Discussion

The **Chairman** invited Mr McCLEMENTS to open the discussion

Mr A McClements (*Bristol Aircraft, Ltd*) (*Founder Member*), said that as many people would wish to take part in the discussion, he would endeavour to be brief Mr NEWBERY was a man whom they had all learned to respect for his ability in his profession and particularly for his reasonableness in dealing with those compromises which were always essential if the job was to go forward Members would expect from him a down-to-earth paper concerning itself with the essentials of the subject, and everyone would agree that that was what they had got They had not been disappointed

Most of those present concerned themselves with trying to do the things which the Author told them they should do, and they tended sometimes, quite naturally, to get absorbed in one thing or another What Mr Newbery had done was to paint the overall picture, which could be used as a work of reference If the paper did no more than that—but, of course, it did a great deal more—it would be well worth while

On the detailed aspects of the paper, Mr McCLEMENTS wished to raise three points that were of fundamental importance, and he hoped sufficiently controversial to start the discussion Mr Newbery had referred to the purpose of development being to establish the highest possible standard of safety and serviceability before the helicopter entered normal operational use One assumed that that meant what it said—the highest possible standard

At the moment, nothing like that standard had been reached It should be borne in mind that in saying this, he was thinking of a higher standard than was achieved today , possibly the standard that was sought by the airworthiness authorities and operators—namely, something like the reliability of the structure of an aeroplane and the serviceability of, say, the commercial ground vehicle One ventured to suggest that no helicopter had ever approached such an ideal, at the time it entered service, and the only criticism of the paper was that it did not strike deeply enough at this point

Why was this standard not being achieved? The problem was similar to that which must have faced those in the engine world some decades ago One looked at what went on in a first-class engine company and at what went on in any helicopter company, and the differences were not in favour of the latter Those in the helicopter field did not achieve a fraction of the effort that was put into a new engine before it flew This was somewhat remarkable, because their very lives depended upon the mechanical integrity of the helicopter, to a much greater extent than upon the integrity of the engine

The mechanical parts of a helicopter were surely more important than those of an engine Surely, therefore, they must get treatment at least as good if the helicopter was to achieve an airworthiness and reliability standard approaching the one the Author mentioned Did the Author agree with this philosophy in looking forward?

Did the Author feel that the helicopter test resources in this country were adequate to give this very high standard? Bearing in mind the similarity between engine and helicopter problems, would he expect the scale of resources and the effort required to develop the helicopter to fall far short of those available to engine development? In his opinion, was sufficient development experience accumulated before helicopters were permitted to fly and before they were permitted to enter normal service use?

It was said that there was usually conflict between the operator who, more often than not, wanted the helicopter quickly and the comprehensive development which must be done and which required time Next, as given in the paper, there were the stages which the programme should follow *i e* , pre-design, design, manufacture, prototype build, development batch and production It was pleasing that the Author had touched on this point and on these aspects of the whole problem It seemed that either the job could be done properly or short cuts could be taken, which in the end were no quicker and usually cost far more In the main, to follow the orthodox course might make one unpopular during the early stages of negotiations, but in the end there was likely to be less of the conflict to which Mr Newbery had referred

With those thoughts as a background, the next question was as follows Assuming that there was a new design following those procedures and achieving the very high standard referred to, what, approximately, was the minimum elapsed time which the

Author would expect from the pre-design to the in-service date of, say, a 10,000 lb helicopter? In answering this question, the Author was asked to forget what had been achieved by various firms, but rather to consider what he, as a technician and, incidentally, an ex-engine man, regarded as reasonable, bearing in mind the standards which had been referred to

The third point concerned "Clearance for Operational Use" As the Author pointed out, there was collaboration between the Ministry of Supply and the Air Registration Board on the formulation of requirements, but the collaboration did not go anything like far enough One could see no obvious reason why, from the viewpoint of airworthiness, there should be any difference between the standards for helicopters carrying service personnel and those carrying civilian passengers At present, in fact, there were quite big differences Excluding differences arising from operational considerations, did the Author agree with this and did he feel that there was any real technical reason why it was not possible to look forward to a common code, and a common interpretation of it, in the near future? Possibly some of the Air Registration Board representatives who were present might wish to take up this point

The Author was to be congratulated on an excellent paper presented in a very interesting and able manner

Mr Newbery thanked Mr McCLEMENTS for his "quite undeserved" remarks Whether the helicopter test resources were adequate for the high standard required and whether the scale of effort should be at least equivalent to that devoted to the engine department, was too big a question to answer precisely, but perhaps his own ideas on the subject might be mentioned by way of illustration

Reference had been made to the gearbox In engine development testing, the gearbox was proved as a result of testing a comparatively large number of engines with their gearboxes under normal power conditions There was no fatigue testing, as such, of an engine gearbox Fatigue testing of a helicopter gearbox was essential In that respect, the standard required of a helicopter transmission was higher than that required of an engine

Although in the early days of his experience on helicopter work—in fact, in the draft specification which he had written—he had considered that the standard on helicopter work should be as high as that on engines—*i e*, the standard of manufacture, inspection, and so on—today this was not, in his opinion, sufficient The standard on helicopters had got to be higher As Mr McClements had suggested, a fixed wing aircraft or even a helicopter could lose its engine without crashing The loss of a gearbox, however, would most probably result in a crash

The test resources which had been provided in the past had not been adequate—one of the points mentioned in the paper was the provision of test rigs Whether the industry had the resources necessary to carry out the work to achieve this high standard was beyond his ken

Answering the question of accumulating sufficient experience before an aircraft flew and before it entered operational use, he recalled that he had introduced into his programme an item of intensive flying He agreed entirely that in the past there did not seem to have been adequate flight experience under operating conditions before an aircraft had entered normal use The service intensive flight trials had gone quite a way to correcting this, but it seemed that before the service took over an aircraft, the faults ought to be eliminated, and the only way to do this was for intensive flying to be carried out as part of the development programme

