The Programme of Development Testing for a Helicopter

by

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A paper presented at a meeting of The Helicopter Association of Great Britain in the Library of the Royal Aeronautical Society, 4 Hamilton Place, London, W 1, at 6 p m on Friday, 9th October, 1959

Professor J A J BENNETT (*Chairman, Lecture Committee*), occupying the Chair

INTRODUCTION BY THE CHAIRMAN

The CHAIRMAN, in opening the meeting, said he was very glad indeed to see so many members present at the first meeting of the new Session, especially as, some of them had, no doubt, been up half the previous night watching the television programme (to hear the election results)

It was a pleasure to welcome tonight's lecturer, Mr NEWBERY, who, since 1951, had been in charge of the rotorcraft work within the Directorate of Engine Research and Development at the Ministry of Supply Mr Newbery had obtained his B Sc degree in 1932 at London University with first-class honours in mechanical and civil engineering and his subsequent career included working in the Airworthiness Department at the Royal Aircraft Establishment and as Resident Technical Officer at de Havilland's, Stag Lane Since 1942, he had been at Ministry headquarters, where he was responsible particularly for transmissions With his long experience of mechanical systems and in establishing requirements for both rotors and propellers, Mr Newbery was an authority on the subject of his lecture—" The Programme of Development Testing for a Helicopter "

MR T G G NEWBERY

SUMMARY

The development testing of helicopters is at a stage where considerable changes are being made in the light of experience but where more changes can be expected as further experience is obtained This paper gives an outline of the work involved to meet present requirements with some suggestions as to where more emphasis would be advantageous The various phases are co-ordinated in a programme to indicate how they can be arranged to give the required results when they are needed The objective is the highest possible standard of safety and service ability before the helicopter enters normal operational use Whilst the paper is more directly related to a Service helicopter and in particular to the transmission, it covers the complete programme, which would be applicable, in the most part, to a civil helicopter also Completion of such a programme would fulfil most, if not all of the specified requirements for civil certification through additional

requirements may apply to a particular type or its role Some possible lines of investigation are suggested to enable future development to fulfil its purposes more efficiently and effectively The opinions expressed are personal and do not necessarily represent the views of the Ministry of Supply

(1) Introduction

During the past decade there has been considerable progress in the art of development and testing of helicopters and also in the formulation of requirements The first publication of requirements specifically for helicopters was in B C A R (Ref 1) followed by the Ministry of Supply draft specification for mechanical transmissions (Ref 2) All the requirements for Service helicopters are now being co-ordinated in Volume 3 of the Ministry of Supply publication " Design Requirements for Aircraft for the Royal Air Force and Royal Navy " (Ref 4)

With the increasing interest in helicopters for both Civil and Service use it seems opportune to pause and consider the effects of this " progress " and to ask whether the required results are being obtained in the most efficient way or whether action is necessary to guide or stimulate the " progress " in any way

This paper outlines the various phases of the work involved in meeting the present requirements and co-ordinates them into a programme The purpose of the development is to establish the highest practicable standard of safety and serviceability of a helicopter before it enters normal operational use and the programme aims at completion of the work in as short a time as possible Two conflicting requirements arise here in that the operator invariably wants the helicopter quickly but comprehensive development requires time and restriction of the time allowed must adversely affect the result

It will be found that the paper is written mainly round Service helicopters and in particular the transmission This is because my experience has been in that sphere but I have tried to include all the other items as well A helicopter completing such a programme will, it is believed, have fulfilled most, if not all, of the specified requirements for Civil certification though additional requirements may be relevant to a particular helicopter or its operational role

For the paper to be fully comprehensive, more space than is available would be required and advantage is therefore taken of papers already given on development Where these deal with particular tests, reference is made to them instead of including particulars Similarly, reference is made to the publications in which requirements are given instead of stating these in detail

(2) Programme Stages

If the various parts of the programme under consideration are to be arranged in the proper order there must be some sort of time base This need not be expressed in terms of weeks or months but can be obtained by dividing the complete period into stages By this means a programme which is applicable to any new type of helicopter can be discussed although the elapsed time involved may vary according to the size and nature of the particular type Since the goal is production of helicopters it is convenient to adopt for the time base stages related to aircraft manufacture and build as follows —

1 Project
2 Design
3 Manufacture
4 Prototype build
5 Development batch
6 Production

There can be no distinct dividing line between one stage and the next because successive stages commence before the preceding ones are completed but, as the programme must be expressed in general rather than precise terms of time and must be flexible, these divisions will be suitable

A new type will start from an idea as to how a requirement, stated or anticipated, could be met It might be a modified form of an existing type, a completely new conception unrelated to current practice, or anything in between and the amount of work involved in development will vary accordingly During the project stage the idea is transferred into a description —more or less detailed—of the actual helicopter with sufficient information to enable the " customer " to assess its merits and prospects

