rapidly changed, he will have greatly enhanced the Operator's chance of a " Profitable Utilisation Potential " in his helicopter.

With the little time left to me, I would like to emphasize one more point, this being the *Mutual Responsibility of the Designer and the Operator.*

To quote an adage, " Prevention is better than Cure," I often think of this when a modification is issued to alter the aircraft to facilitate servicing and maintenance in the field. The point I wish to make is that it is the mutual responsibility of the Designer and the Operator to have in their teams some person who is capable of *foreseeing* maintenance difficulties on the drawing board. In this way they can eliminate the early maintenance " headaches " and consequent modifications which do so much harm to all concerned. The consequent loss of earning capacity is a luxury which we cannot afford. Such a mutual maintenance responsibility will benefit the helicopter movement as a whole.

In closing, I would firstly like to express my thanks to the Helicopter Association of Great Britain for honouring me by asking me to read this paper. Secondly, I take this opportunity of thanking the British European Airways Corporation for allowing me, a member of its staff, to prepare it and base it on the work with which I have been closely associated over the last three years.

PAPER

By MR. A. BRISTOW (C.B. Helicopter Hire Limited).

THE CHAIRMAN : Our first paper was read by a speaker intimately concerned with the work of a regular schedule operator. It is our wish to have our second paper read by a speaker associated with non-regular scheduled operations, since we felt we might thus have an opportunity of ventilating differences in operating techniques. We had hoped to have a paper by a speaker employed by Messrs. Pest Control Limited, but unfortunately their representative is overseas and unable to be with us today. Mr. BRISTOW has very kindly offered to present at short notice a paper based on his recent experience in the non-regular scheduled operation of helicopters, and it a great pleasure for me to accept his offer on behalf of the Association. Mr. Bristow is well-known to most of us, but for the benefit of those who are not familiar with his work, I would mention that he was introduced to the helicopter during his service in the Royal Navy. Subsequently, he was a test pilot at the Westland Aircraft Company, and he then did good work with the original Sikorsky S.51, and later with the Westland Sikorsky S.51. His work included demonstration flying, Certificate of Airworthiness testing, and he played a leading part in the rescue of the Wolf Rock Lighthouse and the " Hare and Tortoise Project," which you will remember linked London and Paris by the quickest possible means, using jet fighters and helicopters. Mr. Bristow was, until recently, Technical Manager for Messrs. Helicop-Air Limited, in Paris, and in that capacity he operated the helicopter in Europe and as far away as Indo China.

HELICOPTER MAINTENANCE FOR THE NON-REGULAR SCHEDULE OPERATOR

By ALAN E. BRISTOW, A.R.Ae.S. (*Member*).

Let me make it quite clear at the beginning that I am not speaking as a paid agent or employee of any Hiller operator or representative, and that what I have to say is an expression of my personal opinions. They are based on over 2,000 hours of commercial operations with the Hiller 360 all over Europe, North and West Africa, during the past twelve months, when as Technical Manager of Helicop-Air (Paris) it was one of my responsibilities to ensure the efficient maintenance of three and sometimes four machines on high utilisation work.

Our efforts were directed principally towards such profit-making enterprises as insecticide spraying and dusting of cultivated crops, forests, swamps and river beds ; the operation of a pilot and engineer training school ; publicity flying for large manufacturing firms ; a non-schedule passenger service ; and sales demonstration.

These operations were frequently in widely dispersed, remote and inaccessible places where maintenance installations and workshop facilities were non-existent. Some of our operations have been under tropical conditions, where fine sand and dust particles were our biggest enemies, not humidity and temperature

It was a scratch start, nobody in Europe had ever attempted a helicopter operation on a " *commercial basis* " ; and we had no trained engineers or pilots to form a nucleus of experience, but everybody was enthusiastic, ready to learn and work hard and long, sometimes under difficult conditions and often with inadequate maintenance equipment, but we were not hampered by union regulations of the 40-hour week.