He entirely agreed that the job must be done properly It was no good taking short cuts

From time to time, the point came out in the Press that the Ministry of Supply had been brought to book for its unrealistic estimation of costs of certain projects One of the reasons for this was that when a project was started, the estimate of the work involved and the time required had been over-optimistic Something had to be done to correct this and here the Ministry had to rely largely on the firms It was far better to make a realistic estimate and to include an allowance for the problems and delays that inevitably would occur than to put in an over-optimistic estimate either of time or of cost

If a programme was cut to meet an over-optimistic time promise for service operation, trouble was almost sure to follow The job must be done properly if a satisfactory standard of reliability was to be achieved and if the helicopter was to be a vehicle that would be fully utilised Probably one of the reasons why helicopters

had not come more into their own had been the unreliability and high cost of maintenance It was only by correcting this that the helicopter could be expected to come into its own

Replying to the question of elapsed time for the programme, he said that he purposely had not included any elapsed time on his diagram (Fig 5) The time could vary very much according to the particular type of helicopter being developed He did not propose to make a guess at this—it was something on which those on the job were far more competent to make an estimate—but obviously when embarking on a completely new design which departed from previous practice, the elapsed time would be much longer than when simply modifying an existing type or when designing a new helicopter that was very similar to one which had already been developed

Mr McClements said that possibly the Author had misunderstood him He was not trying to compare one thing with another on the basis of current in-service standards He was trying to get a measure of the price to be paid in time in going to a higher standard, and he suggested that it would be of interest to many people to know what Mr Newbery, who obviously had thought deeply about what had been done, would consider the time scale to be

Mr Newbery, in reply, said he did not know that he would go all the way with Mr McClements Obviously, much more development work was necessary than had been carried out in the past to achieve the standard that was now being set He was not convinced at this stage that the amount of running required was of the order of that carried out for a new engine Much more work must be done, but, at the same time, one had to be realistic and aim at the most efficient programme His own feeling was that a lot could be done, not by cutting the corners, but by really getting down to the best method of development testing and achieving the results in the shortest practicable time

A lot could be done on a helicopter transmission by rig testing The more use that was made of rigs, the less was the time that would be required in running the helicopter itself The important item was the intensive flying, as this was where one would find out the troubles If it was possible to complete 350 hours on one helicopter, of which 250 hours was without any major difficulty or fault, one would have something which no helicopter so far had had

He did not feel competent to answer the question on overall time, but he would expect that on a completely new design which departed from previous experience, anyone who did it in seven years would be doing well It might take up to ten years —depending on the complexity and on the new features involved

Mr O L L Fitzwilliams (*Westland Aircraft, Ltd*) (*Founder Member*), said that he had looked forward with great pleasure to the paper by Mr Newbery, whose long association with helicopter development put him in a unique position as an authority on the subject It was, therefore, a pleasure to be asked to participate in the discussion He was extremely relieved to have heard the exchange of question and answer between Mr McClements and Mr Newbery, because he had one or two worries which the latter had cleared up

The Author had covered an enormous field, but the real crux of the matter was fatigue testing Mr McClements' comments provided a good opportunity to expand on a phrase which he had first heard from Mr Kember when originating a draft requirement, which presumably he got from the Bristol Aeroplane Company, referring to the establishment of the reliability of a transmission or rotor system as equalling that of a fixed wing structure There was no possibility of inspecting for such a requirement, but it had a meaning, and this meaning was the key to the whole of tonight's discussion

The meaning was that the fatigue lives of the components of a transmission must be established by methods and arguments which were as reliable as those used to establish the fatigue lives of the fixed wing structure In that sense, it was really the heart—not the whole body—of what they were talking about tonight Fatigue testing was not the whole body, but without it the rest was of no value whatever

That was why he disagreed also with Mr McClements, and he was glad to have agreement from the Author, that the comparison of what the engine people did and what the helicopter people were doing was not really relevant and was not a cause for the kind of rather gloomy view which Mr McClements had taken The Author had spoken of the standard of reliability on transmissions having to be higher than

engine standards and by this he meant that they must be fatigue tested In fact, this was perfectly easy, and it became obvious that engine manufacturers must start fatigue testing their engines also There were reduction gears even from the best-known companies in the world, which came off in the air When one looked at the history of these reduction gears, they were not in fact fatigue tested, which was an extraordinary state of affairs

In studying the paper, it was difficult to prepare notes for the discussion because the nature of the paper was such that it did not immediately suggest a series of simple and obvious questions Indeed, the paper covered such an enormously wide field that it could almost be regarded as an agenda for future papers in that practically every paragraph could give rise to at least a lengthy dissertation , and many paragraphs contained suggestions or opinions which could be fully thrashed out only in a series of papers

The paper was informative on many aspects of development work, but its main importance was bound to be based on its contribution to the straightforward object of achieving safety and reliability of helicopters, as defined by the fatigue lives and overhaul periods of their components

In the discussion in the paper of fatigue lives and overhaul periods, one was struck by the curious manner in which the Author in effect expressed his disappointment at the delays and mistimings and omissions of the programmes which had been carried out up to date and which were even now being carried out It seemed that there was an explanation which generally tended to be overlooked and this was concerned with the terms of the aircraft specification, on which the Author himself appeared to be under some misapprehension

For example, it was stated in the paper that " it is normal to specify for military helicopters a minimum fatigue life, *e g* , 1,000 hours " This was not in fact true of specifications issued to the Westland Company up to the present time A typical specification, for example, simply stated that mechanical parts such as the rotor transmission should, as far as practicable, have a life of 1,200 hours, and this sort of wording could be held to explain many features of current and past helicopter development programmes On overhaul lives, the position was even more serious since no overhaul life was specified at all