Whilst a certain amount of design work is necessary in the project stage, designing commences in earnest when it is decided to proceed with the project and one of the first tasks may be the design of models for aerodynamic and dynamic tests Production requires detail drawings and arrangement drawings but preparation of these is only a small part of the design work which includes the calculation of loads under all conditions of operation, estimation of stresses in each part and the assessment of fatigue lives At this stage it is necessary to make assumptions where precise information is not available and calculations must be conservative to ensure adequate strength without overlooking the need for minimum practicable weight These calculations form the basis of preliminary tests and would be checked, where necessary, by measurements during strain gauging, later in the programme

Rigs will be required for testing when parts become available and the design of these should proceed in parallel with the aircraft design though, of course, following the design of the parts concerned This applies also to jigs required for manufacture

Manufacture commences with the ordering of materials and of forgings and castings and this will occur well before completion of the detail design work It will be seen later that the development programme is concerned with parts in the rough state if specialised manufacturing or fabricating techniques are involved

The prototype is the first aircraft of the type to be built and provides a check of the drawings and possibly of some jigs Since adjustments often have to be made the prototype may differ in some respects from subsequent aircraft These " adjustments " may include design changes to improve manufacture, assembly or accessibility

Adequate development testing requires the provision of a number of aircraft but, as alterations are likely to result from the development, these aircraft cannot all be built initially to the final standard A development batch serves the purpose of providing the necessary aircraft and making provision for the introduction of changes without requiring the full modification procedure A corresponding development batch of engines also is required

Another advantage is that the customer can assess the aircraft for layout

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and for servicing Any alterations required can then normally be made before production proper begins

Ideally the development programme should eliminate all faults and establish a final standard to which the production aircraft should be built, subsequent changes being needed only to meet new users' requirements However, whilst the ideal should be the aim, the practical has to be accepted and even if the contractor eliminates all the faults he finds, the operator is likely to introduce new conditions—he may change his ideas of how to use the helicopter—which may reveal new faults

The tests outlined aim at establishing the highest possible standard of safety, reliability and serviceability and should be completed before the helicopter commences normal operational use

(3) Design Aids

Theory cannot always provide all the information needed for design, particularly when departures from previous experience are involved It is also easier to decide the best way to arrange parts when they can be seen in " hardware " than by imagination and drawings Models can meet both these requirements Two types of model may be needed to provide design information

(i) For wind tunnel tests to provide aerodynamic data, and
(ii) for dynamic tests to investigate ground resonance

Wind tunnel tests of models have been described in the paper by M S Hooper (Ref 7) and in the paper on the Rotodyne (Ref 9) Dynamic model tests are described in the paper on the Bristol 173 (Ref 6) and in that on the Rotodyne

The second requirement is met by building a full-size space-model, or mock-up, which reproduces all the salient features of the helicopter (Ref 5) An engine mock-up is provided also so that a preliminary check of engine installation and removal can be made

This mock-up is the centre of numerous conferences and lengthy discussions to decide such points as where equipment should be put and how the cockpit should be arranged The final answer does not often result and discussions continue throughout development until the " Final Conference "

(4) Engine Programme

Although the engine development is carried out, initially, quite separate from the helicopter, it is a very necessary part of the overall programme unless, as very seldom occurs, the new helicopter type uses an established helicopter engine

The type of engine will be decided in the project stage or at the beginning of the design stage and the engine contractor will be required to provide a preliminary mock-up for the helicopter mock-up, a more complete and accurate mock-up or installation engine early in the prototype build stage and the " running " engine(s) before completion of the prototype If a propulsion system is built by the helicopter contractor the engine requirement for this would come before that for the prototype A flight approval test is necessary not later than the ground running stage of the prototype and the bench type test must be completed before the helicopter type test is due to start

The performance requirements of a helicopter may be associated with operation at altitude in the tropics with a limitation of the engine power at other conditions Although the helicopter type test will be based on appropriate powers, as delivered under the prevailing (temperate) conditions, the engine must be tested to clear the conditions which will be experienced at tropical altitude

It has usually been possible to adapt an existing aeroplane as a flying test bed for a new engine for fixed wing aircraft but the same has not applied to helicopters This has meant that engine flight development has been carried out by the helicopter contractor as part of, or incidental to, the aircraft programme So that the engine contractor can ensure satisfactory flight characteristics of the engine, it is reasonable that he should be able to carry out engine flight testing to determine and resolve the engine problems In the absence of a flying test bed consideration should be given to the allocation of one of the development batch helicopters (or the prototype) for flight testing under the control of the engine contractor

Much useful development can be carried out on a rig with the engine driving a rotor system Whilst this will not reproduce flight conditions it will enable satisfactory control and response under ground running conditions to be established It will also provide a better means than the test bed for resolving many of the problems revealed by flight tests Another advantage is that running can be with the engine change unit instead of the bare engine, as is usual on the test bed, and associated features can be checked instead of awaiting running in the helicopter

