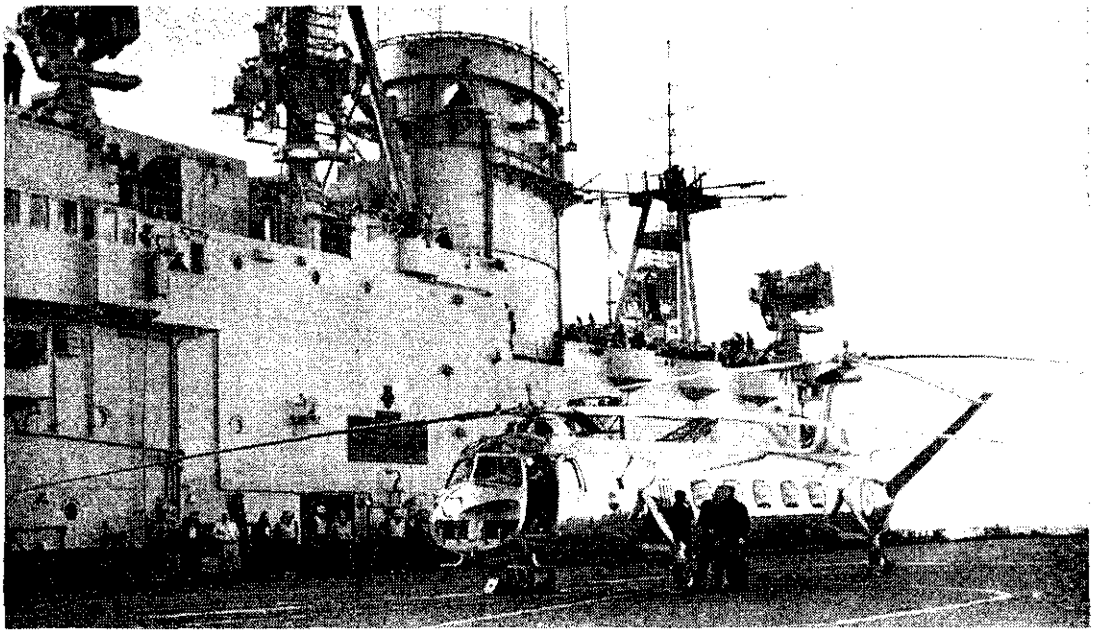

FIG. 2—THE BRISTOL 173 HELICOPTER DURING TRIALS IN H.M.S. 'EAGLE' SHOWING AIRCRAFT ON THE FLIGHT DECK WITH ROTORS SPREAD

THE DEVELOPMENT OF A NEW ANTI-SUBMARINE HELICOPTER

BY

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INTRODUCTION

This article is the sequel to a paper in the last issue of the *Journal* which described the administrative methods by which a new aircraft is designed and developed for the Fleet Air Arm. The present purpose is to consider in some detail the history of one of the current projects, in which the Westland Wessex helicopter is being developed to meet the Naval Staff Requirement N.A.43.

THE BRISTOL TYPE 191 TWIN-ROTOR HELICOPTER

The Naval Staff Requirement N.A.43 was first issued in August, 1952. The requirement was for an anti-submarine helicopter to come into service 'at the earliest possible date'. The helicopter would also be required for several other minor roles such as air-sea-rescue, communications, ambulance, and troop carrying. In anti-submarine work the aircraft would supersede the Gannet and the American-built Whirlwind H.A.S. Mk. 22s. (The Westland Whirlwind H.A.S. Mk. 7 project came later). It was thought, at that time, that there were definite advantages in using a twin-rotor helicopter for A/S work, largely due to the greater stability attributed to the configuration, as compared with a single rotor machine. For this reason a British version of the Piasecki H. 21 helicopter (FIG. 1) was considered, as well as a navalized version of the Bristol

