Helicopter Maintenance

By J H WILLANS

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In the Chair A McCLEMENTS, A R T C , M I MECH E

INTRODUCTION BY THE CHAIRMAN

The CHAIRMAN extended a welcome to non-members of the Association and introduced the speaker He said that Mr WILLANS had a long association with aircraft which extended back to 1935 Apart from a period during the war, when he was engaged on engine and propeller overhaul with B O A C , he had been continuously associated with aircraft maintenance in one form or another After the war he joined British European Airways as Chief Inspector , later he played an important part in B E A 's " sealed servicing " experiments , in 1950 he began his association with helicopters and since 1951 he had been engaged full time on helicopter operational and development problems (including maintenance) as Works Manager of the Helicopter Unit Against that background the Chairman felt that Mr Willans' paper would be of interest and value to everyone

Mr WILLANS, before reading his paper, thanked the Association for the honour it had done him in inviting him to read a paper before it

MR WILLANS

The title of this lecture does not imply that it is an attempt to be a complete guide to the maintenance of Helicopters It was chosen in the first place to leave as wide a field as possible within which I could find sufficient detail to make a lecture out of subjects which had not already been covered in other lectures I have since found that quite a large number of lectures have been read before your Society on the subject of maintenance, and I therefore found it difficult to avoid repeating some aspects of maintenance which have already been discussed I hope you will forgive me if I have at times mentioned aspects of maintenance which have been put before you previously In certain cases I have done this deliberately as my views differ from those already expressed, which will therefore give you another opinion which may be of interest to you All engineering is made up of individual opinions as there are as a rule several ways of doing a particular job Maintenance is especially a profession calling for individuality, and is a subject which cannot be taught Only experience and an aptitude for the work can produce a good maintenance engineer, and no machinery can be kept in good working order without good maintenance engineers Helicopters are no exception to this

As the lecture proceeds you may get an impression that in my opinion British Helicopters are not as good as American ones That is not the case, as I am of the opinion that the Bristol 171, which is so far the only British design with which I have had any experience, is in most respects better than all the others

The golden rule I have always followed is to leave well alone, and interfere as little as possible when a machine is working satisfactorily This is a very broad statement, and implies a nice judgement based on experience of when and how much interference is necessary to ensure safetv The longer I have been a Maintenance Engineer the more convinced I have become that trouble always follows a policy of examining something to see if it is still all right

With the exception of fatigue, there is simply no point in keeping opening up parts which are working satisfactorily, as there is nothing one can do any way All working parts of any machinery consist of rotating parts in bearings of one sort or another, or reciprocating parts, or wearing surfaces, all of which have their proper running fits These fits and clearances invariably give their own warning to an experienced Engineer that they are not in working order, or that they require adjustment or replacement Sight, sound or feel are used to keep watch on the condition of working parts, and I have never known any failure which could be said to have given no warning Designers all have their own ideas about what is an adequate bearing surface, but it still does not mean that a part with an inadequate bearing area is unsafe It only means that it gives notice of its condition much earlier than a part which is properly designed for its job

Fatigue, on the other hand, is quite a different problem This is entirely a designer's problem and responsibility There is nothing a maintenance engineer can do about it, other than realise as far as possible the parts which have reversals of stress while working and keep an eye on them for cracks This applies to the static structure as well as the working parts In fact most fatigue failures seem to occur in non-working parts because no one has realised that there are reversals taking place until it is too late Fatigue failures are far more dreaded by Maintenance Engineers than the troubles given by working parts because they can occur without warning, and show no visible sign, unless one happens to look at a crack between the time it becomes visible and before it grows to a failure, which can happen rapidly between inspections if these are too far apart

The proper maintenance of a machine therefore is a compromise between long intervals and leaving well alone as far as the functioning of parts is concerned, and frequent inspections of parts to guard against fatigue

It is considerations along these lines which have been given to the Maintenance Schedules which are used to keep the British European Airways Helicopters serviceable

There is a Check I which is daily, as it is considered wise to give a general look over the aircraft before flight No work is called for, but merely a glance at tyres, undercarriage legs, oil, hydraulic and fuel systems for signs of leaks, no obvious damage to blades or structure, and a close examination of the rotor

The Check II is at 42 hours or one third of the Check III period of 125 hours The only difference between the Check I and Check II is the cleaning of the oil, fuel, and vacuum system filters, checking gear box oil levels, checking battery acid, and blowing out pitôt and boost lines