(5) Specialised Processes

Some methods of manufacture involve the use of specialised processes and require close control in order to ensure a satisfactory standard in production This involves the establishment of the correct technique and adequate checking to maintain uniformity In such cases the process or technique, when established, should be recorded (on the drawing or in a specification) so that production can be checked and a uniform standard maintained Three examples are given below

A forging is usually required to have grain flow in specified directions and requires working in a particular way Some materials also require a minimum amount of working to ensure freedom from flaws The specialists have the " know-how " but it is usual to cut up one of the first forgings to check the grain flow and the quality of the material

The inspection procedure also must be established and this may involve X-ray examination or other special tests, such as ultra-sonic tests, for flaws (Ref 6)

Similarly, a casting may need special controlled procedure to ensure adequate strength and freedom from porosity Reference 4 specifies the strength tests necessary for approval

Parts can be joined by welding or one of the several processes developed during recent years These also require adequate control and testing (Ref 4) to ensure satisfactory results

(6) Strength Tests

It is not always possible to calculate accurately the strength of a complex part or assembly of parts and where doubt exists it is necessary to make tests These may be to determine (*a*) the failing load, (*b*) the maximum load without distortion or permanent set, (*c*) the distortion under specified loads or (*d*) the distribution of stress, particularly where there are stress concentrations An example of the latter is given by the strain lacquer tests of the Skeeter hub (Ref 8)

Fatigue strength often presents more uncertainty than strength under steady load, particularly in built-up parts, and consequently necessitates testing The principles and procedure for fatigue substantiation are set out in R A E Technical Note Structures 158 (Ref 3) and it is normal to specify for military helicopters a minimum fatigue life, *e g* , 1,000 hours

The final assessment must be based on the loads and stresses which occur under operational conditions as obtained from ground and flight strain gauge tests and there is consequently a temptation to defer fatigue tests till these results are available It is necessary, however, to ensure that the helicopter is safe for the testing to be carried out, initially on the ground and then in flight and, as stated in the R A E Note, " Sufficient pre-flight fatigue testing should be done to show that production components have at least the fatigue strength to which they are designed " Endurance testing at operational loads can only give clearance for a limited time within the fatigue range where a factor on life is effective, beyond this factored load tests are necessary

When fatigue testing of gearboxes was first proposed some doubts as to its practicability and need were expressed but it is becoming generally accepted Further experience is still needed to resolve the remaining doubts and to establish procedure It is realised that running at factored load could, in some designs, result in unrepresentative conditions and misleading results The main danger is probably that the distribution of loading along the teeth would be upset with concentration towards one end but this could, if necessary, be overcome by adjusting the gears Some quite satisfactory tests have been made and it is felt that there should not be any insuperable problem Failure of a gearbox could be disastrous so cannot be countenanced and fatigue substantiation is essential

In assessing fatigue strength or retirement life it is important to take into account the effects of operational use Wear, fretting and corrosion can induce or accelerate fatigue failure Wherever possible therefore, these effects should be included in the tests of relevant parts, *e g* , by testing parts which have been run If indefinite life is established for new parts additional tests could be made to determine the maximum acceptable amount of deterioration Alternatively, parts which have completed specified periods of operational use could be tested to determine the reduction in fatigue strength

It is important that fatigue tests are carried out early in the programme It is realised that this may conflict with the requirement that fatigue substantiation must be based on operational conditions as measured by flight strain gauging but the discovery of a short, unacceptable fatigue life late in the programme can cause serious delay and expense If, therefore, strain gauge results are likely to be unduly delayed serious consideration should be given to the need for tests based on estimated loads With the introduction

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of turbine engines more accurate estimation should be possible since the engine excitations normal to piston engines should be absent

(7) Functional Tests

The helicopter is required to operate over a wide range of conditions Just as a chain can be useless because of one weak link so a helicopter can be jeopardised by one unreliable unit All units must, therefore, be tested to ensure that they will function satisfactorily under all operating conditions throughout their overhaul lives Some units, *e g*, pumps, must maintain a specified performance, so acceptable manufacturing and maximum worn limits must be established Development testing also provides an opportunity for determining the critical test conditions which should form the basis of production acceptance testing In determining performance the power required should be established within limits as an additional check on standard of manufacture

Some assemblies require careful control during build to give satisfactory operation and maximum overhaul life In gearboxes, for example, it is necessary to ensure that gear meshing is such that no condition gives high local loading This becomes more important as gear width is increased or if flexible casings are used Tests must be made, therefore, to obtain the optimum meshing alignment and conditions Another item is the correct preloading of taper roller bearings and the methods of obtaining and controlling this Such assembly procedures and techniques, when established, should be recorded to ensure they are maintained and to provide a ready check

At the same time it will be found where special tools for assembly or dismantling are needed Every effort should be made to avoid this need and where a design change can be made to enable a standard tool to be used, this should be done Essential special tools should be as simple as possible and should be thoroughly tested before the design is finalised Such tools will be required for maintenance and servicing when the helicopter is in operational use (Ref 4)

