Discussion of Standards of Maintenance

(With reference to requirements for the issue of Helicopter Engineers' Licences)

By W L SHIPPEY

On being asked by Wing Commander BRIE to compile a short paper on standards of maintenance (with reference to the requirements), I accepted, it must be admitted, without stopping to think of what was actually required of me I realised that I was not perhaps as familiar with British Civil Airworthiness Requirements as is expected of an A and C licensed helicopter engineer However, as time was short, the first opportunity was taken to rescue my copy from the old trunk in the loft and to concentrate on Sub Section L 1, Chapter L1—9, the title of which is " Grant and Extension Categories A and C (Helicopters—including Engines) "

Actually, on first glance through, it does not appear to vary in any great degree with the requirements laid down for any other type of aircraft or engine, the main difference, of course, being the fact that a helicopter engineer must obtain both his A and C licences from one examination This will be referred to later In actual practice, however, there is quite a large difference, and in this paper it is proposed to discuss the most interesting items from the Syllabus, then briefly to examine the maintenance standards as practised by the B E A Helicopter Unit Finally, it is hoped to arouse interest once more by a short description of what is by far the most intriguing of the helicopter engineer's duties, *i e*, the diagnosis of defects or rectification of snags

THE SYLLABUS

To revert to Chapter L1-1, Paragraph 2 1 2 states that a licence in Category A will not be recommended except in conjunction with a licence in Category C, to cover the particular type of engine installed I have heard it said, and it has been my opinion in the past also, that a potential helicopter engineer is faced with a much stiffer task than his opposite number in the fixed-wing field, as he has to study engine and airframe and memorise his knowledge of both in one go This may be so on the initial grant of a licence, but I doubt if the examination paper for a Bell 47B Franklin 6V4 engine contains a greater number of questions than does a paper for a Stratocruiser airframe That is as it may be, however, but it remains a fact that it could not very well be otherwise It is known that every helicopter power plant, although of a standard basic design, is specially modified for its job This point, together with the fact that the helicopter's transmission system is so akin to engine practice, makes it most desirable, even essential, that the engineer signing his Certificate of Safety for Flight certifies the engine as well This brings me to two little points on which some doubt still exists

(1) Can two engineers, each holding an identical helicopter licence and who between them carry out a pre-flight check, both sign for the aircraft by one certifying the airframe and the other the engine ?
(2) How far can an A and C licensed engineer dismantle a rotor system and replace parts before calling in an approved inspector ?

https://doi.org/10.1017/S2753447200001712 Published online by Cambridge University Press

With reference to this last point, can the A R B say if and when a syllabus for Category B for helicopters is contemplated ? I am afraid that he has told you beforehand the answer to that

Now for further points from the syllabus

Items 1 and 2 are identical to all other categories *Item 3—Maintenance of a Helicopter* There is only one way to obtain proficiency here, and that is contained in the one and only word—experience The twelve months minimum required by the A R B is on the generous side I am still learning after eight years

Item 4 *The various terms used in helicopter construction and aerodynamics, and the functioning of each component part* *Item 5* *The assembly of helicopter structures with reference to the assembly and functioning of the rotors* The requirements here are so obviously essential that little further need be said except that for each different type of aircraft a fresh course of instruction is necessary, together with several months in the workshops on the overhaul of the various components, in order that the engineer may really get to know his aircraft This also applies to *Item 19* *The principle of operation of the transmission and the inspection and rectification of faults in the system* Little need be said about the remainder of the syllabus, *i e* , electrics, instruments, landing gear, engine, etc , as these are common to all aircraft

There is, however, one item, *i e* , *No 6—The adjustment of the rotors for the purpose of rectifying faults experienced in flight as a result of a defect or maladjustment* Although I do not like the reference to maladjustment, it must be admitted that we have had reports for instance that the stick is too far over to the right and by readjusting " outside neutral rigging limits," the fault has been remedied This matter of defects, however, is always something of a problem, and can be enlarged upon considerably by way of illustration I propose to devote the third part of my paper to this subject

Before passing on to the subject of maintenance, I would like to make one or two observations on the matter of licencing, with an eye to the future