These jobs have been dictated by experience Some of them are seasonal, as the vacuum filters are found to be much dirtier in dry weather, and the pitôt lines are more liable to collect moisture in wet weather They are, however, quite small jobs, and are therefore, for the sake of uniformity, done as the Checks become due The fuel filters are done as a precaution in order to keep an eye on the condition of the system Nothing much is ever found, but it is better to find a little and deal with it, rather than find too much too late The oil filters are the only ones which really could not go much longer without attention This is really a reflection on the oil used

The Check III period is 125 hours This Check is no more than the Check II with the addition of magneto and carburettor checks which have been dictated by experience as being necessary, together with a far more detailed examination of the main rotor head

The real check period on which the serviceability of the aircraft is based is the Check IV at 250 hours At this check the whole of the inspection panels and cowlings are removed and the aircraft is examined in detail throughout All the engine work is done at this check, and the aircraft is jacked up for undercarriage, brake, and wheel examination and checks Gyroscopic instruments are removed for calibration, as they will not run for longer periods in Helicopters

It does not mean that an extensive programme of work is carried out at this check If no defects are found, no work is called for It is an examination to ensure a further 250 hours trouble free service As it seldom happens that there is nothing to be attended to, it proves that the examination is necessary It can be argued that a longer period could be done and still not effect the safety of the aircraft This is true, because most of the work done is for the purpose of dealing with corrosion, making good protective treatments, taking up wear in working parts, dealing with fluid leaks of various kinds, and so on All of these could be allowed to go on longer without any question of danger The result would only be perhaps rather more wear, and more extensive treatment at the time when they would eventually be attended to

There is, however, quite another and more serious aspect which cannot be overlooked That is the question of fatigue

If the day-to-day checks are to be the absolute minimum of work, then a time must come when it is no longer safe to continue without a close examination The alternative is frequent, more extensive, and yet not complete examinations These have by long experience been proved to be a cause of more unserviceability in themselves than would have been the case if they had not been done

A period of 250 hours is a long time Any other transport vehicle, of a far more robust structure, if it could travel at the same speed of 100 miles per hour or more would have travelled 25,000 miles in this time with almost no work being done on it I know of no road, rail or sea vehicle which could do this distance, even at its own slow speed, with so little attention

In the case of a helicopter the engine revolutions for cruising conditions can vary from 2,100 to 2,500 per minute, according to type A period of

250 hours is 15,000 minutes There are threefore between 31,000,000 and 37,000,000 reversals of vibrations at frequencies of 2,100 to 2,500 per minute being fed into the structure during a check IV period

The main rotors are geared down about 1/11 of the engine revolutions There is therefore a far heavier vibration at a frequency of about 200 per minute giving a total of about 3,000,000 reversals superimposed on the engine vibrations

In addition one can get this changed to an even heavier vibration of three times the rotor revolutions caused by the three blades Superimposed again on this, the tail rotor is geared down in some aircraft to just under ½ engine speed, and this again can appear as three times its vibration

The main point I want to bring to your notice is not the frequencies, or the amplitudes of the vibrations It is the total number of reversals they may be causing

It is generally accepted that most ferrous materials show a curve of tensile strength against reversals of load of such a shape that it flattens out at about 10,000,000 reversals, and the material is considered safe beyond this point

In the case of most helicopters this point is passed in 250 hours as far as ferrous materials are concerned, but unless the load on each piece of ferrous material is low enough this does not mean it is safe It is here that the Maintenance Engineer is entirely in the hands of the Designer

In the case of non ferrous material there is no such relationship between load and number of reversals The rotor heads and blades in some cases contain non ferrous material carrying very heavy loads, and subjected to the heaviest vibrations in the aircraft The number of reversals in 250 hours is less than 4,000,000

It is for these reasons that it is not considered safe to go much beyond 250 hours without a close examination of the working parts which are of non ferrous material Cracks may have become visible, but have not got beyond control in that time, as far as the structure is concerned If cracks appear in the more serious parts one is lucky to see them before it is too late They can spread so rapidly to disaster that no frequency of maintenance can guarantee safety One relies entirely on good design and good material, but at the same time a close look at reasonably frequent intervals must be given

A Check V is in certain cases used at a period of 500 hours for items which can go longer than 250 hours At this check all flexible hoses in the fuel, hydraulic, oil and vacuum systems are removed Flexible fuel tanks are tested, certain structural bolts removed for examination, and teleflex controls are lubricated