In the discussion following Mr Webb's recent paper on the Engineering Assessment of Helicopters by Boscombe Down, Mr FITZWILLIAMS had had occasion to point out that if the specification required, for example, a minimum overhaul period of 1,000 hours, Boscombe would have a clear duty to establish whether or not this requirement had been met If such a requirement existed, this would not only clarify the extent and nature of, and responsibility for, intensive flying trials prior to entry of the helicopter into service, but the methods employed in such trials would probably also act as a valuable guide toward the analysis of data collected during overhauls throughout the life of the aircraft, resulting in much more rapid extension of overhaul lives than hitherto had been the case

He wished to record an impression that a transmission cleared by modern methods for unlimited fatigue life would be consistent, subject to properly thought out intensive flying procedures, with the achievement of a 1,000 hour overhaul life within a very short time following entry of the helicopter into service

In the original draft of D E R D 2061, unlimited fatigue lives were suggested as a requirement Unfortunately, the meaning of this phrase was misunderstood at the time, especially in relation to light alloys After discussion at the R R C C , the word " unlimited " was changed to " acceptable " by an amendment issued in November, 1953 , so that although D E R D 2061 was now mandatory in some specifications, fatigue lives were merely required to be " acceptable " and there was no definition as to the precise meaning of this word

He would like to see " unlimited " reinstated in D E R D 2061 and hence in the aircraft specifications, and given its proper present-day meaning, as follows

For steel parts, ' stresses below the infinite endurance limit ",
for light alloy parts, " below the endurance limit for 109 cycles ", and
for parts subject to fatigue damage from transient loads only, " 50,000 flight hours minimum, based on an agreed percentage of life spent in the relevant transient conditions "

In both the Author's publications and also in Mr Fisher's paper, and elsewhere where fatigue tests were discussed, it was customary to urge that fatigue tests be conducted early in the development programme Unfortunately, when put in this way the achievement of early fatigue tests was apt to remain a pious hope By putting

'' unlimited life '' as a clear basic requirement of the specification, the whole procedure would fall into proper perspective

For example, the design case for transmission and rotor components would immediately be switched from simply the need to meet operating conditions, as defined by endurance test programmes, to a clear case of designing for a clean run in the fatigue test Moreover, a clear requirement for 1,000-hour overhaul would also open the way to a definition of minimum bearing performance under overload conditions, since what was frequently referred to as wear in bearings was in reality simply fatigue failure

If the fatigue and overhaul requirements were clearly stated in this way, it would not necessarily mean any weight penalty in the resulting transmission, since if the Design and Stress Dept could be certain of adequate fatigue testing facilities at the outset, they could and should under-design components for this case with the positive intention of undertaking a local strengthening programme based on test results, which was the only way of getting an efficient structure or mechanism

Moreover, a programme arranged in that way would generally give immediate knowledge of safe permissible lives to cover early development and even early service flying during the sometimes long period which necessarily elapsed before a full set of flight vibratory stress measurements had been completed

Positive requirements on fatigue and overhaul lives would also automatically cover provision for the repeat testing of components and assemblies periodically throughout the life and subsequent development of the aircraft

In case there was some doubt as to the means of fatigue testing assemblies containing gearing, he could only say that the Westland Company was now preparing for fatigue tests on the Wessex main, tail and intermediate gearboxes on rigs which had been developed in the light of earlier experience and which, he felt, would produce completely reliable results It might be of interest to add that distortion due to overload was not a worry in the testing of these particular assemblies

It was thought that experience with the type of rig used for this purpose would also, in due course, show the way out of the present dilemma in respect of overhaul periods as affected by modifications to the transmission At present, the introduction of even the most obvious improvement generally had the effect of knocking the overhaul period back to some relatively low figure At present this was a serious problem, but in future, when overhaul periods might rise appreciably above 1,000 hours, it would be absolutely necessary to find some means whereby modifications could be introduced without drastic penalty to the overhaul life of an assembly

Mr FITZWILLIAMS concluded by apologising for the time he had taken in discussing this one aspect of the paper He could only hope that the Association's forthcoming new status as a section of the Royal Aeronautical Society might provide opportunities for specialised lectures on this and on some of the other extremely important aspects of helicopter development that were outlined in the Author s excellent paper

Mr Newbery, who thanked Mr FITZWILLIAMS for his comments, explained that in preparing the paper he had to condense it to get it within the permissible length for publication It might be for this reason that some of the phrases did not ring true He well realised that there might be much advantage in expanding the paper to cover the subject more fully There was no doubt that a comprehensive document would be very useful He agreed entirely that there were parts of the paper which could in themselves form subjects of separate papers

As those directly connected with it knew, the specification D E R D 2061 was never officially promulgated It remained in draft form, the intention being to cover the requirements in other documents, and Volume 3 of the Ministry publication was now covering the helicopter requirements

It was gratifying to hear Mr Fitzwilliams' remarks about fatigue testing, because this was something he had himself been '' pressing '' hard for some time and it was of essential importance in the helicopter He apologised if he had made an incorrect statement by saying that the Services specified 1,000 hours fatigue life It might be more accurate to say that they wanted 1,000 hours fatigue life When the specification was written, however, one hesitated to put it in as a firm requirement because it was impossible to be sure of obtaining it in the time available Admittedly, that might be the wrong way to do it, but, after all, the Services required the helicopter , they required it within a certain time and everything possible had to be done to meet their requirements If the time requirement could be met with a fatigue life on a particular

item that was below the 1,000 hours at that stage, but an improvement could be seen which would lift it up to the 1,000 hours not too long after the helicopter went into service, then obviously, from the service point of view, it was better to accept this than to delay accepting the helicopter until the 1,000 hours was achieved There might be some sense, therefore, in not being too rigid in specifying the 1,000 hours in the specification Nevertheless, this was what the Services were wanting