Lubrication is another important factor and where oil feeds are provided it is necessary to establish that an adequate supply is available under all conditions and flight attitudes including starting after a period of standing The transmission should use the same oil as the engine and, with turbines, this would normally mean synthetic oil D E R D 2487 Care will be necessary to ensure suitable rubber mixes for seals and to eliminate any oil leakage

Various systems, *e g*, hydraulic, fuel, powered controls, are incorporated in the helicopter and these require testing on suitable rigs (Ref 5) Suitably designed rigs can be used for functional testing under the full range of conditions and simulation of possible single faults, and also for endurance testing where appropriate This might even be extended to fatigue testing

Accessories will normally have been tested by the manufacturers to specified requirements They should, however, be included in the helicopter development tests where appropriate so that any effects peculiar to the application can be checked

(8) Endurance Tests

Having established satisfactory functioning it is next necessary to ensure that this will be maintained throughout the longest possible overhaul life This has been one of the shortcomings of helicopters generally and operators are becoming more insistent on better reliability and serviceability with longer periods between overhauls The aim should be to reach 1,000 hours as quickly as possible after operational use commences which means, of course, very much more development testing than has been normal in the past It must be remembered that overhaul lives can only be established on the basis of operational experience since development testing cannot hope to reproduce all the operational conditions of use and maintenance

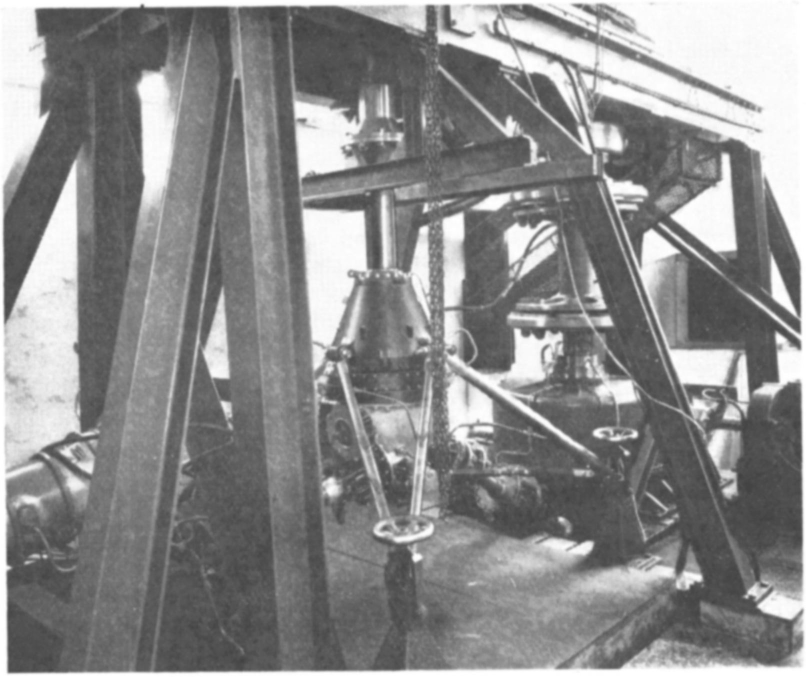
The rigs used for functional tests should be suitable for endurance testing also and will permit more intensive running than would be possible with a complete helicopter Two methods of testing are possible (*a*) using conditions reproducing actual operational use and (*b*) concentrated testing under the more severe conditions giving results in a shorter time Each has obvious advantages and disadvantages and care is needed in interpreting the results, bearing in mind the differences between rig testing and operational use It is suggested that testing should start with conditions (*a*) for a period of, say, 250 hours with the first inspection at 50 hours and subsequent inspections determined by results If all parts are satisfactory more concentrated testing could be undertaken The total period of testing must depend on results but a minimum of 500 or 600 hours would be necessary to establish that 1,000 hours service overhaul life could be expected

It is always a problem to decide what to do when a weakness is revealed and a part is changed during a test No universal rule is possible but enough testing of the new part is required to establish that it has an adequate overhaul life One is reminded of the broom which had been in continuous use for so many years although there had been numerous new heads and new handles A report that a gearbox has completed 500 hours testing can be quite misleading if it is not made quite clear whether, and if so when, any part was changed

The results of development testing can be nullified if there is a change in the standard of manufacture—either in the machining limits or in the assembly technique The limits are specified by the designers and are checked and proved during development but the production department is sometimes tempted to change them to facilitate manufacture The change may appear to them to be insignificant or unimportant but it can, in some cases, alter completely the results It is important, therefore, to see that specified limits are not unnecessarily tight but it is even more important to ensure that the standard which is tested and proved is the standard which comes off the production line