Lubrication plays a vital part in helicopter maintenance Almost the whole of the lubrication of the working parts is done at a Check I or Check II, and of these the greasing of the rotors and their drive shafts is done daily The grease is forced in until plenty has appeared out of the other end of the bearing Discoloured grease is taken to mean trouble and the bearing is dismantled, or the part removed for examination The type NA-5700 push-on grease nipples are preferred as the pull-on type SP21 nipples do not allow high pressure to be used They leak past the gun and leave the bearing insufficiently lubricated All the B E A helicopters are converted to the push-on type of nipple

There is another side to the maintenance schedules which I have so far not mentioned This concerns the word " overhaul " The maintenance of a helicopter in a serviceable condition is divided into two separate categories The maintenance schedules lay down a list of work to be done and parts to be examined, which when carried out, means that the whole of the aircraft is kept at all times in a serviceable condition There is therefore no such thing as an overhaul There are however units on the aircraft with internal working parts which cannot be certified as serviceable by an external examination The maintenance schedules therefore list all these units and define the times at which they are to be removed from the aircraft for overhaul They also define in some cases the ultimate scrap life of certain parts which are subject to fatigue

After these units have been removed and replaced, one deals with them as a true overhaul They are treated in exactly the opposite way from the rest of the aircraft, as they never have much maintenance throughout their lives They do their working time on the aircraft, and go into the workshops for a complete strip down and detailed examination After renewal of any worn parts, or rectification if this is possible, they are rebuilt, and in certain cases tested

The overhaul of these units is the most expensive part of the maintenance of a complete helicopter There are not only quite a lot of them, but their removal, stripping, rebuilding, testing and re-installation is a costly cycle, without taking into account the expense of renewing worn parts

Using figures for the Bristol 171, there would be about 3,800 man-hours expended on the maintenance checks per year at a rate of 2,000 hours per year per aircraft Using 12 man-hours per flying hour as an average obtained so far for these aircraft, 2,000 flying hours would cost 24,000 man-hours By deducting 3,800, it means that the unit overhauls cost about 20,200 man-hours, or more than five times as much as the maintenance man-hours When it is realised that there are still certain units such as the power plant over and above these figures as they are not overhauled by B E A , and are not included in these man-hours, the urgency of increasing overhaul lives becomes clear These figures are based on the very low lives of only 250 hours for most of the units Some of them have been increased since, but still not enough to make them economic I see no reason at all why most of them should not have considerable increases in time, judged by their condition at overhaul They would be far safer if they were not disturbed, but it is difficult to get these views accepted

There is not much chance of bringing down the maintenance check costs as the hours are stretched as far as is safe, as explained above, but small adjustments can be made by keeping a close eye on the schedules and up-grading some items Every little helps We are not doing anything like 2,000 hours per year per aircraft at present, which in itself causes some waste We are also forced to do far too many useless Check II's on a calendar basis mixed up with our flying time basis owing to a meaningless clause in our authorised schedules

At the present time there is little relation between the overhaul lives of units and the maintenance checks This is not serious, and as it is hoped that the overhaul lives will steadily increase there is no point in trying to line them up The unit's span of life is recorded on a chart and it is removed at the next earlier Check III or IV It does not pay to remove most of them at a check II unless it is a quick job The Check III's and IV's all have some units listed for removal and the elapsed times of these checks therefore differ according to the particular units being removed Later, when most major units have about reached their ultimate safe overhaul lives the major checks can be evened out by planning which units to remove It is not worth doing at the present time In fact, costs are kept down by getting every hour out of the units rather than throw them away for the sake of planning equal check times

While accessibility for removal does help a lot to reduce elapsed time and man-hours for the maintenance checks, it is not a major problem The later types of aircraft are considerably better than the earlier ones There is still room for improvement in detail, but the major units are now on the whole easily removable In saying this, I am making allowances for single engine power plants in small aircraft which although bad, cannot be altered within the limitations imposed by the structure

By far the largest costs can be saved by more attention to longer lives for units which need not then be removed so frequently, and when they are, by much quicker turn-round times This means less man-hours for overhaul, and fewer units in the overhaul circuit The Airline can help itself to reduce the number of units in the circuit by cutting out transport costs and delays, by overhauling all units within the same workshops where the maintenance checks take place