Similarly, concerning the question of overhaul life, although nothing had yet been specified, from conversations with representatives of the Services it was clear that what they were looking for—not perhaps immediately, but in the not too distant future—was a helicopter that would achieve an overhaul life of 1,000 hours Such an overhaul life could not be determined as a result of development but must be fixed as a result of operational use Development could only establish what would be a satisfactory initial overhaul life, because development could never reproduce all the conditions that obtained in actual operational use, so that the extension of the overhaul life by stages must come from operational use What the Services would like was an overhaul life reaching eventually something in the order of 1,000 hours

Squadron Leader Armitage (*Ministry of Supply*), said that the trouble in following people like Mr McCLEMENTS and Mr FITZWILLIAMS was that all one's carefully-thought-up points had been completely dealt with and there was nothing left to say He was certainly not entering into the controversy where these giants had been in the ring, but he would like to make one or two general comments

On the one hand, as was only natural, the customer wanted the helicopter in service as quickly as possible At the same time, he wanted a reliable article and it was up to designers, producers and those responsible for its development to try to find some reasonable form of compromise—because compromise it essentially was Everything about the helicopter was a compromise It was a compromise vehicle This was one reason why it was capable of being such an extraordinarily fine aircraft

He certainly did not propose to suggest how to go about the task, but there were one or two things that came to mind First, the customer must start by specifying far more exactly what he wanted This was one of the points to which Mr Fitzwilliams had referred It was perfectly true that anybody who did not ask did not deserve to receive One did not want a customer who specified in very oblique terms in a standard of preparation or specification a lot of vague things that he might or might not like and who finally produced at the bottom of the specification no more than that " This aircraft is required in service by a certain date," which often became the overriding requirement of the whole thing This was very largely why at this stage one was still left with such an extremely unsatisfactory article from the viewpoint of serviceability Admittedly it possessed safety, but this was being achieved only at the expense of serviceability—in other words, by keeping the overhaul life extremely short

The industry should set its sights on quite another matter Here was the need of a compromise Broadly speaking, one would stick one's neck out and agree that a 1,000 hours overhaul period as a minimum seemed a reasonable target As the Author had said, it probably could not be achieved at the moment the aircraft went into service, but there appeared to be no reason why it should not be achieved within a very short time, say, one year, of the first entry of the aircraft into service, with an interim life of, say, 500 hours acceptable

When one thought of it, with the experience that was available both in this country and in America, such a goal was not really so very far off , but unless somebody did something about it and exerted a really good heave, everybody would linger along as they were for a very long time and it would then be too late The helicopter would just have had a bad name and would gradually hang itself

It must be done quickly, but it was by no means impossible In fact, it was probably much easier than many people thought It would, however, require a great deal of effort by a lot of people and it would require a great deal of thinking by those responsible for development—not only the design firms, but people responsible for asking the design firms to develop aircraft, among whom, of course, were the Ministry of Supply and any major customer

Mr Fitzwilliams had already touched on the necessity for fatigue substantiation, and this was quite clear Another important item was the intensive flying The importance of fatigue had been emphasised by many people, certainly by the Author, for a long time, and it was now becoming fairly well appreciated On the other hand, the importance of intensive flying in this country had not been appreciated in the

least Even now, no intensive flying that was worth talking about was being done There were some things at Boscombe Down which gloried in the name of operational reliability trials, but as intensive flying they were absolutely laughable This was not the fault of the people at Boscombe Down They wanted to take the trials further, but the compromise of trying to get the aircraft into service by a certain target date was the final consideration

A definite distinction could be drawn between operational reliability flying and intensive flying Operational reliability trials, that were essential in the case of Service aircraft at Boscombe Down, could possibly be restricted in scope purely to proving the aircraft as being capable of carrying out its specified duties On top of that it would be possible to have intensive flying trials as such going considerably further, but only on the serviceability and engineering side How the loading should be done, one did not know It might be sufficient to have one or two aircraft on the operational reliability aspect to do, say, 500 hours apiece, but on the intensive flying and serviceability side it would be necessary to have at least two aircraft doing at least 1,000 hours Nothing less would achieve anything

The final point concerned the tie-up between the Air Registration Board and the Ministry of Supply There might be some tie-up , not having much to do with this aspect, one did not know There did, however, appear to be remarkably little tie-up when the question of the estimation of component lives arose The Ministry of Supply's estimation of life and the Air Registration Board's estimation of life were, outwardly, similar procedures, but in actual fact it simply did not work out like this

This was not casting any brickbats at the Ministry of Supply or the Air Registration Board What one was saying was that the Ministry, the Board and all the customers concerned had a very urgent case to get together and sort these things out The biggest criticism of the whole of the helicopter operation was that there was an incredible amount of experience, accumulated by designers, operators and developers, which was going to waste People were running along in their own narrow little channels and they were not sharing their problems and their experience nearly half enough

The Helicopter Association was an extremely good example of what could be done on a smaller scale If one could imagine this done on a larger scale, it should be possible to get somewhere quite quickly

Mr Newbery replied that if the customer specified his requirements more clearly—and not only that, but adhered to them once he had laid them down—obviously the job could be done much better As he had already mentioned, however, the Services were torn between two requirements First, they wanted to get the helicopter into operation After all, if they planned their operations on the basis that they would have the helicopter operating at a certain time and it was not there, all their planning would be upset They were torn between this and the requirement to get the best possible article As Squadron Leader ARMITAGE had said, there must be a compromise The problem was to arrive at the best compromise

One of the things which certainly delayed the programme and increased the cost was changes in requirements after the job had been started Sometimes this was unavoidable, but one got the impression that this was not always the case