Given all the good luck, determination and effort in the world, such an enterprise could never have become profit-making had the flying equipment not proved simple to maintain, reliable in hard and continuous work, extremely versatile and, relatively speaking, inexpensive to operate.

I believe the Hiller 360 to be vastly superior in every way to any other type of helicopter in commercial service today. With this challenge before the Meeting I am looking forward to keen criticism from the British manufacturers represented here today.

In the first three months of our four-ship operations it was our policy to have a ground engineer present at all flights. This, although costly in one way, served as valuable field training for our four engineers, who quickly learned to appreciate what was required of the machines.

As the activities increased, 100-hour inspection began to come round fairly frequently, and during a period of 10 days three machines came up for 100-hour inspections, which took on an average 34 man hours per machine.

It was decided, therefore, to experiment by entrusting what little day-to-day field maintenance there was to the pilot and to achieve minimum " out of service " time the two most experienced engineers were assigned to the base maintenance shop.

This system worked extremely well and it was proved that the services of a full-time engineer were only necessary at 100-hour inspections and major overhauls, provided the pilot has done our six-weeks maintenance course which we ran concurrent with the flying training.

To avoid adverse criticism from A.R.B. and M.C.A., let me hasten to add that I do not advocate pilots signing out ships when fare-paying passenger work is involved, even though the pilot may in point of fact be a licensed aircraft engineer.

During the first six months our labour and material requirements were considerably higher than those reported by contemporary American operators of the 360, who quoted one to two maintenance man-hours per flight hour and a total material cost of 1.68 per flying hour.

Our initial maintenance man-hours per flight hour was in the region of 5 : 1, but in the last five months of operations we were averaging 2½ man-hours/flight hour, which was inclusive of man-hour figures spent on frequent dismantling, tracking and re-assembly of machines after air shipment outside Europe. This, I consider, was still high.

The reduction in maintenance man-hours was attributed to such factors as :

1. Increased experience of the ground engineers and the mechanical aptitude of the pilots.
2. The immediate availability of maintenance equipment and spare parts.
3. The amount of progressive maintenance that our dispersed operations enabled us to do.
4. The management's ability to plan operations well in advance and yet remain within the scope of the organisation's ever-growing technical skill.

Whereas the maintenance man-hour figures have been directly proportional to items 1—4 above, the material costs between each machine have never showed any similarity. The material costs were dependent to some extent on items 1 and 2 and were related indirectly to the others, but they were far more influenced by such factors as :

1. The date of origin of the machine and the number of modifications that had been incorporated at the factory.
2. The type of work on which each machine was employed.
3. The climatic conditions under which each machine was operating.

To illustrate how much these factors increased the material costs, I have made a comparison between our oldest machine (and this is determined by its date of construction) which has only flown 420 hours in twelve months, and our latest 1950 model which, although delivered in Paris only four months ago has since flown over 300 hours in France on passenger-carrying services and publicity work. The old machine, on the other hand, was employed exclusively on two of the most strenuous types of work, viz. : crop spraying and dusting, and pilot training, where protracted use of high power and rough handling were common features.

The 300-hour inspection on the old machine required 120 man-hours and cost 340 dollars in engine and airframe part replacements. It should be mentioned that for helicopters employed on agricultural work, engine major overhauls were done at 300 hours, but for all other work major over-

hauls fell due at 600 hours. The total material cost over the 400-hour period on the old, partially modified machine, represented 2.30 dollars per flying hour, which was high in comparison with the operations. The 120 man-hour figure was considered very creditable as this was the Company's first 300-hour engine inspection done by its own personnel. The high airframe material cost was to be expected as it was inclusive of minor repairs from a student accident, and the incorporation of several modifications, however, it was added to by damage being done during dismantling of certain components by an inexperienced engineer.