The greatest help can come from the designer of the units If one takes it for granted that adequate areas and correct materials have been chosen to give long life between overhauls, this is still not enough Having run its overhaul time, when the unit is stripped it must be possible to readjust the fits and clearances without scrapping expensive parts in order to obtain a further cycle of overhaul life from the unit This is a point which is badly neglected in some designs Obtaining the fits and clearances can be a very expensive process in terms of man-hours and equipment required to do it

I have had experience of British and American designs which show some very interesting differences The first thing which is noticeable is the almost total absence of bevel gears in both types of gear boxes This may be due to cheapness in first cost but there is no doubt it also has a big effect in the overhaul cost A pair of bevel gears have to be matched, blued, and shimmed to get them to work together with the correct back lash The parallel gearing requires no adjustment It does of course mean that no adjustment can be done to bring the back lash down when it gets excessive, which involves scrapping a gear wheel, but so far experience has shown that they run many hundreds of hours without adjustment Enough experience has not been obtained to show that bevel gears will produce better results in the end, but it is already quite clear that unless the lives of such gears are almost indefinite, the job of making them fit to do another overhaul span is more costly than it is worth

The most marked difference between the two designs is in the bearings used The American gear boxes almost exclude roller or taper roller bearings The British boxes are exclusively built with taper roller bearings

With American ball bearings and ball thrust races, the whole assembly is done with the minimum of fitting with easily obtainable nip on the races In the case of the British taper toller bearings it is not only a long job to get the correct adjustment, but in some cases quite elaborate tools are required to pre-load the bearings, and even then there is a technique and experience required to make sure the bearing is in its right place Unless these bearings show a distinctly longer life than ball bearings, the extra work they cause is not justified They are heavier and more expensive

Another difference between British and American practice is in the shims used to obtain end float or end nips The Americans use peel-off shims The British boxes are built with solid steel shims which have to be ground down to size each time, after quite an elaborate procedure has been gone through to find out how thick the shim ought to be The old shims are scrapped, unless working fits in certain cases are closing towards thinner shims each time I see no justification for this slow and expensive system Nothing has ever been found wrong with the peel-off shims

There is a tendency for designers to produce units which require elaborate equipment to dismantle or rebuild them Special tools which speed up a job which could in any case be done without them are justified by time saved The use of tools required because a job cannot be done without them is seldom justified They are in most cases an added expense to overhaul which has been brought about by a complicated design which overlooked the aspect of a simple means of taking the unit apart Too many cases occur where a design has been made to fit the manufacturer's own workshop facilities The point of view of an Airline with simple equipment has been overlooked

By far the most important factor requiring attention if a helicopter is ever going to be an economic vehicle is to increase the overhaul lives of the major units These are far too low at the present time With the exception of the rotor heads, the units are composed of parts which are not subject to fatigue reversals of stress which require flight testing to prove them They are ideal units for ground rig testing and this should be done night and day and accepted as proof of serviceability for much longer overhaul lives I see no other way of getting economic increases in lives

The rotor heads are quite a different problem and are subject to such complex stresses and vibrations that flight testing is the only safe way to prove reliability Even here something can be done, as a tethered aircraft will give most of the loads and vibrations necessary It is after all not so much a question of fatigue failure as one of wear of working surfaces Fatigue failures can only be checked in true flight, but it is also a fact that the whole of the parts of most rotor heads subject to fatigue reversals are externally exposed and can be watched in service The bearing surfaces on the other hand are all internal, but as these are not subject to fatigue, but only to their working loads, it is reasonable to assess their serviceability for overhaul lives on the results of ground running

The whole problem is one of urgency, and it is not too much to say that the future of helicopters is bound up with a completely fresh outlook on the question of the lives of their major units

The main drive clutch is another unit where there are interesting differences between American and British practice The Americans seem to favour vertical driven surfaces and drive through shoes which expand outwards with increasing centrifugal force The British clutches employ horizontal circular disc driven plates which are gripped between circular driving plates whose load is obtained from centrifugal fly weights The American clutches seem to give more wear, and have more parts scrapped in a much shorter time than the British ones

Between the main clutch and the gear box, all types of aircraft have a free wheel unit Their details and positions are different, but the results are equally satisfactory as they give no trouble One American free wheel unit is a separate item, while the British one is part of the input drive to the main gear box The American one is more simple and easier to overhaul The British design has a spring upon the reliability of which the safety of the aircraft depends A broken spring could disconnect the main drive, and springs are above all items subject to failure These springs are subject to the shocks of the ratchet teeth during all over-drive of the main rotor

