Discussion of Standards of Maintenance
(With Reference to Requirements for the Issue of Helicopter Engineers Licences)

Four Lectures presented to the Helicopter Association of Great Britain at the Royal Aeronautical Society, 4 Hamilton Place, London, W 1 , on Saturday, 7th February, 1953

In the chair J S SHAPIRO, Dipl Ing , A F R Ae S

Introduction by the Chairman

Ladies and Gentlemen As you all know we have a series of lectures and a discussion this afternoon dealing with standards of helicopter maintenance

I will first ask Mr McCLEMENTS to deliver his Paper Mr McClements is so well known to you that I need hardly introduce him He is a graduate of the Royal Technical College of Glasgow and at present he is at the Head of the Department of the Ministry of Supply devoted to helicopter research and development , prior to that he was known to most of you as the Chief Experimental Engineer of the B E A Helicopter Unit

Maintenance—Some of its Broader Aspects and Implications

by A McCLEMENTS, A R T C , M I Mech E

It is a good thing to occasionally lift our sights from the job in hand and focus our attention on the broader purpose of our actions For example, if we ask ourselves what the purpose of maintenance is, we might answer that it is to keep the equipment we are using in a condition which does not fall below a certain standard In the narrow sense, a definition of some such sort would pass, but surely, if we accept it as a complete answer to our question, we are really saying that maintenance is an end unto itself This, of course, is quite ridiculous because maintenance is not just done for the fun of it, rather its purpose is to carry out certain work, in close association with quite different types of work, so that the integrated effort enables the equipment in use to satisfactorily perform the task in hand—in the case of a commercial airline, this would be to earn money by giving the best possible public service Some such reply I think would be a more complete answer to our question

By this illustration I think you will appreciate the point I am trying to make which is that the engineering effort in an operating concern, however good it may be in respect of its detailed labours, is not good enough unless it arranges the overall result of its actions to suit the organisation as a whole With this thought in mind, I am going to try and indicate some of the points which seem to me to stand out to guide the maintenance engineer who is endeavouring to fit his actions into the broader pattern of his organisation in the interest of overall efficiency

https://doi.org/10.1017/S2753447200001694 Published online by Cambridge University Press

The Broad Argument

Getting right down to fundamentals, let us enquire how a commercial aeroplane spends its " life " Presumably, the main parts of its " life " are

(i) Periods of revenue flying = A
(ii) Periods when the machine could be engaged in revenue flying, but is not = B
(iii) Periods when the machine is not available for revenue flying because it is being maintained = C

Hence, " life " in calendar time can be expressed roughly as

$$A + B + C$$

Examining these qualities, it is obvious that B is entirely the concern of others in the organisation and it is in no way dependent on the engineering effort Hence, we can dismiss quantity B by saying that it is nothing to do with us, and concentrate on quantities A and C If we do this we can now consider " life " in the absolute sense as $A^1 + C$ In other words, we are saying that for C hours of grounding time spent on maintenance, we are offering A^1 hours of flying time and it is no concern of ours if the A^1 hours are flown intensively or spread over a long period Hence, the absolute " life " of the machine is

Available periods for revenue flying (A^1) + Periods when revenue flying is not possible because the machine is being maintained (C)

Now one of the things in which the operator is interested is the fraction of the aircraft's " life " which is available to him for revenue earning I call this the Utilisation Potential Factor (U P F) because it is the factor which gives a direct measure of the very best utilisation potential which the engineering group makes available

Clearly

$$\text{U P F} = \frac{\text{Available Periods for revenue flying}}{\text{Available Periods for revenue flying} + \text{Unserviceable Periods}}$$

