 5/1 6 3 9 160	6 3/1 3 5 0 130	7 2 1 9 5 3 190	7 8/2 2 5 6 230	—

Fig 20 shows the advantage of the helicopter over the train, in terms of time saved against train times The two lines are for helicopter block speeds of 100 m p h for 100 mile stage and 70 m p h for the same distance, the upper line representing the former One can take these speeds as based on a reasonable cruising speed with different wind allowances, the latter including a very high value for wind These results can be used to make a rough estimate of time-saving by use of the helicopter in this northern industrial group It is assumed that the traveller does rather more than 300 train hours per year made up of a journey each week of 6 hours return and a monthly return journey of 12 hours, *e g*, Sheffield-Newcastle weekly, and Sheffield-Glasgow monthly The saving in hours of travel, taking the mean of the two lines on Fig 20, and assuming that the monthly journey excludes the current weekly journey and a year of 50 weeks, is 260 hours or about 6 weeks As an alternative, it would be fair to assume that on the long journeys 3 days and 2 nights away from base are necessary for one day's business, *i e*, two days more than would be needed when travelling by helicopter On this basis, total saving is 8 weeks The total direct (helicopter) mileage of these journeys is almost exactly 10,000 miles If the traveller is paid at £1,000 per year, the 8 weeks saving is equivalent to £160 per annum to his firm In addition a reasonable allowance for expenses (hotel bills, meals on trains, etc) on the long journey would amount to about £40 per annum

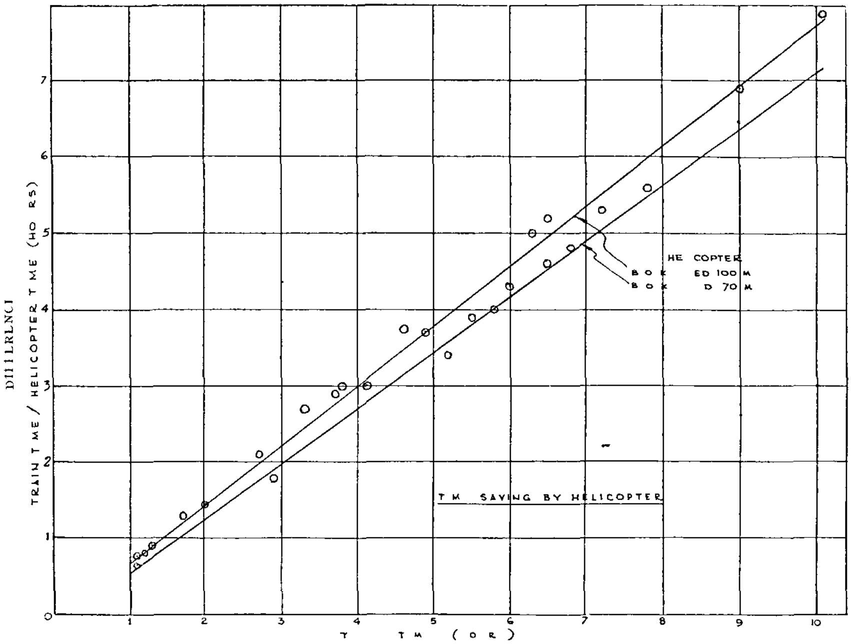

Fig 20

The total is equivalent to 4 8 pence per helicopter mile, *i e*, it would pay the firm to spend this much extra on fares over and above train fares to save the time by helicopter travel Since air sells time as its primary commodity (and, of course, greatly increased convenience on many journeys), compared with alternative means of transport, the figure just derived is a most significant one Just to complete the picture, the first class railway return fare is equivalent to 2 9 pence per direct (helicopter) mile, taking the railway journey as 15% greater than the direct journey, as an average

These are the superficial effects of this direct mode of transit The results of improved communications would be reflected in many more important ways—in better and wider business relations, an increased tempo of business, a more rapid spread of new techniques of manufacture, better interchange of technical knowledge, and so on, all of which would greatly enhance the simple direct saving calculated above These are arguments of a general kind, but they have special significance when applied to our own distribution of industrial towns, especially in the north where geographical features make surface communications difficult Hence I think it fair to conclude that the prospects of the use of the helicopter in Great Britain are good, with special reference, at the outset, to the North of England and Scotland In these areas we have the opportunity of linking great centres of population and of industry, on the one hand, and of providing a direct means of communication over many difficult and inconvenient routes in Scotland, especially in the Islands An analysis of traffic potential made by various authorities in the U S A, indicates a law of maximum potential traffic which varies as the square root of the product of the populations of the centres connected, and inversely as the distance between them Hence the areas named should offer great possibilities for this new form of transport, since we are linking great centres of population and the distances between them are short

Finally, I must acknowledge most gratefully the invaluable help of the B E A Helicopter Experimental Unit and my other staff in preparing this paper and if I mention MR WHITBY it is because he has been especially helpful to me in making calculations and preparing the diagrams, especially those on wind strengths and other meteorological conditions The Meteorological Office have supplied much data to us also, and the Decca Company data for their system I have to thank British European Airways for permission to give the paper and I should say that the views expressed are entirely my own

Ref 1 *R A E Memorandum No CL 1185*—“ The Effect of Atmospheric Absorption and Background Brightness on the Visibility of Point Light Sources ”