In addition to this the British design uses a " torque limiting clutch " If one design can dispense with this extra unit, I see no reason why the other should find it necessary It is a heavy and expensive unit requiring overhaul equipment beyond the capacity of a small operator This means more units in the overhaul circuit to allow for transport back to the makers and a more expensive overhaul If the object is to make lighter drive shafts, and save them from starting torque, it is a cheaper and better design to put the weight of this redundant unit into the drive shafts It is known that they do not slip in service with normal care in starting I feel that the whole design of a centrifugal main clutch is wrong The clutch should be under the Pilot's control as in motor car practice In the case of a helicopter, the clutch cannot be foot-operated and be in the engaged condition until it is disengaged by pressure The clutch should be engaged at all times, and be capable of being disengaged before starting the engine On the gradual release of pneumatic or hydraulic control pressure the clutch should engage, thus giving a controlled engagement which would prevent snatch in the main drive, and go a long way to easing heavy wear on clutches due to rapid centrifugal starting loads as at present

The tail drive shafts, if they must turn corners, should have gear boxes and bevel gears The next best thing is a double Hard-Spicer type of coupling The various types of " constant velocity " joints and flexible joints of other designs give far too much trouble, and cause too much maintenance to keep them even reasonably serviceable Bevel gear boxes give no trouble and little maintenance is required They are heavier than other means of turning corners, but the slight loss in pay load is more than gained in maintenance costs The Hardy-Spicer couplings require more maintenance to keep them serviceable and are limited in the angle through which they will drive

The drive shafts, both main and tail give very little trouble indeed The bearings of the tail drive shafts are mounted in or on rubber, and appear to have indefinite life in spite of the fact that the tail cone structure on which they are mounted is far from rigid The British design makes it possible to move the whole drive shaft through the bearings and thus provide a fresh inner race track surface

The entire transmission system really gives very little trouble on any of the designs It also reveals very little rectification or replacement of parts when the various units are stripped for examination This only proves that the overhaul lives are far too low Even the engines in the types of helicopters with which I have had experience give less trouble with the ignition system than the same engines give in fixed wing aircraft The reason is that there are no lower cylinders to get the plugs oiled up Oiled plugs have so far been almost unknown There is, however, a certain amount of trouble to compensate for this in the oil seals in helicopter engines because the starters and magnetos are below the engine These seals do leak, and are not at all easy to renew It is far easier to replace oiled plugs than a magneto Turning a fixed wing engine on its back for a helicopter without special attention to the oil seals is not satisfactory

Special mention must here be made of the rotor blades, both main and tail Very little trouble has been experienced with tail rotor blades of either American or British construction as far as the construction itself is concerned The construction of all of them so far has been timber of one sort or another A metal rotor blade is now in service, but it has not been in use long enough to make any comparisons There are, however, one or two other aspects which have given trouble The root end bearings of several of them have given trouble which has been completely overcome except in the case of the British design Here constant trouble is experienced and an absurdly low life is given by these needle bearings which leads to severe vibration The blade covering of the British blades is another source of trouble due to cracking of the surface finish leading to flaking off in service No trouble is found with the American blade surface finish of two different kinds Tracking and balancing of tail rotor blades is vitally necessary, and yet there is a curious difference between American and British designs The Americans make provision for both these adjustments, which certainly makes a smoother running rotor, and possibly has some connection with better results on the root end bearings The British blades have no provision for either balancing or tracking them They are supplied in so-called matched sets, but I have found that they are out of balance with no means of adjustment, and can also be seen to be out of track when running

The main rotor blades have never given any trouble at all as far as construction goes, although I have had timber, timber and steel, steel and fabric, and all-light-alloy construction in service The surface finishes also have varied considerably, from practically nothing on the British blades to an extremely hard smooth surface on one American design Even the fabric covered blades on another American design gave no trouble The lack of finish on the British blades has led to severe tracking trouble owing to moisture penetration