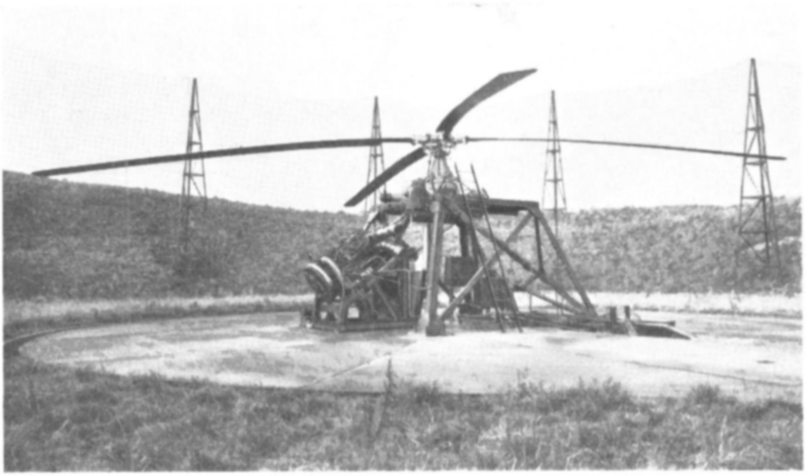
(9) Rigs

Having made numerous references to the use of rigs it might be useful to deal briefly with the rigs themselves Experience has shown that development can be considerably delayed if adequate provision of rigs is not made In some cases a rig has been planned for production acceptance testing and it has been considered that this could be used for development also, but such an arrangement is never satisfactory If adequate development testing is



by Courtesy of Westland Aircraft Ltd

Fig 1 Wessex gearbox test rig



by Courtesy of D Napier & Son Ltd

Fig 2 Gazelle/Wessex rotor rig

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to be possible without undue delays then development rigs are essential The balancing of the value of simple or elaborate rigs and the range and number of them, in terms of cost, against the value of time saved and results achieved could form the subject of a paper on its own Another factor will undoubtedly be the size of the production orders obtained or expected

A rig need not necessarily be complicated but its value will be increased as it can more nearly reproduce the range of operational conditions and be controllable from one condition to another Simple rigs are often best and it may be better to have two simple rigs each meeting a part of the requirements than one elaborate rig to do it all

A typical gearbox test rig was described in the paper on Helicopter Production (Ref 12) This was the back-to-back rig used for Whirlwind main rotor gearboxes and Westlands have made improvements in the corresponding rig for the Wessex, such as provision for applying rotor loads (Fig 1)

by Courtesy of Bristol Aircraft Ltd

Fig 3 Bristol 192 on gantry rig

This type of rig may have undesirable inherent vibrations but these can be measured and allowances made when fixing the test conditions They should, however, be reduced to a minimum because they upset the reproduction of operating conditions

Another valuable rig is the main rotor tower which enables the main rotor hub and blades, with the blade controls, to be tested within certain limits (Ref 8) Speed and lift can be obtained but the forward flight condition cannot be simulated except in so far as this is given by the wind Mention has been made of an engine/rotor system rig which provides additional rotor testing as well as engine development Fig 2 shows the Napier Gazelle rig with Wessex rotor

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Reference has been made also to the system test rigs and there will be others for specific tests of different units, for functional, endurance, strength and fatigue tests, the number and types depending on the particular helicopter design For the Rotodyne (Ref 9) and the SE 3200 (Ref 11) rigs were constructed to enable tests of the complete propulsive systems to be made The same idea was used for the Sycamore and the Bristol 192 (Fig 3), using airframes suspended from gantries Such rigs provide valuable experience of the complete installation and reduce considerably the aircraft ground testing required Not only can endurance running be carried out but preliminary strain gauge tests also can be made and early results of these can be of considerable value

(10) Prototype

As mentioned earlier the prototype provides a check of design and enables alterations to be made where necessary or desirable It may differ from the development batch in that build is started appreciably earlier so that jigs can be finalised and production procedures may be used for as many of the development batch as possible

The mock-up provides a preliminary check of installations and the prototype enables checks to be made with the actual parts An engine, or E C U , would be provided for installation purposes but it might be changed before running commenced Points to be checked include installation and removal of the E C U , bearing in mind the requirement for the shortest possible E C U change time, maintenance and servicing, including accessibility of relevant items, and ease of removal and fitting of units The Engine Change Unit was devised to facilitate engine change and this idea has been extended on the Wessex to the main rotor gearbox The possibility of other applications might merit investigation

(11) Development Batch

The time required for completion of the development ground and flight tests will depend on the availability of sufficient aircraft to enable tasks to proceed simultaneously Building would commence as soon as possible after the prototype and changes would be introduced as early as possible without unnecessary interruption of the programme Some of the last of the batch would be expected to be to the production standard, at least in all essential respects

The primary tasks may be listed as —

(i) control and handling,
(ii) vibration investigation, including ground resonance and strain gauging,
(iii) performance

whilst additional tasks will include —

(iv) engine flight testing,
(v) endurance tests,
(vi) development of special equipment installations, (*e g* , radio, auto-pilot, roles),
(vii) servicing and maintenance evaluation,
(viii) A & A E E trials and climatic trials,
(ix) type test,
(x) final conference