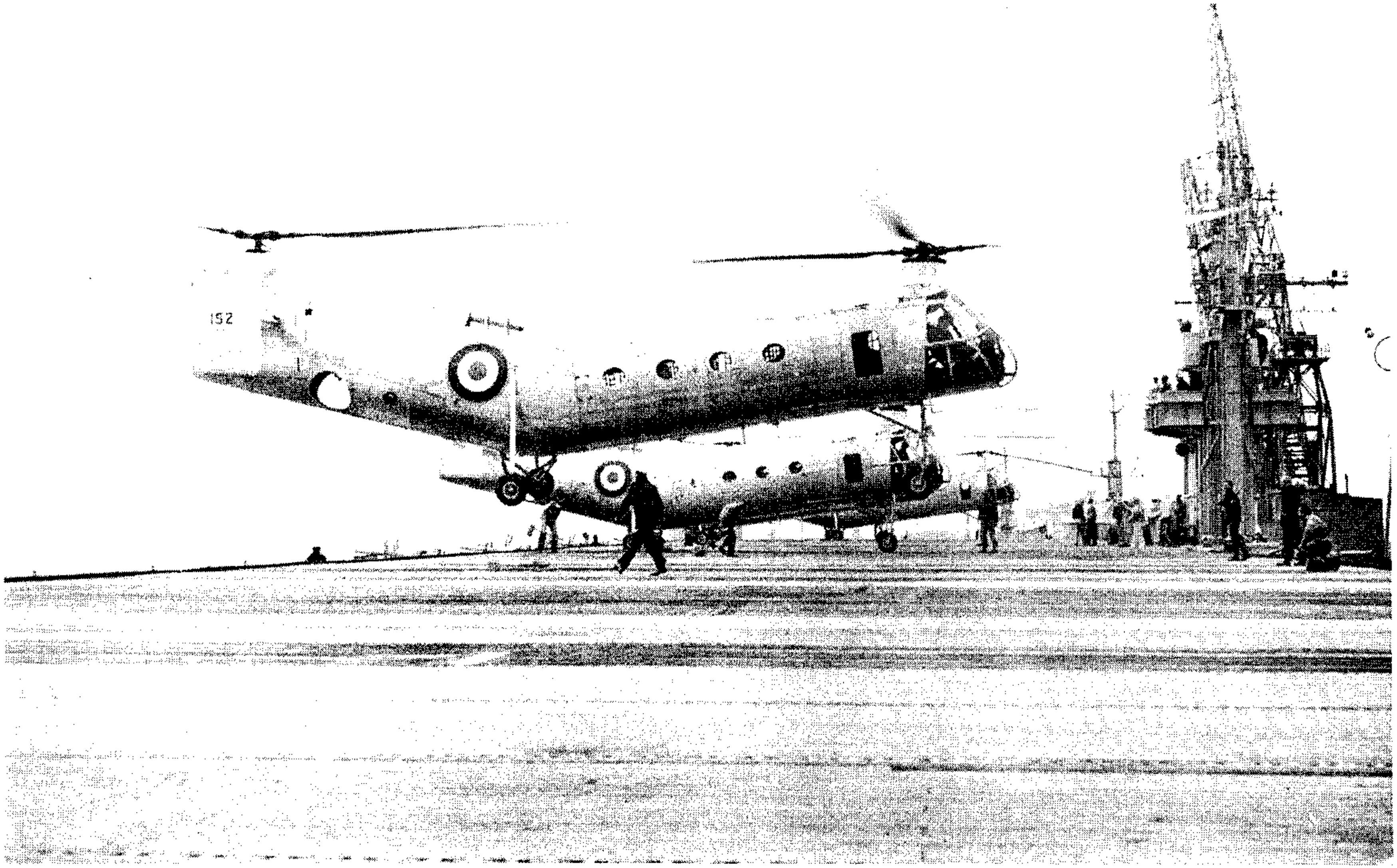

FIG. 1—THREE VERTOL (FORMERLY PIASECKI) H.21 HELICOPTERS OF THE FRENCH ARMY ON THE FLIGHT DECK OF A CARRIER

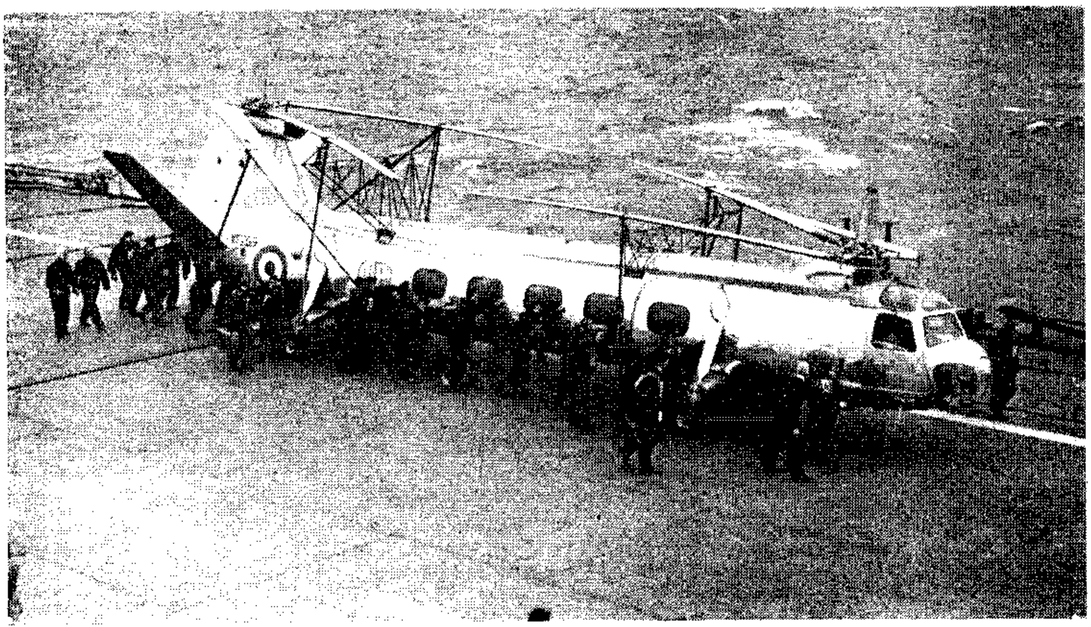

FIG. 3—THE BRISTOL 173 BEING MANHANDLED WITH ROTORS FOLDED GIVING SOME IDEA OF THE SIZE OF THE AIRCRAFT

173 (see FIGS. 2 and 3), then under development for civil operations. This aircraft was to be powered by two Alvis Leonides Major engines. The H. 21 proposal was put forward by the Fairey Aviation Co., who wished to redesign the machine to take an Armstrong Siddeley Mamba engine.

After prolonged discussion between the Admiralty and the Ministry of Supply and, in particular, between D.A.W. and D.(R.N.)A. it was agreed that the original requirement of N.A.43 should be rewritten around a navalized version of the Bristol 173, subsequently known as the Bristol 191. The in-service date was to be 'early 1957'. This revised Staff Requirement was accepted by the M.O.S. in September, 1953.

In December of the same year, the Advisory Design Conference on the Bristol 191 was held, and Specification H.R. 146 D and P was issued. A production contract for 65 aircraft was placed in May, 1954, and the Mock-Up Conference followed two months later.

The main difference between the 173 and the 191 was that the latter had a shortened fuselage to enable it to go down carrier lifts. The third 173 prototype already under construction, was to be completed with the shortened fuselage, for aerodynamic tests and transmission type tests. In order to save time, no other changes were to be made on this aircraft. No 'prototype' as such was needed. All aircraft were to be made on production jigs, but arrangements were made to bring forward the first three aircraft by pre-production methods (e.g. by the use of hand made forgings).

However, following trials of a Bristol 173 in H.M.S. *Eagle*, the Admiralty became concerned about the difficulty of operating a number of such large helicopters from carrier decks. The overall length of the 191, with main rotor blades spread, was 87 feet, which compares with the 80 ft width and 690 ft length of the flight deck of a *Colossus* Class carrier. These figures speak for themselves.