The problem of main rotor tracking is one which simply must be solved if the helicopter is ever going to be a commercial vehicle The smallest American design with a two-blade rotor is the only one which is almost trouble free At the other end of the scale is the British design where the defect assumes alarming proportions Blade tracking consumes an enormous quantity of man-hours, and even that is not the end of the trouble Quite apart from the time consumed and the number of men required to do this job, almost perfect weather conditions and daylight are required This means that it is almost certain on most days of the year, and especially in the Winter, that an aircraft coming in from service in the evening cannot be put on service the next day, and perhaps several days may pass before conditions are such that it can be rectified In addition to all this a test flight is required where at least 1,000 feet cloud base is necessary to be able to check the auto-rotative revolutions of the main rotor, which in turn may lead to further adjustments and another test flight

Blade tracking can be done at night (given the same perfect weather conditions), but the result is never very satisfactory as no good way has been found of observing the blade tips Even then the test flight usually cannot be done until next day Permanent illumination of the blade tips has been talked about and could be done without too much trouble, but that is not the right solution Tracking itself must be abolished

The airframe structure has never given any trouble in either American or British designs Both of them are similar as the power plant and main gear box are mounted on a tubular structure, on the front and rear of which is bolted a plate, rib and stringer construction for the cabin and the tail cone One American design is plate construction throughout with only a few tubes in the cabin roof to carry the main gear box There are surprisingly few fatigue cracks in view of the heavy vibration to which the structure is subjected Even the removable panels are quite as good as fixed wing cowlings and all the types of fasteners seem to give good service As most otner features seem to be equal, the type of fastener which is done up by pressing is preferred as it is quicker One weak feature is cabin doors and their locks This is, of course, not confined to helicopters, but I feel strongly that past experience on all types of fixed wing aircraft, together with the vibration which is inseparable from a helicopter, points to the fact that far more attention must be paid to doors if wind and rain are to be excluded Even weight must be sacrificed to achieve this There are already enough built-in causes for passenger complaint in any helicopter which cannot be avoided, to make it essential that at least this one of wet and draughts must be solved

The undercarriages and brakes on all types of helicopters are hardly worth mentioning as they have so little to do Except in emergency when some kind of shock absorbing equipment is probably necessary, the aircraft is landed at such a slow rate of descent with no forward speed that one is tempted to suggest that nothing but four fixed pegs is required This would save quite a lot of pay load and some maintenance, because the legs and wheels that are fitted must be looked after I think it is time that no overhaul life is given to helicopter undercarriages They have so little to do and no disaster follows if they go down, that they are one of the items which could be left on the aircraft and only removed when their condition makes it necessary I have got this practice in operation on one type and it will be interesting to see the difference in results at a later date

Almost the same remarks apply to the main wheel brake system It has so little to do that it is almost just a parking brake It is not wise to say this, however, as roof tops and their problems have not yet been tackled An emergency run-on landing on an aerodrome or field may make brakes unnecessary where there is plenty of room A roof-top might completely change the picture Even here, however, a touch-down near the down-wind edge of the roof will not have the same result as an overshoot through an aerodrome hedge at the end of a runway ! The brakes will not have much effect on the result I have had both mechanical and hydraulic brakes in service and as usual the hydraulic system gives more trouble, but not to a serious extent

Rotor brakes are quite another story Here the designers seem to have taken the opposite point of view All rotor brakes so far have been treated as parking brakes, and as such have done their job with little trouble The fact is, however, that is is necessary to pull up a rotor as quickly as possible, both from the passenger and ground staff safety point of view, and to prevent blade lifting in high winds in the Winter For this purpose the brakes so far provided have been a complete failure They have been far too small to absorb the energy without rapid wear and constant unserviceability There is now in service for the first time a rotor brake of American design which may prove adequate for the job, but it has not been in use long enough to prove anything Unlike the others this is a mechanically operated band brake

The electrical equipment on all the types of helicopters has been reasonably free from trouble Electrical equipment on fixed wing aircraft of both American and British designs gives more trouble than it ought, with the British equipment giving more Helicopters reproduce this picture They are if anything slightly better as they are free from all the power plant actuators, undercarriage warning systems, cabin equipment, and wing flap systems which all give trouble on fixed wing aircraft

The fuel systems on helicopters can be said to be identical with fixed wing aircraft, as no two aircraft have ever been designed alike There are the same units roughly in all systems, placed in more or less inaccessible positions to fill up odd corners left over in the general lay-out, and helicopters follow this practice closely ! No special troubles which are peculiar to helicopters have been found