These are not necessarily in order of importance

If a propulsive system rig has been provided the preliminary running and control problems will have been solved, otherwise functioning and control will form the first ground running task However, if there is uncertainty about ground resonance it may be necessary to do some checks of this before running, particularly if the aircraft will not be tethered A gantry rig, as used by Bristol Aircraft Ltd , enables the " ground running " to be carried out without ground resonance being a problem

During build an aircraft should be instrumented for strain gauging so that a check can be made, as running proceeds, for any resonant condition or any unexpected high vibration loads or stresses Sufficient measurements should be made to permit a re-assessment of fatigue before flying commences

Ground testing should continue as necessary to provide 50 hours running as a basis for flight clearance

The first flight of a new aircraft is an event always attended by the thrill of expectation tinged with a degree of apprehension Its result can bring satisfaction, relief and/or furrowed brows However, valuable as the results are, they can be overrated since if they are " completely successful " they may engender a false sense of security " Things are never as good or as bad as they at first appear "

Control and handling will be the first task but, if these are reasonable and safe, flying should not be delayed unduly till improvements, which may be desirable but not essential, are made As much information and experience should be obtained as quickly as possible

Flying will progress in stages of successive extensions of the flight envelope as each stage is proved satisfactory This includes strain gauging as well as handling As the envelope is extended performance measurements will be made The length of time required to complete the whole envelope will depend on what difficulties are encountered and how long is required to overcome them

The importance of early fatigue tests has already been emphasised and this implies the earliest possible completion of strain gauge tests There have been cases where this work has been uncompleted when the aircraft has gone into service and it is felt that greater efforts should be made to prevent such a situation One of the problems seems to be unserviceability of the equipment in which case some research and development to give reliability may be needed There is also the problem of unserviceability of the aircraft, for which special measures, such as quick replacement of parts, might be necessary No effort should be spared to enable the fatigue assessment which is made before release of the aircraft for operational use to be complete and unrestricted

A new type of engine will require adequate flight testing to ensure satisfactory control and response as well as satisfactory functioning and performance under all conditions Allocation of a helicopter to the engine contractor is the only really satisfactory way of doing this work

Another aspect on which it is felt emphasis should be placed is the accumulation of adequate flight experience as part of the development programme For this purpose it is suggested that one helicopter should be allocated for intensive flying and, if necessary, one for intensive ground running in support of the initial flying

The flying would commence within the successive stages of flight

by Courtesy of Westland Aircraft Ltd

Fig 4 Wessex tethered for ground running

envelope extension but should be, as far as possible, under operating conditions The accumulation of at least 350 hours flying under such conditions is considered not unreasonable so that, with the flying of the other helicopters a total approaching 750 hours might be expected

In parallel with the flight development the work on special equipment will be proceeding and there will also be the maintenance and servicing evaluation

When the firm's tests have reached suitable stages aircraft will be sent to A & A E E for official trials including handling, performance, engineering assessment, radio and navigation and items appropriate to the type and roles One aircraft would probably be allotted for intensive flying to assess operational reliability (Ref 10)

Climatic trials under tropical and cold weather conditions have to be made at the appropriate seasons and aircraft would be prepared for these as early as possible in the programme The development will have included as much testing as practicable to ensure satisfactory results from these trials

As a final check of satisfactory development the complete helicopter undergoes a "functional and mechanical reliability test," or "type test" as it is usually called, which involves both flying and ground testing The basic schedule, applicable to a single-engined machine, includes 100 hours ground running and 50 hours flying For a twin-engined machine these times are increased by single-engine testing so that each engine completes running equivalent to that of the single-engined helicopter It will be realised that if a twin-engined machine can fly on one engine, the higher engine power can only be used with one engine out so such testing must be single-engine running

The broad basis of the schedule is that the engine should complete the equivalent of an engine type test Flying, however, should be as nearly as possible to operational conditions, and some adjustment to the ground tests may be necessary to meet the overall requirements The flying can be completed first and the ground testing can be run with the aircraft either tethered (Fig 4) or suspended from a gantry as used by Bristol Aircraft (Fig 3)

It is emphasised that the type test is the culmination of development and a final check of all the earlier work Consequently the helicopter used should embody all modifications and should be to the production standard in all respects

There is constant collaboration between M O S and A R B to ensure that, as far as is practicable, the requirements are common to both Service and Civil helicopters Efforts have been made also to achieve agreement with American authorities

When the aircraft build standard for production is finalised an aircraft is prepared for the Final Conference (Ref 5) when a thorough check is made by the various " experts " to see, as far as possible, that everything is satisfactory