This latter observation brought home to me a lesson I had learned and long since forgotten from R.4 days. Dismantling of components just for the sake of dismantling or because it is called for in a manufacturer's schedule is, in my opinion, unwarranted and unjustifiable in the absence of evidence of wear, erratic operation or pilot's complaints. It was our experience that this practice usually did more harm than good to components which functioned perfectly prior to dismantling.

The sharp contrast in maintenance man-hours and material costs on the 1950 model were most encouraging and I believe these figures were indicative of the real operating conditions.

Taking the 300-hours period as the basis for this comparison, the man-hours figure on the new model was 25% less than on the old machine and the total material cost was one-third of that on the old model, which represents 40c. material cost per flying-hour.

Again the human factor, in this particular case the mistake of a ground engineer, was responsible for 80% of this material cost.

Excessive wear in the free-wheeling unit on the new ship, which meant a new assembly, was traced to faulty installation by one of the student engineers who had taken it apart at 200 hours just to have a " look see." On the old ship at 400 hours this component was literally " as new."

The moral of this story is that an experienced engineer is worth his weight in silver dollars and sleeping dogs are best left to lie.

Furthermore, the man-hour figure on the 300-hour inspection of the new ship was reduced by the fact that the engineer responsible for this helicopter had been able to follow a schedule of progressive maintenance and that no modifications were outstanding—they had all been done by the factory prior to delivery.

The factor most responsible for the reduction in material and labour costs on the new machine was, I believe, the manufacturers' ability to perfect rapidly his product coupled with close and fast technical liaison between factory and operator. A special department was created in the Hiller Company to study operators' problems and recommendations, not only theoretically, but also practically in field operations and to test new equipment. Through his relations with this department the operator became an integral part so to speak of the manufacturer's organisation instead of just a file classification in the Commercial department, who " milked " him as much as possible and wrote long evasive letters which meant £.s.d. from the letter heading to the signature.

So it came about that the recommendations of this technical liaison department fostered the new money-saving features of each new model.

One of the first questions I am asked by ground engineers who come

frequently to inspect the Hiller 360 shows how they start to assess the amount of maintenance required on a particular helicopter, and how reliable it is. " How many modifications have you had on this machine so far, Mr. Bristow, and how many of these have been mandatory ? "

This is a profound question for it strikes at the very foundation of any commercial operation—reliability ; underline that !

Since the 360 went into production in 1948, over two years ago, only thirteen modifications bulletins have been issued, of which six have been mandatory. This is a fine record in the helicopter industry. It could never have been achieved had the manufacturers not concentrated on a simple, effective design, and investigated its reliability very thoroughly before rushing to put the machine on the commercial market.

Of course, with all the elaborate and extensive ground and flight testing of independent components, complete assemblies and the complete helicopter, goes a fair amount of good luck ; accepting this we all know, or should know by now, that no matter how carefully and conscientiously a C. of A. prototype test flight programme may be designed to show up a machine's weaknesses as well as its better points and performance, it is not until the machine has got into operators' hands that it really get put to the test : the test which only the hard usage of time will prove its worth.

The time and money losses inflicted on helicopter operators by the sometimes steady flow of mandatory modification sheets can be crippling, and if the British helicopter industry is ever to get into its stride and produce a helicopter suitable for commercial operations it must put aside elaborate designs with infinite mechanical complexity and concentrate on a simple, effective, versatile design that incorporates inherent stability.

Quite apart from the actual maintenance characteristics of any type or mark of helicopter there are other factors which can, when properly worked into a company's organisation, prove to be maintenance-cost lowering factors, and I believe that amongst the most important of these are the ground equipment requirements.

A helicopter that needs elaborate and costly ground equipment for efficient operation will obviously be more costly than one requiring one or two items of ground equipment. In this respect, the Hiller requires a flat working-top ladder to give the engineer free and easy access to the rotor head for disassembly and reassembly work at all major and 300-hour inspections ; for daily and 25-hour and 100-hour inspections, the work called for does not require any breaking-down of the rotor or transmission assemblies and no ground equipment is necessary.