Concerning the achievement of the 1,000 hour overhaul life, it had been suggested that a start could be made with a 500 hour initial overhaul life, and this should be possible of achievement It meant, however, that the sights would have to be set much higher than at present It depended on how much was done in the various stages, the background of rig testing, development testing and particularly the intensive flying To increase this initial overhaul life depended entirely on the rate of flying by the user The quicker he could pile up the hours, the quicker the life could be extended, because the result depended on practical experience

On the question of the intensive flying and the operational reliability trials, one was rather nervous about relying on two aircraft There were two purposes of these trials One was to prove reliability, and the other was to prove reliability on all the aircraft There were, of course, variations between aircraft One aircraft, for example, might go through the reliability trials without the least suggestion of trouble, whereas another aircraft might be full of trouble Obviously, the more aircraft that were tested, the more representative would be the results Two was not a sufficient number The problem was rather similar to fatigue testing The more specimens that were tested, the less severe would have to be the factors, because one would be getting a bigger representation of the production articles

A further point about relying on two helicopters was that one of them might have an accident If one was put out of service, there was only one left, and tests on one specimen would not be good enough It was preferable, therefore, to have at least four helicopters on the intensive flying

The following written contribution was read by Mr J Leach (A & A E E) who added his own congratulations to the Author on his clear and able manner of presentation of the paper

Mr H J Webb (*A & A E E*), said that congratulations were to be accorded to the Author on the clear and able manner in which he had described the development of the helicopter engine and transmission system It could almost be regarded as a prologue to his own paper given during the last Session of the Association on the flight testing of the helicopter

The following experience could be considered in relation to both papers A helicopter recently entered service after following roughly the pattern described by the Author and later following the flight testing technique recommended in the earlier paper Soon after becoming established in service, a number of major failures occurred in engine and transmission which, although examples of the failure had occurred during the development period, caused a further extensive development programme to be put in hand

From that example, several lessons could be learned It was established that the production engines were considerably rougher than the earlier development batch As recommended by the Author in paragraph 4 of the paper, more extensive development testing of the engine would probably have revealed the inherent weakness which caused the increased roughness of the engine The excessive engine vibration sought out the weak spots in the transmission and produced failures in service which were not shown up during rig tests

It should also be noted that five early production aircraft were subjected to intensive flight trials, several of which achieved nearly 250 hours Examples of the subsequent failures had not occurred on rig tests and, in addition, as the later " rough " engines were not fitted for the intensive trials, the true significance of the failures was not appreciated at the time

The lesson to be learned was that early development testing on rigs and in flight must take place on representative installations in regard to functional and physical standards for production aircraft This was clearly stated in paragraph 8 of the paper

It was strongly recommended that as much early rig testing as possible should be done, even to the extent of having duplicate installations The duration of testing should, of course, aim at a target of considerably more than 1,000 hours, as the operator would eventually expect a much higher retirement life on such expensive items

With regard to the duration of the intensive flying trials discussed in paragraph 10 of the paper, Mr WEBB had previously recommended that the ultimate duration on each of four or five aircraft should aim at a target of 1,000 hours, this to be completed before the squadrons were formed From the experience gained on such trials as described above, many other minor defects came to light which, by early modification action, enabled a more serviceable aircraft to be put into service It was considered that 1,000 hours could be attained by careful programme planning in six months

A further value of intensive trials of the finalised helicopter was that checks could be made of the effects upon the whole installation of wear, fretting and corrosion and comparison made with the results from the rig tests described in paragraph 6 of the paper

Underlining the warning given by the Author concerning the effect of a change in the standard of manufacture during the development period, Mr WEBB said that the effect of any significant change should be carefully considered to ascertain how it affected the results of the trials In some cases, it might be necessary to extend the trials

Mr Newbery replied that everybody was still learning They had learned much from the example quoted by Mr WEBB As Mr FITZWILLIAMS had said, people's ideas were changing His own had changed very much in the last few years As stated at the beginning of the paper, the stage had been reached at which changes were being introduced but one was still learning and still more changes would be introduced

He did not agree entirely with Mr Webb's assessment of this particular problem One of the points in which the programme had not come up to requirements was that although intensive flying was carried out, it was not carried out under full operational conditions It was only when the helicopter was used in its operational role that the problem came to light That was why he had stressed repeatedly the need for the flying to be done under operational conditions Experience showed very clearly that although the helicopter might be flown intensively, unless the operational conditions were reproduced, it was easy to miss one particular condition which would cause trouble

If four aircraft could achieve 1,000 hours, that would be very nice If it could be done in six months, that would be excellent, but it would mean six months' delay between the time when the aircraft was available and the time when it went into operational use As mentioned earlier, however, when the Services wanted an aircraft they wanted it early, and it was doubtful whether they would be prepared to accept a six months' delay

Mr H E Le Sueur (*Air Registration Board*) (*Member*), said that, in order to be tidy, he would deal with the points in the order in which they had been raised He suggested that the Author had omitted one item from his equipment One was reminded of the tale of the child who said " It smells like butter " " It looks like butter " " It tastes like butter " " What is it ?" " Butter " The Author should include a rig aircraft on his chart There was nothing on earth that vibrated in exactly the same way as a production aircraft as did a similar aircraft, and the best rig for testing systems subjected to vibration was a rig aircraft

Both Mr McCLEMENTS and Squadron Leader ARMITAGE had spoken about fatigue A piece of D T D 610 or L 72 was exactly the same with an Air Registration Board Release Note as an A I D piece If the A I D released Part had a justified life of 1,000 hours on military aircraft, there was no reason why it should not be 1,000 hours on civil aircraft also, with the proviso that if the civil aircraft flew two hours on one flight whereas the military aircraft flew only ten minutes, a difference in factor of 12 might arise

About nine years ago Mr LE SUEUR had been engaged in helicopters However, having to change his field of operation he left helicopters for something like seven years, and then returned One of the things that amazed him was the difference in lives between civil and military helicopter parts, which prompted the reaction that something was wrong somewhere On telephoning this man and that, he was told " Oh, that was before my time I don't know how that was done It was somebody else before me who did it " This was the only apology he could give for the inconsistency