(1) It would be of some help if the power plants of the Bristol 171 and 173 should happen to be similar so as to enable engineers to concentrate on the control system of the 173 In other words a man licensed on the Alvis installation on the 171 should be able to sign for it on the 173

(2) Would the A R B , when compiling an examination paper for the extension of a type of aircraft, consider the omission of questions on standard items of equipment, *i e* , instruments, batteries, magnetos, bonding, etc , in order that the candidate who is already qualified on these details, can apply himself wholly to the mastering of the new aircraft This point is somewhat controversial, however, as there is always a likelihood of one becoming rusty and a little revision does one no harm

And now a suggestion The Syllabus could perhaps include an item on that vitally important part of helicopter maintenance—lubrication A knowledge of the types of lubricants specified and, what is just as important, how often and how much, is really necessary This applies particularly to continuously operating ball and needle races which are not fed with pressure oil and from which the grease is continually thrown out by centrifugal force

Maintenance Standards

The maintenance system as practised by the B E A Helicopter Unit is not different basically from that in operation by either of the Corporations

and the charter companies A system of checks is carried out in the cycles of flying time laid down in a master schedule and approved by the A R B This system, implemented by an experiment on progressive maintenance, was fully described by one or two of my colleagues some two years ago before Members of both Associations, and need not be repeated here except perhaps to refresh the memory on one or two points and to draw a few conclusions It will be remembered that progressive maintenance was carried out during the whole of the Liverpool-Cardiff passenger operation For those who are not familiar with, or may have forgotten what is actually involved in progressive maintenance, it will be in order here to just run over the check system and show how it operates

On the S 51 helicopter, operating on the 5—25—100 hour cycles, we have the following schedule

> Check 1, 5 hours (daily) , Check 2, 25 hours , Check 3, 100 hours , Check 4, 200 hours , Check 5, 400 hours , of flying time

The Checks 1, 2, and 3 are purely maintenance inspections of the complete airframe, engine and ancilliaries, whereas Checks 4 and 5 are component changes whereby major components are removed for overhaul and replaced by overhauled parts which have been given a new life There are further checks at multiples of 400 hours for such items as fuel tanks, undercarriages, the various electric motors, etc , also, the engine has a life of 700 hours Broadly speaking, every component is changed once or more times during each 1200 hours period of flying time

Reverting to the progressive portion of the maintenance schedule, *i e* , Checks 1, 2, and 3, it will be remembered that at each Check 1 there was carried out part of Check 2, and part of Check 3, so that at the end of every 25 hours of flying, the Check 2 cycle had been completed, and likewise at the end of every 100 hours, the Check 3 cycle Whilst this method had the disadvantage of using up more man-hours on actual maintenance, it was found to be possible to utilise the aircraft continuously, thus obviating the need to withdraw it from service for periods of from 1 to 3 days to carry out the 25 and 100 hour inspections In spite of the somewhat costliness of this system, it must be remembered that engineers were available at both the Cardiff and Liverpool ends of the run anyway, and as the aircraft had a 4 or 5 hours stop at each point, it was better to duplicate a certain amount of work in the removal of cowlings, etc , than to keep the engineers on waiting time Also, it must be pointed out that the job was never rushed, and the record of freedom from mechanical failures at this time was of the highest level

A modified form of progressive maintenance has been a feature of the Birmingham passenger and freight services whereby only the Check 3 (100 hours) inspection is split up into four parts, one of which is carried at each Check 2

For future operations, however, especially where an operator is employing much larger fleets of aircraft on high intensity services, it is doubtful if there would be any advantage at all in the progressive system, unless there were scheduled turn-rounds away from base of 3 hours or over, which would not be likely, as the revenue/ton miles, etc , would add up in this case to quite a lot in the course of twelve months