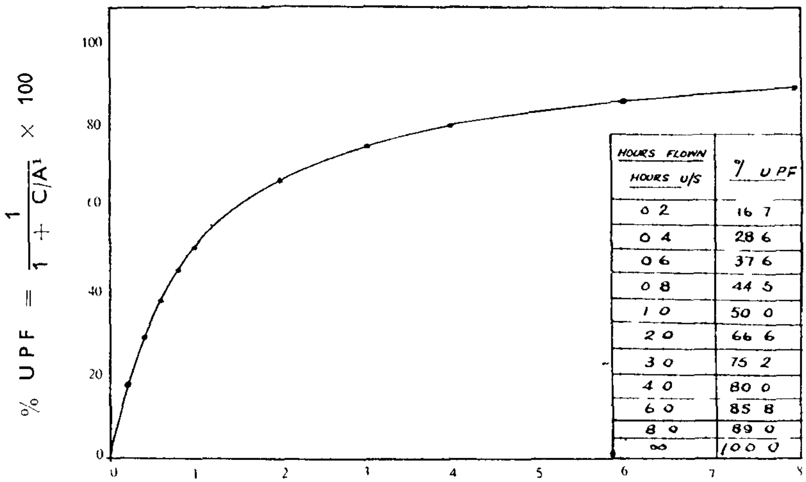
$$= \frac{A^1}{A^1 + C}$$

$$= \frac{1}{1 + C/A^1}$$

I have plotted this relationship in Fig 1 from which you will see that below a value of the A^1/C ratio of about 3 (which means 3 hours flying for 1 hour grounding on the average), small improvements in the grounding time, not associated with curtailment of the flying time you are offering, result in quite big improvements in the possible utilisation Above this figure (which corresponds to an available annual utilisation of some 6 500 hours) the trend is not so marked

Hence, we can say that, until the maintenance engineer can offer much higher annual utilisations than he now offers, anything he can do to keep down the standing time associated with maintenance has an important effect on the earning potential of the machine This, of course, is only a generalisation and I cannot just leave it at that Up till now, we have been considering only one machine , further I have not paid any real attention to the economic implications of what we are discussing

The operator, in fact, is not concerned only with one machine, but with a fleet which at any time comprises aircraft engaged on revenue earning and reserve aircraft He obviously wants the maximum number of his fleet engaged on revenue earning and the minimum number engaged in a reserve capacity By just offering him the lowest possible accumulated standing time over a period, are we doing enough to keep down this number of reserve machines to a minimum ? The answer to this question is " not necessarily " because in a block of time, we may have periods of grounding of very irregular lengths—some very long and some very short If such is the case, reserve aircraft must be held available to stand in during the long



HOURS FLOWN / HOURS U/S	% UPF
0 2	16 7
0 4	28 6
0 6	37 6
0 8	44 5
1 0	50 0
2 0	66 6
3 0	75 2
4 0	80 0
6 0	85 8
8 0	89 0
∞	100 0

Relationship between ultilisation potential and ratio $= \frac{A^1}{C}$

periods of grounding On the other hand, if our total time of grounding in a block of time is made up only of a lot of short periods, it might be possible to avoid the planned use of reserve aircraft completely Obviously the latter condition is the ideal and the one which the maintenance engineer should endeavour to achieve, provided on balance its achievement is an economic proposition

Now, the overall economic implication of these arguments is, I think, fairly straightforward Fundamentally, we can say that the achievement of improvement in standing time over the complete maintenance cycle is only worth while if any extra cost which it involves is more than offset by the profits which the aircraft can make in the extra flying time offered Also, the achievement of a regular cycle of only short periods of planned grounding time throughout the maintenance cycle is only worth while if any extra cost which it involves is more than offset by the saving in reserve aircraft costs

Summarising, I am suggesting that the maintenance organisation might profitably aim at

(i) cutting down the total standing time associated with the whole maintenance cycle,

(ii) manipulating the maintenance cycle in such a way that it comprises only short periods of grounding time,

and (iii) arranging its methods such that (i) and (ii) can result in an attractive economic balance

Methods

If we consider each of the above qualities in turn, we can continue this argument on the following lines