He agreed with 99 per cent, no, 98 per cent of Fisher's Paper 158 If, however, he agreed with Fisher and, in so doing, Fisher agreed with him, there must be something wrong All he could hope was that in future when the Ministry of Supply and the Air Registration Board accepted fatigue lives on aircraft parts, they could both agree the figures In the one case where the possibility of different types of operation might be involved the figure could be resolved to a safe number of flights instead of hours' duration Inconsistencies on existing aircraft were unfortunate

Mr FITZWILLIAMS' recommendation on tightening up the specification was a fine idea This was just what was wanted Why not have 1,000 hours overhaul life on a component ? Let A & A E E test it to 1,000 hours so that the life would be established One did not know who was to pay for the testing, but this was what was wanted in the civil field as well as in the military field What was required was somebody who could say " This helicopter will last for 1,000 hours and will not break in the air after, say, 200 hours "

The tightening up of the specifications would obviously give the desired reliability when the manufacturer came along and said to the Board " Here is a rotorcraft It is exactly the same as the military one A I D have passed it All the lives have been agreed You have agreed the method of testing with the Ministry of Supply Right We want the same lives and the same overhaul periods for our civil version "

In the civil field, however, there was the necessity of dealing with people who build aircraft without Ministry of Supply contracts Help and experience was available from the Ministry of Supply, together with a general appraisal of requirements for rotorcraft The Board was thankful for what the Ministry of Supply did, and this was helpful

In his comments about safety, Squadron Leader Armitage had suggested that

the safety requirement was achieved The following figures might be of interest The use of the rotorcraft in the United Kingdom had been limited since 1949 There had been only something of the order of 65,000 hours of total flying by 61 rotorcraft All these were full Public Transport certificated rotorcraft

During the same period some 50 or more major accidents had occurred to these 61 rotorcraft, with 11 aircraft written off A number of these accidents had been fatal It must, however, be said that these fatalities had in general been due to extenuating circumstances, such as loss at sea or pilot error in training, rather than due to actual rotorcraft failure It was on record that there had not yet been a fatal accident by helicopters in scheduled transport To lose 11 rotorcraft out of a total of 61 in ten years of flying was, however, hardly satisfactory

Last year in the United States there were two scheduled operations accidents, and two non-scheduled operations accidents—one of which was fatal All four of these accidents were due to engine failure In general aviation in the United States last year there were 75 accidents, including agricultural, executive, general industrial, and other types of operation Of the 75 accidents, 10 were fatal, and 4 of these fatal accidents were in contract charter

The number of accidents could be greatly reduced by —

(i) Improved pilot training, particularly in respect of the knowledge of the aerodynamic limitations of the rotor system, for example, over-pitching
(ii) Increasing the number of engines
(iii) Improving the design and reliability of rotorcraft transmissions, particularly clutches
(iv) Designing against fatigue
(v) Improved ground personnel training

Some of these items had been well covered to-night by, one was glad to say, the constructors' representatives themselves Under items (iii) and (iv)—*i e*, the reliability of the rotorcraft transmission and designing against fatigue—the necessity for more rigorous testing must not be overlooked It was necessary to ask whether the programme of testing suggested by the author, particularly his 750 hours total flying before certification for airworthiness, was really sufficient to ensure reliability for civil scheduled transport operation

Mr Newbery replied that what he had suggested concerning the total of 750 hours was that there should be 350 hours on one aircraft under "Intensive flying," giving a total of 750 hours as part of the development programme On top of this, there were the intensive flight trials to be completed before normal operations Thus with four aircraft, taking even a modest assessment and fixing the initial overhaul life at 250 hours, if each went through the overhaul life of 250 hours there would be another 1,000 hours, giving a total of 1,750 hours

He was not clear what Mr LE SUEUR had in mind by asking for a rig aircraft The first aircraft to become available was the prototype A lot of the work, given a propulsion system rig, could be done before completion of the first airframe By getting this background of running, it was possible to reduce considerably the amount of running which had to be done in the aircraft

One shortcoming of intensive ground testing in an aircraft was that it was usually held up by the odd unserviceabilities, the delays caused whenever something went wrong, which did not occur on a rig This was why the rig testing should play a much bigger part and the actual endurance work on the aircraft should be concentrated on the intensive flying This was the better way to get the work done efficiently and in the shortest time

He was in entire agreement that when basic fatigue lives were being established, there was no technical reason why they should not be the same for the Air Registration Board as for the Ministry of Supply, and he was sure that the R A E would be only too pleased to collaborate with the A R B in arriving at the same figures

Mr Kember (*Air Registration Board*), said that he wished to make one or two comments in connection with the Board's requirements for helicopter turbine engines and transmission systems The engine requirements were almost complete as far as their use in this country was concerned, but although there had been two discussions with the American authorities on them, agreement had not yet been achieved The transmission requirements were in course of preparation, but considerable work remained to be done before they could be discussed with the American authorities

It was, however, hoped that agreement for their use in this country would be reached in the fairly near future

A number of aspects nevertheless still remained to be resolved For instance, the Author had mentioned in his lecture the existing helicopter type test which involves a combined ground and flight test His own view was that it was not entirely logical to embark on the flying of the test immediately after a long period of high-powered running on the ground Moreover, if the ground testing was necessary to provide a reasonable assurance that it was safe to do the flying, it did not seem right to permit the flying part of the programme to be conducted in advance of the ground testing

His opinion was that the two forms of testing should be completely divorced and the basic type test run on the ground followed by a quite separate period of flying to cover those conditions that could not be simulated on the ground *i e*, primarily the role conditions If this were done, it might appear as though the total amount of testing was being increased, but this need not be the case if the form of the type tests was such that they were equally useful as development tests It would be interesting to hear the Author's views on this point