And now for one or two observations on points which have occurred to me as needing consideration It is laid down in the master schedule that a Check 2 is to be carried out at every 25 hours flying time or 14 days calendar time, whichever comes first It is somewhat irksome, not to say wasteful, to have to carry out a Check 2 at 23 flying hours, just because the 14 days has elapsed, and to have to carry out another one on the following day in order to complete the progressive Check 3 Surely it does not matter if there are 4 or 5 or even 6—25 hour inspections carried out during the 100 hours, which is usually the case anyway, although, as will be noted, at very erratic intervals Briefly, there seems room for improvement here

The second point is on the matter of component lives Considerable loss of maximum availability would be avoided if a little thought and effort could be given to the keeping " in step " of the flying hours of the various components To illustrate what is meant by this, I will quote the case again of the S 51 The Bell is not as guilty in this respect The Check 5, or 600 hour inspection, needs practically a complete strip down of the aircraft, during which all the gearboxes, clutch and fan, tail rotor and main rotor head are removed for overhaul At 700 hours there is an engine change necessitating a further partial strip down, although it must be admitted that this is due to an increase in engine life granted some six months ago It would, however, appear possible to arrange things a little differently by concentrating on the 30/120/240 hour instead of 25/100/200 hour cycles The engine change could then be carried out at the Check 5 at 720 hours, which would, incidentally, keep in step with the life of the flapping links (720 hours) and hub (480 hours), both expensive items We now have sufficient experience to know that the additional 40 or 80 hours which would be gained between overhauls on the head or gearbox would in no way affect safety, and is approved by Sikorsky Aircraft It is not necessary to state that increase in the overhaul life of components is always something to be aimed for

Touching once more on the standard of maintenance as practised by the Helicopter Unit, it is interesting to note a slight modification in the system, which has been put into effect since last August It was up till that time, and still is in the remainder of the Corporation, the practice to carry out all the work of maintenance by skilled engineers, some of which are licensed Their work was given a hundred per cent inspection by full time inspectors, all of whom were invariably licensed, although this fact was not strictly necessary under the terms of the firm's inspection approval, as licensed engineers were only essential for the final signing out of the aircraft and engines for flight Now, however, at Gatwick the use of full time inspectors on the maintenance side has been dispensed with, licensed engineers being employed to carry out the actual operations, to supervise unlicensed personnel, and to sign for their own work This system is quite in order as far as the A R B are concerned, and has something to be said for it in view of the fact that it makes more efficient productive use of all available labour

When it comes to dealing with components on overhaul in the workshops, however, a rather peculiar situation arises All work must be covered by approved inspectors, who need not be licensed, as there is no ' B ' or ' D ' licence in being to cover helicopter overhaul Although the work of overhaul requires an equal, if not higher degree of skill, it can be certified by a virtually

unqualified inspector whilst the licensed engineer cannot, in turn, certify anything that is not strictly under the terms of his A and C licence The writer would like to see something in the nature of a Board of Trade certificate replacing the B licence which could serve as an Inspector's qualification It would have to be unrestricted in the general sense to one or more types of aircraft or helicopter, and the examination could be based on the information contained in the A R B Inspection Procedures for Civil Aircraft

Defect Diagnosis or Trouble Shooting

The material for this part of the paper has been accumulated over a period of seven years of operation and maintenance of five types of helicopters, *i e* , R4, R6, Bell 47B3, and Bristol 171, on experimental flying, and the S 51, on which by far the largest number of hours have been flown both experimentally and operationally

General Observations

It is perhaps better to draw attention to the reliability of the helicopter at first in order to emphasize that the number of defects encountered from day to day by no means reach alarming proportions Whilst the need for improvement is always there, it is a fact that the actual failure which can be attributed to the helicopter being what it is, *i e* , its rotors, transmission, horizontally mounted engine, controls, etc , is amazingly small The majority are faults in ancilliary equipment, electrics, instruments, radio, etc , and could occur in any aeroplane

It is very difficult to analyse the different defects under classified headings, but in order to convey some idea of what is in the writer's mind regarding this matter, it is proposed to cover the field in order of importance as affected by safety precautions, maximum availability of aircraft, man-hours involved in rectifications, component life, etc It will be noted that most of the types of snags have an opposite For example, as well as the heading of defects which are recurring, there will be a heading for defects which are not recurring and which are only isolated cases One or two examples of each kind will be described, the methods of diagnoses and rectification, and what further action was considered necessary