(12) INTENSIVE FLYING TRIALS

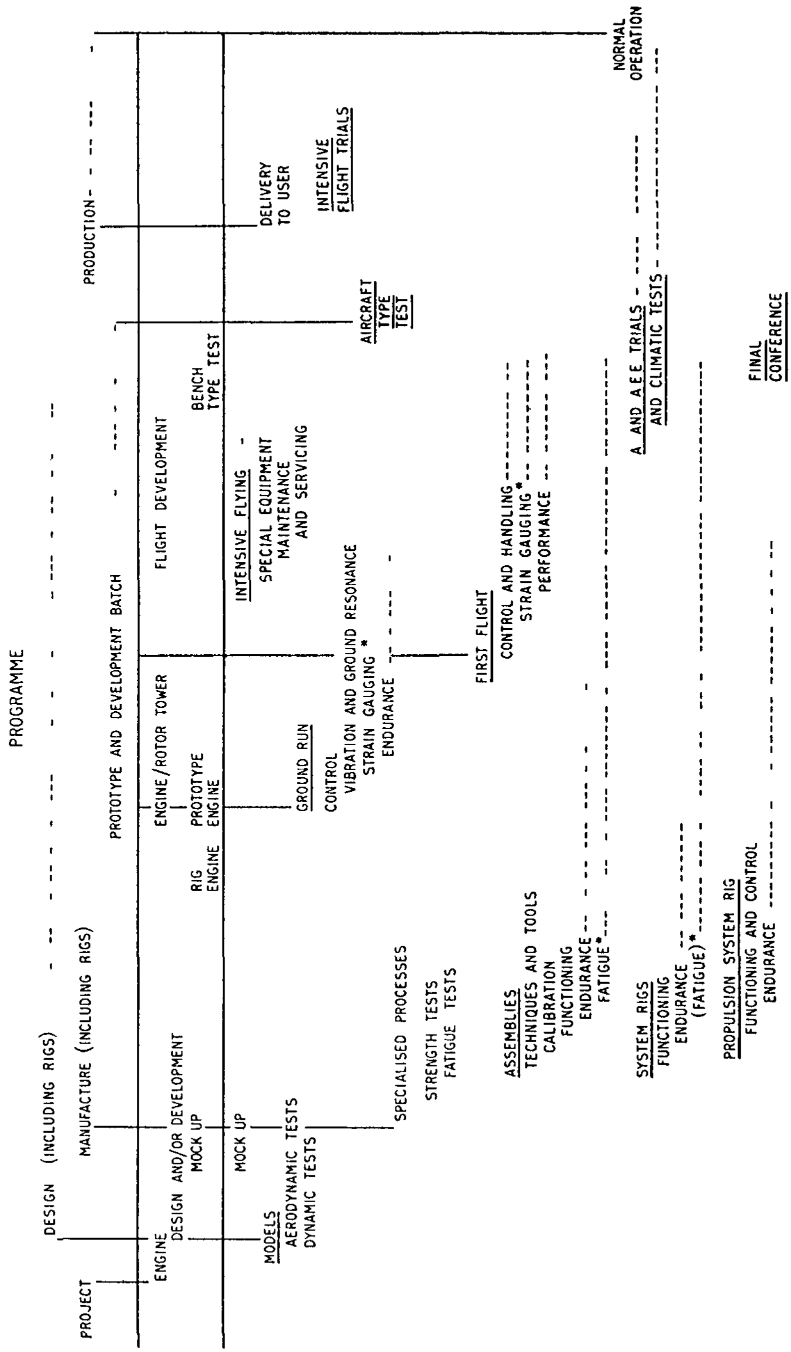
The final proving of a helicopter comes when it is used in its particular operational role or roles It has been a normal requirement that Civil aircraft should complete a period of flying or route proving trials before a full C of A is granted Service experience has confirmed the wisdom of this, and it is becoming more general practice for service intensive flying trials to be carried out before general operational use commences All development must be based on anticipated operational requirements and role conditions but the nearest approach to the true conditions will be obtained from operation by the user Service in the way it is intended to operate and maintain the helicopters If development has been completely successful there will be no failures during the intensive flying and that would be an achievement indeed as the trials should aim at revealing any weakness The trials do provide an opportunity, however, of discovering any faults not revealed by development and of correcting these before, or early in, the general operational use

The number of helicopters used and the length of the trials will depend on a number of factors but it is suggested that a minimum of four should each complete an initial overhaul period which, with an adequate development background, should be not less than 250 hours and could be expected to be 400 hours The initial operational overhaul life would then be based on the results of inspection on completion of the flying and subsequent increases would be based on the results of inspections after periods of operational use

(13) THE PROGRAMME

The different parts of the programme having been outlined it now remains to co-ordinate them into a programme This is shown in Fig 5

First there are the programme stages proposed to give a time basis and it must be remembered that the spacing is not representative of actual elapsed time Then is given the engine development programme



* NOTE EACH STAGE OF FATIGUE TESTS AND STRAIN GAUGING WOULD BE FOLLOWED BY A RE APPRAISAL OF FATIGUE STRENGTH

Fig 5 Programme

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The aircraft programme falls automatically into sections

(i) models for dynamic and aerodynamic tests in the design stage and also the mock-up,

(ii) tests of parts and assemblies as these become available from manufacture,

(iii) checks during the prototype build,

(iv) ground running and flying as development batch aircraft become available including intensive flying,