Then there were the alternative philosophies regarding the method of restraining the helicopter during the ground tests—rigid tethering and suspension from a gantry It was obviously inevitable that ground testing could never be fully representative of flight conditions On the other hand, he was not sure that either of these means of testing went as far as possible towards covering flight conditions

Another question that arose in the certification of the transmission was whether overload testing in addition to fatigue testing should be required in respect of those parts of the transmission the failure of which could be catastrophic It might be that fatigue testing was adequate in respect of the more simple components and even gear trains, but there might be justification for doing overload testing of the lubrication systems of the gearboxes These and a number of other aspects would have to be discussed with the design organisations in this country before the requirements could be agreed

Did the Author see any possibility of a rotor system r p m governor being developed in the near future in order to relieve the pilot of one of his many responsibilities?

Mr Newbery replied that the r p m governor was already in existence The Saunders-Roe P 531 was flying with a rotor governor, and other types were under development

The question of the type test requirements could be discussed for hours All sorts of solutions could be arrived at as to what the type test should be, depending on what one was looking for He regarded the testing which Mr KEMBER suggested as being included more in the development work, and the aircraft type test merely as a final test to show that what had been done had given the right answers As such, it could be made almost any sort of test one liked, as long as it gave a standard, reliable check that one had the right answers

Instead of the combined ground running and flight programme, it could be argued that it should be all flying, since this would be completely representative of the operational aspects The advantage of ground running, however, was that generally speaking it could be done much quicker than flying

There was a case to include flying because there might be certain flight conditions which could give rise to trouble, and a certain amount of flying to check this should be included in the type test There was no requirement that the flying should be done after the ground running, it could be done first The ground running was not intended to prove that the aircraft was satisfactory for flight The flight tests and intensive flying should have been done earlier and shown not only that the aircraft was fit to fly but that it had been developed to a stage where not only would it get through its type test without failure, but that it would go through the intensive flight trials and into operational use with a good overhaul life and not give any trouble This was what was being aimed at

Obviously, sufficient must be done to show that the type test flying could be undertaken without any worry Whilst one had an open mind on this, one still felt at present that for the most satisfactory form of the type test as a final check—no more than that—to show that what had been done had not left any obvious faults, the 100 hours ground running and the 50 hours flying was a very good compromise

Mr R. H Whitby (*B E A*) (*Member*), in a written contribution which was

read by Mr McClements, expressed his regret that he was not able to be present to take part in the discussion that could be expected to develop around the Author's interesting paper

It might be of interest to indicate the extent to which the introduction into service of a well-tested helicopter with reasonable overhaul lives could affect the costs of operation At the time of introduction into reasonably extensive service, one would expect that the mechanisms of the helicopter would have an achieved overhaul life of not less than 500 hours If, however, operations were started when the life was only half this figure, the increase in spares holding of these mechanical parts (excluding engines) would put up the operating costs of the aircraft *throughout its life* by at least $1\frac{1}{2}$ per cent If, on the other hand, the overhaul life at the time of introduction could be as high as 1,000 hours, this would show a saving of 1 per cent on operating costs *throughout the aircraft life*

A rapid development of overhaul life in service was desirable because, quite apart from the financial effects of large spares stocks, the cost of the overhauls themselves was serious, while they had a low value Thus, if a 500 hour overhaul were increased to 1,000 hours, the operating costs in that period were reduced by no less than 5 per cent Apart from these aspects of low overhaul lives, any improvement in reliability obviously made for big savings in money through the avoidance of unexpected snags, interruption of services and unplanned maintenance

He wished to ask two questions relating to the technical content of the paper First, to what extent did the Author consider that special arrangements to take account of climatic conditions had to be incorporated in test rigs? Secondly, regarding intensive flying trials, would he not agree that the same resources which would be needed to give 400 hours of flying from each of four helicopters might give about 1,000 hours' flying from one helicopter in roughly the same period, and would not this be of real value than the shorter flying period over a larger number of specimens?

In that connection, it was worth noting that some very high flying rates—*e g*, about 1,000 hours in six months—had been achieved in the United States and the extent to which " broomheads and handles " were changed was quite limited One would also put in a plea for this type of intensive flying work being done in very close contact with the operators or even by the operators themselves

The **Chairman** said that as time was getting late, the reply to Mr WHITBY could be left until the written discussion

Mr Newbery, in his written reply to Mr R H WHITBY, pointed out that the rig tests should cover " all operating conditions "—including climatic conditions —as far as is practicable Service helicopters usually undergo climatic trials but the functional aspects of these should be regarded simply as checks that development has been adequate and successful It may not be necessary to build into the main rigs the facilities for reproducing climatic conditions—it may be better to add these when they are required

It was agreed that 1,000 hours flying with one helicopter should be possible with the resources required to achieve 400 hours on each of four helicopters and there are arguments for and against each course The main factor would probably be the development experience obtained, particularly the individual and combined totals of flying hours On past practice it was felt that the advantage would lie with the shorter period on a number of helicopters If, however, development testing and flying were sufficient to give assurance of a probable 1,000 hours overhaul life there would be a stronger case for one helicopter completing that period The trials should certainly be carried out by the operator because only then will the full operating conditions of use and maintenance apply

Mr J S Shapiro (*Servotec, Ltd*) (*Founder Member*), said that in the course of the discussion his list of questions had been greatly reduced, but one still remained It seemed to be one that loomed very large both in the paper and in the discussion The question was simply, what was fatigue testing? He had not, perhaps, followed sufficiently the development of this branch of science in helicopter development in the last few years, but he would like to know what was the difference between fatigue testing and endurance testing On the answer to this question hinged the whole of tonight's discussion

Since he had not seen the answer, or could not detect it in the language of Mr FITZWILLIAMS, who was a great stickler for clear phrasing, he had been very puzzled

during the evening because he had failed to see the real advantage of pre-flight or pre-development and rig testing as a means of short-cutting It might be so, or it might not What was fatigue testing, how was it done and what did it involve?