At major overhaul periods main rotor, rigging and static balance are usually checked, although they are not mandatory unless parts have been replaced or rigging settings changed.

The Hiller ground equipment has been carefully designed to serve several purposes, thereby saving space and high initial cost. For example, the rigging table is also used for static balancing of the main rotor blades and as a surface table for any precision work, and a recent mod. enables the tail rotor blades to be balanced on the same piece of equipment.

Another example in duel purpose ground equipment is the lifting tackle that draws the main drive shaft, serving also to suspend the main gear box and to remove the engine; in fact the installation is such that the engine,

main transmission and main rotor, complete with blades and rotor-matic, can be removed with this adjustable lifting tackle in less than one man-hour, employing one mechanic and one pilot as a mechanic.

While the old engine is being unbolted from the clutch and transmission assembly—no special equipment is required except a few blocks of wood to steady the gear—the new engine from store can, complete with accessories, be fitted in two man-hours prior.

There is no need to emphasize how important this rapid change round is to the operator on a scheduled or agricultural operation where time is so vital. It is an operation that can be done away from an airfield or maintenance base ; in fact, it can be done in any convenient field provided the operator in planning his technical organisation has installed a light-weight collapsable derrick on his mobile workshop lorry. No expensive crane equipment has to be hired or even purchased.

This same mobile 2½-ton lorry workshop is sufficient when equipped with a battery charging unit, work bench and vice, electric drill, compressed air system, driven off the lorry's engine, for cleaning after dusting and rivetting, inflating tyres or floats, etc., to render the operator completely independent of standard airport facilities, and in our roving contracts this summer, camp beds were carried to give the pilot and engineer freedom of movement when operating in country areas where accommodation was sometimes difficult or non-existent.

What has all this to do with helicopter maintenance ? It means maintenance man-hours saved and high utilisation, and a lower price to the customer.

Let me briefly touch on some of the outstanding maintenance features of the Hiller 360.

1. By using aerodynamic forces to do the heavy work of controlling the main rotor blades, construction is very considerably simplified. The patent rotor-matic system prevents feed back in the cyclic-pitch control system and obviates the need for friction locks and irreversibles, all of which are expensive and require frequent servicing.

Direct control eliminates cables, pulley, push rods, fairleads, etc. (which have been known on rare occasions to permit reversed controls) and allows rapid inspection without the removal of panels to follow rambling control systems. When panels have to be removed stowage racks have to be provided to avoid panels being walked on and damaged.

2. Normally helicopter structures are stressed to a minimum normal factor of 2.8 and a minimum yield factor of 4.25. The Hiller 360, however, has as its minimum stress factors 3.5 and 5.25 which, so to speak, builds in reduced maintenance and improves the safety standards. Of course the lifting components and all mechanical devices are designed to much higher minimum stress factors than 3.5 and 5.25.

3. By employing the tension torsion bar blade retention system in the main and tail rotor assemblies the high centrifugal loads are transferred to the strongest part of the hub attachment—the centre—instead of being borne by the thrust bearings in the outer section or lip of the hub.

This design simplification reduces the number of bearings and practically eliminates the possibility of bearing failure which has been a common occurrence on contemporary helicopters.

4. Talking of blades, when a simple piece of dural sheet, folded in monoque form, will make a tail rotor blade capable of withstanding heavy impact stresses don't fill the propeller manufacturer's pockets "with any more tin" by designing a super-laminated wooden blade at ten times the cost of the metal blade, with shatters instantly on striking anything solid and becomes a hazard to spectators and crew. Furthermore, when two-bladed tail rotors are simpler to construct, easier to service and balance, and have few moving parts and do their job efficiently—why then three-bladed tail rotors?

5. The lubrication system for the engine and the gear box transmission is simplicity itself; the transmission oil is bled from the engine system at engine inlet and is pumped to the top of the gear box, through which it passes *en route* to the engine and reservoir.