(v) A & A E E trials,

(vi) aircraft functional and mechanical reliability test (or type test),

(vii) intensive flying or route proving trials

Some of the tests, in particular the endurance running and fatigue tests, extend over long periods The aim should be to complete the fatigue tests before the type test but this may be impracticable They should, however, be completed before normal operation commences

It is emphasised that this is a general programme which may need to be varied or adapted for a particular type of helicopter Some items may have been omitted and some of those mentioned may not always be applicable

In general it is thought to be in reasonable agreement with current practice though additional emphasis has been placed on specific aspects where it is thought this is necessary

(14) Conclusion

As stated in the introduction "the purpose of the development is to establish the highest practicable standard of safety and serviceability of a helicopter before it enters normal operational use" This requires an adequate period of development and testing including flying under operational conditions as nearly as this can be done In planning a programme allowance must be made for time necessary to correct faults which may occur, since no design is likely to be perfect At the same time the period involved may be reduced by special measures to minimise delays in completing the work which normally takes a long time and by providing facilities for producing modified parts quickly

Collaboration between the Ministry of Supply and the Air Registration Board provides standardisation of requirements as far as possible but there may be differences in detail interpretation and application Where Civil as well as Service approval is involved the requirements for both are covered, where practicable, when the schedules are formulated Some additional work may be necessary for Civil approval of a particular type or because of the operational role

Past experience has shown where changes have been necessary and these have been included in the present programme Future experience will undoubtedly show where further changes should be made for there is still much to be learned about the development of a helicopter which will meet the standards of reliability, serviceability, efficiency and cost desired by the users

Looking to the future, it is suggested that consideration should be given to the following points —

(1) The strain gauging technique should be reviewed to improve reliability of equipment and to obtain results in the minimum time

Present practice is, in general, to make measurements under stabilised conditions over the full range There may be advantages in taking continuous records during normal flying and additional records as shown necessary by the results

(2) Much more use is now being made of rigs for unit testing and this practice should be applied as fully as possible Testing techniques should be reviewed to obtain maximum results in minimum time Taking gearboxes as an example, there is much to be said for cyclic testing covering the operating range but it might be possible to concentrate on the more severe conditions or even a degree of overload At present there is no standard procedure

(3) Overhaul lives have been severely criticised and attention to engineering improvements might yield valuable dividends Investigation by an independent operator of this aspect could be advantageous

(4) Much more information is required about actual operating conditions as they affect integrity and serviceability Only a clear picture of what is involved can enable the development testing to fulfil its purpose

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APPENDIX 1

Examples of Test Items

1 *Parts and assemblies*
- (i) Specialised processes—Forging, castings, welds, adhesives
- (ii) Strength—Parts under pressure, complex parts with stress concentrations (*e g* , rotor head), fabricated units (*e g* , fuselage), engine mountings, undercarriage, tanks, transparencies
- (iii) Fatigue—Any part which cannot be substantiated by calculation Rotor blades, controls, transmission (shafts, gearboxes, freewheel)
- (iv) Calibration—Pumps, lubrication system (oil feeds)
- (v) Functioning—Systems, *e g* , fuel, lubrication, hydraulic, electrical, controls, air conditioning, gearboxes, rotors, brakes, fire detection and suppression
- (vi) Rig endurance—Gearboxes, rotors, controls, hydraulics, clutch, freewheel

2 *Strain gauging*
Rotor blades, shafts, gearbox supports, engine mountings, controls, structure, and any part where vibration data are required for fatigue substantiation

3 *Helicopter ground tests*
Ground resonance
Engine starting, control, response, rotor engagement, rotor brake
Aircraft controls—functioning and forces
Interconnection of rotor and engine controls (rotor speed governor)
Functioning of systems
Cooling of engine, accessories (*e g* , generators), gearboxes
Noise, vibration, cockpit and cabin air contamination
Strain gauge measurements
Endurance testing
Taxying, towing, ground handling (hard and soft ground), wheel brakes
Roles equipment
Maintenance and servicing—accessibility

4 *Helicopter flight tests*
Handling, control, stability, control forces
Engine control and response
Cooling
Functioning of systems
Noise, vibration, air contamination
Strain gauge measurements
Progressive extension of the flight envelope—take off, hover, climbs, descents, autorotation, flight forwards, backwards and sideways, manoeuvres, landing (vertical and run-on), up to maximum all-up-weight and over the c g range
Performance
Endurance flying under operational conditions

APPENDIX 2

Finagles Laws

A masterly exposition of " Finagles Laws " was published in Product Engineering on 21st April, 1958 The following extracts might be considered relevant The article suggested that proof of the laws (if any were needed) rested in the answer to the question " Is not this your own experience ?"

1 If anything can go wrong with an experiment (or test) it will
2 Even if it is impossible to assemble a part incorrectly, still a way will be found to do it wrong
3 Deliveries which normally take one day will take five when you are waiting
4 After adding two weeks to a schedule for unexpected delays, add two more weeks for the unexpected unexpected delays