Vibration

This trouble has been one of the chief sources of worry to helicopter engineers and operators, and has been discussed at length from time to time in various papers The frequencies of vibration, *i e* , low medium, high, once per rev , three per rev , etc , give some indication as to their origin and Sikorskys and Bells have published trouble shooting charts which have proved to be of some assistance in tracing the source of vibration and effecting a remedy The main concern of the maintenance engineer, however, is to be able to form a rapid and accurate opinion as to the seriousness of the trouble It is here that the pilot in making his report can provide valuable aid by giving a concise and accurate description of the symptoms of trouble For instance, if a pilot reports that he has a once per rev vibration that is becoming progressively worse, it may be caused by a malfunctioning damper which can be cured by pumping or priming If this does not effect a cure, something much more serious should be looked for such as the failure of one or more of the flapping link needle bearings

There is no hard and fast set of rules, however, which can be applied in all cases, and past experience has shown that it is only by a sometimes tedious process of trial and elimination that the faulty part can be brought to account Even then there have been cases where a perfectly serviceable rotor head or set of blades have given continual trouble on one aircraft and have been quite acceptable on another and in desperation it has been decided to rob one machine in order to prove a theory on another Other causes of roughness on the S 51 have been faulty tracking, backlash in controls, or brinnelled bearings These invariably show up as stick stirring and are more or less obvious They can usually be detected by test flying or close visual inspection

The chief points to be considered when assessing the seriousness of vibration are as follows

(*a*) Has the trouble suddenly developed or has it been gradually getting worse over a period of flying ?

(*b*) Has the aircraft just come off overhaul or is it half way between two major inspections ? If the first is the case it may be due to faulty assembly of a component

(*c*) Is the pilot reporting the defect familiar with the " feel " of the aircraft in question or has he just changed over from a period of flying on another of the same type ?

To sum up, it will suffice to recall that there is at least one black sheep in every batch of vehicles turned out by manufacturers, either railway engines, aeroplanes, or helicopters, and it is a known fact that no matter how many times the machine is rebuilt it is always looked upon by its crew as something to be left in the hangar if there is an alternative available

The Bell 47B3 is usually less problematical than the S 51 If there is a fuselage thump it is pretty certain to be blades out of balance or alignment Stick stirring is more often than not due to the need for tracking or irreversible levers too slack, whilst a kick in the fuselage can be traced to the stabiliser bar dampers being adjusted too tight and not compensating for gusts

We have had only one instance of roughness in the Bristol 171 and that was cured by tracking the blades Indeed, one of the most outstanding qualities of this aircraft is its remarkable smoothness—probably due to the greater flexibility of the rotors and its higher rotor r p m Before leaving the subject of vibration, it is of interest to note with regard to tracking that what should result from applying certain theories does not always work out in practice There have been cases with certain sets of blades where the action of adjusting one blade tip to fly 1 or $1\frac{1}{2}$ inches out of track has produced a smoother aircraft

Defects occuring in the Transmission System

The number of snags encountered in the gear boxes, clutches, fans, drive shafts, and couplings, have been conspicuous by their absence This applies to all our aircraft Apart from one spell of spinning bearings in the Bell tail boom and one case of a seized clutch and one of a broken oil pipe in a Sikorsky gear box, there have been no others worthy of mention Indeed, the number of modification kits pushed out by Bells have necessitated strip downs far more frequently than for any other reason

Engine faults

We have had to contend with no more, or no less, than the normal number of engine snags In fact, we have in only one case had to remove an engine that was not time expired, which is more than can be said of some fixed-wing installations The following are among the chief troubles we have experienced, and constitute an average cross section of engine faults encountered by any operator

(*a*) Magneto bearing failures due to their being assembled with incorrect types of grease, *i e* , grease not standing up to temperature

(*b*) Momentary engine cuts due to carburettor icing

(*c*) Foreign bodies in the air intake damaging impellor and, in one case, damaging a piston

(*d*) Ignition faults on Sikorsky and Bell due to various causes giving r p m drops (mag drops) and radio interference