I would ask our helicopter designers to observe the same basic mechanical principles that contribute most to the smooth regular and continuous operation of any mechanical device, and make it inexpensive to maintain and operate all the year round in all weathers and climates all over the world.

To designers I say :—

1. Observe simplicity of design and construction.
2. Maintain robustness in construction.
3. Give the operator maximum accessibility for daily inspection, lubrication, schedule overhauls and component replacement.
4. Ensure long life of components and low cost of replacement parts.
5. Use standard parts in large scale production.

Let me enlarge on these headings and working up the list I want to underline the importance of standardisation in sub-assemblies and ancillary equipment.

When a standard lorry starter or generator and any other piece of ancillary electrical equipment in mass production will give reliable service, use them, don't design your starter gear ring so that a special coupling has to be designed, produced, tested and A.R.B. approved, etc., *ad infinitum*

Standard commercial gears and bearings and centrifugal clutches, etc., all of which are in mass production for industrial applications, can be used in the helicopter industry—Hiller have proved this—and our industry must follow suit if the prohibitive prices of British helicopters are ever to reach a realistic commercial level. By using standard mass produced components long life and low replacement cost will automatically be achieved.

When considering accessibility, Mr. Designer, dress yourself in overalls and imagine, if you can, that it is you who have to change the plugs, time the mags., install a new clutch assembly or repair a starter, or change an engine. If you find yourself fumbling with a couple of fingers in a restricted space in an uncomfortable position, completely without means of seeing what you are doing—remember its not good enough.

Think to yourself, can standard tools do the job—would your car tool kit meet most field requirements?

Cut down the amount of locking-wire and split-pin work as much as possible with due regard to safety.

I can't leave this question of accessibility without a few words about cowlings. I am not going to get entangled in a discussion over the type of cowlings to be employed—there are specialists enough on this subject—but I would ask helicopter designers to give operators the same accessibility to the helicopter's engine as is given to the engine of modern automobiles.

I would ask that designers learn from past experiences, incorporate the lessons in future designs instead of being content to shoot out modification sheets. In this plea let me quote just one example which should ring a bell or two among those present.

Every manufacturer of a civil certificated helicopter employing a tail rotor configuration has had to modify its tail rotor system to give added strength to resist the high fatigue rate introduced by high frequency and rotor vibrations—an accepted characteristic (and I regret to say this is how most designers view this sort of vibration).

Bearing mounting brackets or attachments have been of too light construction, transmission shafts have not had proper type of U-joint or constant velocity couplings, there have been insufficient support and aligning bearings over the length of the drive shaft.

Please don't think I want battleship standards introduced and that I am not deeply conscious of the necessity for the strictest weight control—but let's have strength in the proper places.

The machines have usually successfully passed through the type test programme, some have been satisfactory up to 200 or 300 hours, but then the failure comes, and it is the poor operator's lot, usually when he can least afford unwarranted delays, and the maintenance engineer in the field has to use all his ingenuity and initiative to make a temporary repair.

We *cannot* afford to be interested in helicopters which are 100% efficient as far as performance is concerned, but we *are* interested in helicopters which are 90% efficient but 100% reliable.

PAPER

By MR. J. LEASON (Society of Licensed Aircraft Engineers).

THE CHAIRMAN : We have heard papers read by two gentlemen who represent the Helicopter Association of Great Britain, and now we are to have a paper from one who represents the Society of Licensed Aircraft Engineers.

Mr. JOHN LEASON has been in the aircraft industry for 16 years, and, like Mr. Voss, he first met the helicopter in the Development Department of Messrs. General Aircraft. He is a Founder Member of the Association and of the Society, and he joined the B.E.A. Helicopter Unit at its inception in 1947. I have known him since that time, and am familiar with his ability in the helicopter maintenance and inspection fields. He is now Deputy Chief Inspector in the B.E.A. Helicopter Unit, in which capacity he has done a great deal to lay down the standards of helicopter inspection adopted by that Unit. He has also contributed materially to the maintenance methods which Mr. Voss has mentioned in his paper.