Hydraulic systems in all aircraft are prone to trouble, and so far helicopters have been free from these as they have had no use for such systems There have been no auto-pilots and no retracting undercarriages There is now one American design in use with hydraulic servos to assist the manual operation of the flying controls It is too early to say much about its serviceability but I shall be surprised if it is better than fixed wing aircraft owing to vibration The usual leaks and broken pipes will be intensified unless great attention is paid to proper support for all parts of the system

Instruments on the whole give no more trouble than in fixed wing aircraft, but that is not saying much as they give far more than they ought All instruments are fitted either to keep an eye on the functioning of some other piece of equipment at a distance, or are the direct means of the safe navigation of the aircraft As such they ought to be the most reliable part of the whole machine The fact is that the first category are less reliable than the equipment they are installed to observe, and the second have to be at least duplicated before one can feel safe All this is true of helicopters with the added fact that the specifications used to manufacture and overhaul instruments make no allowance for helicopter vibrations, and the instrument panels in which they are mounted cannot be brought within the fixed wing standards of vibration There is therefore a gap between the two which spells unreliability and unserviceability for the helicopter which cannot be closed by the Maintenance Engineer

There is nothing in helicopter oil systems which is in any way different from fixed wing aircraft The systems give practically no trouble I have had both American and British systems which show the usual fixed wing differences The American systems have rigid pipes with short hose connections, coolers with integral viscosity valves, and inlet and outlet filters in the engines The British systems have heavy rubber flexible piping, separate viscosity valves, and only scavenge filters in the engines It would appear from the results that there is really no justification for the heavy and expensive rubber hoses used in the British systems Another difference between the two which can lead to trouble is the fuel and oil shut-off valves in the British systems The American systems only shut off the fuel Where fuel is shut off in an emergency there is no reason why the oil should not be shut off too, but when there is nothing wrong with the engine, and auto-rotative landings are being made for training purposes, the oil must not be shut off while the engine is still turning This has happened, and it does an engine no good

The only point worth noting in connection with the Radio equipment in helicopters is the microphones It has been found necessary to use throat microphones in place of ordinary ones, or where ordinary ones were used, to have a press-to-speak switch incorporated, so that the cockpit noise could be cut out Apart from this, the equipment is identical with fixed wing aircraft and gives no more trouble Even the Decca equipment has given excellent results and serviceability

The various detail features in which I have praised American design in preference to British does not mean that I am of the opinion that American helicopters are better than British Good as they are, on the whole the Bristol 171 is a better aircraft, but that does not mean that certain details could not have been improved to make them near a maintenance ideal No aircraft has ever been perfect

There is one last aspect of maintenance which I have so far not mentioned This is the question of utilisation This problem is, of course, not confined to helicopters, and it is for this reason that I have left it until the end It is an extremely important part of maintenance There are so many variations in methods used to solve this problem that great care and experience is necessary before a decision is made as to which is the right answer to any particular problem

The maintenance schedule to which an aircraft is maintained gives the list of work to be done or parts to be examined, and the frequency at which it must be done Within that limitation there is a choice of ways in which it can be done

This varies from doing the whole of each check at the time it becomes due, to doing only daily checks, with parts of all the other checks added daily in such a way that the whole of a major check is completed within the time laid down for it to be done

Since the maintenance schedule is a list of work to be done, it therefore represents a fixed quantity of man-hours required to carry it out No amount of planning or dividing it up will get around the basic total of man-hours required to carry it out

Planning will, however, reduce or vary the elapsed time required for the aircraft to be off service in order to carry out the maintenance schedule

Planning can be used to see that each task required in the schedule is done in the minimum time by providing tools, equipment, spares, and freedom to work in an orderly sequence, and without delay Beyond this point lies a danger that over-division of a schedule into small parts can increase the total elapsed time and man-hours required by repeating motions which have already been done This is where so-called progressive maintenance leads to, by removing the same cowlings and inspection covers several times on different daily checks, to do work on different units behind the same panels because there was not time to do all the units behind the panel at one time

Breaking up a major check into small parts which are then attached to successive minor checks has its uses, but must be used with care and experience, and only as a necessity It can only lead to more expensive maintenance It also breaks down the golden rule of leave well alone as long as possible

Local conditions, such as time available for checks, men available, and number of aircraft to do a given task, as well as regular or irregular flying schedules all have a major influence on the way the maintenance schedules are carried out

The first point which must be allowed for is peak loading of the flying programme This is usually of a triple character , daily, weekly and seasonal