Duration of total standing time associated with maintenance cycle

The duration of the total standing time, whether in practice it consists of lots of blocks of short periods or a mixture of blocks of long and short periods, will be influenced to a large extent by the total amount of work to be done—in other words, by whatever is called up in the maintenance schedules The duration of the standing time will also be directly influenced by the facility with which the work can be done, *i e*, by the lay-out of the machine and the accessibility of its parts

Hence, if we want to cut down the duration of the standing time as much as possible, it is clearly necessary to prune the maintenance schedules such that, when the aircraft in question go into service, the schedules are truly realistic , it is also essential that the machine should have been designed for easy maintenance

The contents of the maintenance schedules and the ease, or otherwise, with which maintenance can be carried out rests largely with the manufacturer of the equipment However, one wonders if the manufacturer by himself is able to strike the best compromise in respect of these quantities Personally, I do not think he is, because in general he is not intimately concerned with operations You, the maintenance group are, however, so I feel that one of your broader responsibilities is to co-operate closely with the manufacturer when his project is in the early stages of design Further, in doing this, I suggest that you keep an eye on such aspects as the following

(i) The effort being devoted to the establishment of the " lives " of component and assemblies ,

(ii) The amount of attention being paid to installational detail ,

(iii) The care being taken to keep systems simple ,

(iv) The safety devices being introduced—are they necessary , are they likely to be a source of trouble in themselves ? ,

(v) The disposition of ancillary equipment—can it be got at easily ? ,

(vi) The trouble being taken to make refuelling, oiling and greasing easy ,

(vii) The skill required for the assembly of components—is assembly a specialist job requiring labour of exceptional skill—must it be so ? ,

One can keep adding to this list, but the above items should be sufficient to illustrate the type of contribution you can make by co-operating with the designer

The manipulation of the maintenance cycle

The maintenance cycle will say what must be done and the stages in flying hours when it must be done In practice, what has to be done will include, *inter alia*

(*a*) The addition of fuel and oil after stated intervals of flying,

(*b*) Cleaning of airframe and cabins after stated intervals of flying,

(*c*) Greasing,

(*d*) Visual inspection of each part of the aircraft after stated intervals of flying,

and (*e*) Removal, overhaul and replacement of components when their "lives" are up

If the above work is done in an approved manner, it will not be difficult to demonstrate that the aircraft, as a whole, is always in an airworthy condition, and C of A renewal will be granted on this basis without appreciable further work when application is made, *i e*, C of A renewal will be on a "progressive" basis

The manner in which you decide to do the above work is a matter of choice You have at least two alternatives, *viz*

(i) The maintenance cycle will state that after periodic intervals of flying, certain blocks of work must be done These blocks of work will be of the type (*a*) to (*e*) above, and they will recur several times over the complete cycle Now, the work which the cycle states must be done after, say F hours flying, may be *all* done at F hours flying, the aircraft being grounded for the time required for *all* of the work to be done

(ii) Instead of doing all the work which must be done after F flying hours at F hours, it might be better to do some of this work before F hours, thereby cutting down the required grounding time at F hours to the interval necessary to do only what is left over

Since the periods between items (*a*), (*b*) and (*c*) above are likely to be of short duration entailing short periods of grounding, it is likely that it will only be worth while operating items (*d*) and (*e*) in the way mentioned in the latter alternative which, of course, is quite a permissible way, provided, during the next period of F hours flying, the same work is brought forward by the same amount If we consider F broadly, it will be appreciated that this "evening out" process is capable of very wide application

If we now consider what kind of life a fleet of aircraft flying at a very high utilisation rate might have, it would seem likely that public demand would not require periods of continuous flying over 24 hours per day, followed by periodic intervals of several days when no flying was wanted Instead, one might anticipate a fraction of each 24 hours when most of the flying was required and during the remainder of the day flying at a very reduced scale, but the daily fluctuation would go on continuously in a seasonal way Thus, we might expect periods during each 24 hours when maintenance could be done without affecting operational demands