Among the extremely interesting things he had learned, he was particularly interested by some of the remarks of Mr LE SUEUR If one assumed that 61 aircraft were actually insured for ten years, this represented about 600 insurance years The fact that eleven had been written off revealed the profits of insurance companies, since one knew approximately the rates

In tonight's discussion, the word "reliability" had been used rather loosely It was a shock to find that Mr MCCLEMENTS did not consider helicopters to be as reliable as lorries Was there some substance in these statistics? If members had to go away tonight with the idea that helicopters must be operated with the kind of reliability to which they were accustomed in, say, motor vehicles, it might be a little frightening This, however, was simply a loose use of the word "reliability" Probably what Mr McClements meant was the unserviceability might occur earlier

Mr McClements And more often

"Yes, but we know about it," replied Mr SHAPIRO It did not naturally mean that an accident occurred more often One should distinguish strongly between the two, as, indeed, the public distinguished, because, as Mr Le Sueur had said, there had not been an accident in scheduled services and people did fly in helicopters

He added that when wanting to go from Paris to Brussels by helicopter, he was told that he would have to wait a month

Mr Newbery, replying to the question "What is fatigue testing?" pointed out that Fisher's paper expounded the philosophy of substantiation of safe fatigue life for rotorcraft, and explained what was intended in fatigue testing To put it very briefly, one could consider the slope of a simple fatigue S—N curve and the scatter that would be given over a large number of specimens There would be in the first part, a pair of parallel lines containing the scatter and extending over a certain number of cycles It was possible here to put a factor on the life based on the scatter At the bottom part of the curve—the horizontal part—however, if one specimen was tested under operational conditions—*i e*, endurance testing—it was impossible to know where this came in relation to the curve, assuming it was below it—in other words, assuming there was not a failure That meant that however long the test was, unless a large number of specimens were tested, it was not possible to ensure that all specimens would be below the curve

The way that this was overcome was to do fatigue testing at factored load conditions, the factors being applied to cover variations between different specimens and also possible errors in the measurement of the load Therefore, the test was run at factored load conditions which covered the scatter on the bottom part of the S—N curve This, briefly, was the philosophy behind the fatigue testing

Mr Shapiro So wherever you say it in the paper, it means factored fatigue testing?

Mr Newbery replied that that was so, because endurance running as such, when one was thinking in terms of a long life, could give only a very limited fatigue life

Mr F S Wood (*Structures Department, R A E*), said that like Squadron Leader ARMITAGE, he had one or two things to say about fatigue Some of them, however, had already been said He was delighted to find that practically everybody without exception was accepting the gospel according to Fisher, who, although unfortunately unable to be present tonight, had thoroughly appreciated reading the paper

He endorsed the Author's reply to Mr SHAPIRO That was the philosophy that was being followed

One or two small technical points arose from the paper The first was the Author's recommendation for getting the strain gauge testing done as early as possible in the flight programme This was of importance, particularly if it was intended to have any intensive flying aircraft, because unless strain gauge tests could be done early, one found oneself with limited provisional lives derived from fatigue assessments based on estimated loads, and the intensive flying could be held up for lack of parts whose provisional fatigue lives had expired, until the strain gauging, followed by any necessary fatigue testing based on the flight loads, had been completed

He wholeheartedly agreed that much more information was required about operational conditions Perhaps they were a little ahead of the designers of aeroplanes here in asking for strain gauge measurements as an integral part of the approval of the aircraft , but where the aeroplane people scored over the helicopter people was in knowing a little more about the operational conditions they were covering

If a strain gauge test done during the flight trials could be guaranteed to cover the worst operational conditions, and virtually unlimited life could be established under those conditions, one would not be too badly off If, however, any manoeuvres gave rise to damaging stresses and a finite life had to be assigned, then in order to have a reasonable life it was necessary to know as much as possible of the frequency of occurrences of those manoeuvres in operational flying

Overload testing must be done before fatigue clearance of gearboxes

The question of strain gauge techniques could in itself form the subject of a whole discussion The Author's suggestion of continuous recording, for example, was well worthy of study, but it would involve vastly different methods of reading and analysis than were available today

On the subject of super-reliability of parts of a transmission system the failure of which could become catastrophic, was it correct to assume that the Author was of opinion that the conventional type of fatigue clearance such as had been put forward and accepted in substantiation of a fatigue life would be adequate for that sort of part, or did he suggest that something over and above that was needed as far as fatigue strength was concerned ?

Mr Newbery replied that if fatigue testing was done and it established either indefinite life or a finite life, that would cover the point whatever the type of helicopter He agreed very much that the fatigue life must be related to the operational conditions and the frequency at which the damaging conditions occurred As Mr LE SUEUR had mentioned, this could very well be a point which caused differences in fatigue life assessment between service and civil operators If there was a definite life, it must be related to the operational conditions

The assertion that the strain gauge tests must be done early to enable progress to be made with the intensive flying was a very valid one It was stated in the paper that when the intensive flying was started, the flying must be within the flight envelope which had been cleared, and this depended partly upon strain gauging

The **Chairman,** in closing the meeting, said that time did not permit of any further questions and the remainder of the discussion would have to be conducted by correspondence

Everybody would agree that Mr NEWBERY had given a very clear exposition of the complex procedure for proving that a helicopter was satisfactory This provided a direct answer to those who from time to time suggested that a cheap autogyro or a cheap helicopter could be provided with only a small amount of capital

The CHAIRMAN then proposed a vote of thanks to Mr Newbery for his excellent lecture, and this was accorded unanimously by acclamation