The daily peak means that all aircraft are required to be serviceable during the hours of daylight Daily maintenance must therefore be done at night

The weekly peak means that more aircraft are required during weekends than the middle of the week All checks therefore which take longer than a night but less than four days to complete must be done during the middle of the week to make the aircraft available at the weekend

The seasonal peak means that checks with an elapsed time of more than a week should be planned to take place during the Winter months

In attempting to avoid the peaks one runs into the difficulty that the number of aircraft in the fleet, together with the planned intensity of the flying schedule, make it impossible sometimes to avoid a particular peak

To avoid a seasonal peak it may be better to divide the fleet in such a way that some aircraft are laid off for major checks during the Winter to make them available with a clear run in the Summer, the remainder being in use throughout the year This will almost certainly be expensive as units will come off for overhaul before their time This system means that a constant staff cannot usefully be employed throughout the year

The other extreme of dividing all major checks into small parts is not possible with a large fleet, and where aircraft do not return to the same base every night It is quite impossible to work planned maintenance, and it is impossible to provide the units requiring changing at the base where they will be required, especially when weather prevents an aircraft from reaching its planned destination

The cheapest and most reliable system is to do as little as possible, and then to plan each check to get it done as quickly as possible At the same time units should stay on for as long as safety will permit and be left alone

I have touched briefly on so many details, and not even mentioned far more, that it gives one an idea of the vast field covered by a maintenance engineer

This lecture has been read by the courtesy of British European Airways, but any opinions expressed are entirely my own

Discussion

The **Chairman** said that Mr WILLANS had not disappointed us He had delivered an interesting paper, making it deliberately provocative knowing full well that not everyone would agree with everything he had said Such an approach had much to commend it, because, among other things, it opened up the way to a live and stimulating discussion

Mr Willans had referred to two types of equipment and it would be only fair to give some time during the discussion to the representatives of the Companies who were most closely associated with that equipment The major Service Users operated similar equipment, and their representatives should also be given an opportunity to comment He therefore proposed to invite representatives from the Westland and the Bristol Aeroplane Companies, and from the Royal Air Force and the Royal Navy to start the discussion Then the discussion would be thrown open

Mr F L Swain (*Member—Westland Aircraft Ltd*), said that Mr WILLANS had given an interesting lecture, but as Mr McCLEMENTS had commented not everyone would agree with all he had said In that respect he himself had a few points to raise

First of all Mr Willans stated that the component lives of helicopters in his Schedule finished at 250 hours and at this figure he knew of no other vehicle which would travel as far as the helicopter could in this period with so little attention

The point here was that a stage had now been reached in helicopter construction, particularly with his own Company where component lives were gradually being raised to what might be called very realistic figures The tail rotor gear box in both helicopters produced by Westlands had an overhaul life of 600 hours When it was stripped after that period the gear box was in perfect condition and but for the fact that it had to be stripped it would run for a further 600 hours without further attention

His Company had main gearboxes with lives of 480—500 hours and here again on stripping, these gear boxes were found to be in excellent condition and replacement of parts was a rare occurrence It was a matter of crack detection and rebuild and the component went back into service

A large percentage of main rotor head components were overhauled at 500 hours and a small percentage at 250 hours

As he had already pointed out a stage had now been reached when component lives, particularly in the two helicopters built by his Company, had reached a realistic figure which permitted high utilisation In fact the S 51 serviceability was equal to any aeroplane of its size and weight at the present time

Mr Willans in his experience with British helicopters, had obviously met with considerable difficulty in tracking rotor blades and found it an impossible task at times He asked that tracking be abolished With the metal type rotor blade, as fitted to the Westland products, the simple method of a flag was used The blades could be tracked and remain satisfactory for as long as 400 flying hours The metal blade was not susceptible to weather, temperature, and humidity variations Furthermore tracking within $\frac{3}{4}$ in of each blade would give a smooth running helicopter

The servicing of helicopters, be the group large or small, could be made much simpler by the use of the unit change system Under that system the major components were replaced and the components removed and passed into the shops for overhaul With this method the time the aircraft spent on the ground was reduced by $33\frac{1}{3}$ per cent The total man hours required to operate a helicopter unit are considerably reduced because the unit change system permits a steady flow of work for Engineers who would normally have periods of inactivity when the helicopter was serviceable These economies are essential to all helicopter operators