If this assumption is correct, the second of the above alternatives is the more attractive, because it aims at spreading the grounding period dictated by the maintenance cycle into a number of blocks of time in such a way that *all* maintenance work necessary can be done *when the aircraft is not required for revenue flying* Theoretically, there is little difference between the amount of work required, and the overall standing time required between the two alternatives The main differences lie in the facts that the latter, which I call the " progressive system of maintenance "

(i) gives the operator a much higher degree of flexibility in doing his flying at a time which is operationally convenient to him Thus, his aircraft reserve holdings can be reduced

and (ii) provides scope whereby the work associated with maintenance can be spread uniformly, thereby cutting down labour standing time

The choice of method for operating the maintenance cycle will depend on the operational commitment In general, alternative (i) above is probably the more suitable where flying is at a relatively low rate and of a non-regular nature Alternative (ii) is well suited to cases when flying is done to a regular schedule, based on a known future programme entailing high utilisation, provided the area of operations is of such a size that the work stages necessary can be kept under control

Economic Balance

Having, in association with the manufacturer, equipped yourselves with aircraft which, from the maintenance angle are readily accessible and which have truly realistic maintenance schedules you have gone a long way towards making the economic balance look favourable It now remains for you to use your labour force efficiently

It seems to me that the most likely way of achieving an efficient labour effort is to employ the labour force at a steady load continuously and not in a series of high activity periods followed by periods of inactivity This follows since, for the same annual output of work, the " peak load " method entails the use of far more men because the labour strength must be related to the peak and not to the mean condition Assuming that this philosophy is sound we see, then, that by manipulating the maintenance cycle in the " progressive " way, we are going in the right direction towards the achievement of an attractive economic balance because we are evening out our effort and thereby making it possible to utilise our labour force in an effective way

Concluding Remarks

I am fully aware that the overall implications of maintenance are in practice complex and difficult to assess because, for one reason alone, they become confused with operational considerations, notably traffic and scheduling Hence, in this paper, I have made no attempt to carry out an exact analysis but rather to highlight some of the more obvious and important considerations which, in general, can be taken on their own merits In attempting some years ago to divorce maintenance from the other factors with which it tended to become confused, I found it convenient to invent the term " Utilisation Potential Factor " This factor has been used to-day to take maintenance on one side for the purpose of discussing some of its implications

While the ground we have covered is quite general, I think some of it has a special place in-as-far as the helicopter engineer is concerned, because

(i) the helicopter is made up of many parts which are amenable to this "progressive" type of maintenance,

and (ii) in general, the helicopter is likely to operate within the boundaries of relatively small areas Hence, it is likely to remain within striking distance of its engineering base thereby lending itself to the close control which "progressive maintenance" requires

Of the points which we have considered "progressive maintenance" may well have the most direct effect on the detailed labours of the maintenance engineer because its satisfactory working is completely dependent on his flexibility in dealing with the extra records which result Please do not be "put off" by this remark because the record system need not be over complicated

In closing, I would like to point out that the practical application of the progressive system of maintenance has been found not to be over formidable The system was used during the British European Airways Liverpool Cardiff Helicopter Passenger Service—indeed it made the Service possible—and, thanks to co-operation and flexibility of the engineering staff, it worked very well

I am indebted to the Chief Scientist, Ministry of Supply, for allowing me to present this paper The arguments put forward and the views expressed are entirely my own

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Mr Shapiro We thank Mr McClements for his very interesting Paper giving the general background of maintenance and I shall now ask Mr J H Spaull to deliver his Paper which deals with some of the human aspects of maintenance, the licensing of helicopter maintenance engineers Mr Spaull is a Senior Surveyor in charge of licensing with the Air Registration Board since November, 1942 He has been with that Organization ever since its inception in 1937