(*e*) Oil leaks which have been difficult to trace, eventually being found to originate in rocker shaft glands

Other Kinds of Defects

Most of the other troubles we have encountered have recurred in spells and in some cases have been obviated by modification action, wherever this is possible Many manhours have been used up in the rectification of cabin heaters and rotor brakes, both weak points on the S 51 These faults will not ground a machine or cancel a service, however, and engineers are entitled to use their own discretion in the event of a last minute failure of this nature cropping up Whilst faulty fuel gauges, of course, are not accepted, it is comforting to know that it is easy for a helicopter pilot to force-land if he happens to suspect his fuel supply

Conclusions

There is sometimes a tendency in the interests of speed for maintenance engineers to remove complete components for replacement in the event of trouble Closer investigation could in many cases reveal that the fault lay in some very small part of the component or perhaps in the need for slight adjustment It is stressed, therefore, that to avoid cases of engineers having cured the trouble without knowing the cause, all information from investigations should be made available to maintenance personnel It must be remembered, of course, that the engineer may be limited by the scope of his licence

It is conclusive that the overhaul life of some of the less important components could be extended and in some cases doubled with beneficial results I quote a recent case of an aircraft being grounded for a fortnight because two replacement auxiliary fuel pumps both leaked, whereas the one that was removed, time expired, was functioning perfectly Normally these items are only functioning for a minute or so when starting the engine

In conclusion, it is desired to express grateful acknowledgement to British European Airways, to Wing Commander Brie, and the members of the B E A Helicopter Unit for the assistance and facilities given in writing this paper Also, I should state that the opinions expressed are my own and have no official significance

MR SHAPIRO Thank you, Mr Shippey, for a most interesting Paper I am sure this will give us much ground for a good discussion I shall now call upon Mr H E LE SUEUR to deliver his Paper on Airworthiness of Helicopters and Lives Mr Le Sueur has, since June, 1949, been a Design Surveyor at the Air Registration Board and was engaged in investigating the airworthiness of rotary wing aircraft, the S 51, Bristol 171, the Firth project, the Hiller and Bell helicopters From 1947 to 1948 he was Assistant Lecturer at the Medway Technical College, Gillingham Prior to 1947 he was in the Stress Office of Short Brothers

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Airworthiness of Helicopters and Lives

By H E LE SUEUR, A F R Ae S

When asked if I would contribute to this afternoon's discussion I wondered what there was that I could say in such a field as Standards of Maintenance Coming from the Design side of this vast organism the Aircraft World and having had very little to do with the maintenance of aircraft, let alone helicopters, in what way could I contribute when there were so many other far more knowledgeable, capable and experienced people and, in any case, when were the Design side concerned about maintenance of anything, their heads always in the clouds, hovering at Mach numbers of one or above with a safety factor of 1 5 ?

However, I wanted to say something, but then how could I say it ? Having read and re-read the proposed title of the discussion, I eventually came to the conclusion that there was a possibility that those engineers requiring helicopter licences should know how such things as " what an Airworthiness Authority is likely to consider to be a safe scrap life " are obtained

I would therefore crave your indulgence whilst I try to formulate a procedure which, in my opinion, might satisfy some fictitious Airworthiness Authority—I will not say the A R B , for although this discussion is being led by that body, of which I myself am an employee, I must say that the opinions given here are my own and not necessarily those of the A R B

The Conversation The problem then is this the Helicopter Designer or Engineer, with the aid of his staff, has produced a helicopter He has proved that it flies, hovers and does everything that he wanted it to do In fact, it is an experimental success However, the powers that have sponsored his design now look for some return for their financing of the project It is therefore necessary to sell the product or, at least, others of similar design Everybody should buy it It will revolutionise the whole of transport, both public and private BUT the Airworthiness Authority say " STOP, you dan't throw lumps of metal around the sky, slung under whirling pieces of machinery—it's not safe ! "

The designer says " It is safe and, to prove it, I am prepared to fly the machine "

https://doi.org/10.1017/S2753447200001712 Published online by Cambridge University Press