Weight growth due to various changes to the aircraft introduced during 1954 also caused some concern, and as a result it became apparent during the autumn that the Leonides Major piston engined version of the 191 would fall somewhat short of specification performance. While Napier Gazelle gas turbine engines

FIG. 4—THE WHIRLWIND H.A.S. MK. 7 HELICOPTER IN FLIGHT. THE WEAPON BAY CAN BE SEEN IN THE FUSELAGE

promised a better performance, they could not be made available until at least a year later than the Leonides.

A detailed investigation was made into this situation by D.(R.N.)A. in February, 1955, following which, discussions began concerning the possibility of cancelling part or all of the order in favour of an aircraft more suitable for the particular naval requirement. Numerous compromise proposals, to avoid cancelling the whole naval order, were put forward. These included a proposal to cut the order to a development batch, aimed at bringing the Gazelle-engined version into service as soon as possible. These discussions continued until the end of December, 1955, when it was finally agreed to cancel all but two of the order for 65 aircraft. These two were to be used to assist the development of the type for the R.A.F.

Of course, this decision could not be reached without detailed investigation into the cost involved in cancellation charges, and in placing an order for an alternative helicopter. Above all, a more promising project had to be available for adoption, and it is at this point that the Westland Wessex first comes into the picture but, before coming to this aircraft, brief mention should be made of the 'interim' anti-submarine helicopter, the Whirlwind H.A.S. Mark 7 (see FIG. 4).

THE WHIRLWIND H.A.S. MARK 7 HELICOPTER

It will be seen from the foregoing that doubts about the Bristol project first arose late in 1954, but that the cancellation did not come about until early in 1956. By this time the in-service date of early 1957 for an entirely new project was clearly impossible to achieve, so that an order for Whirlwind H.A.S. Mark 7 helicopters was placed during 1956 to cover the intervening period until a new aircraft could be developed.

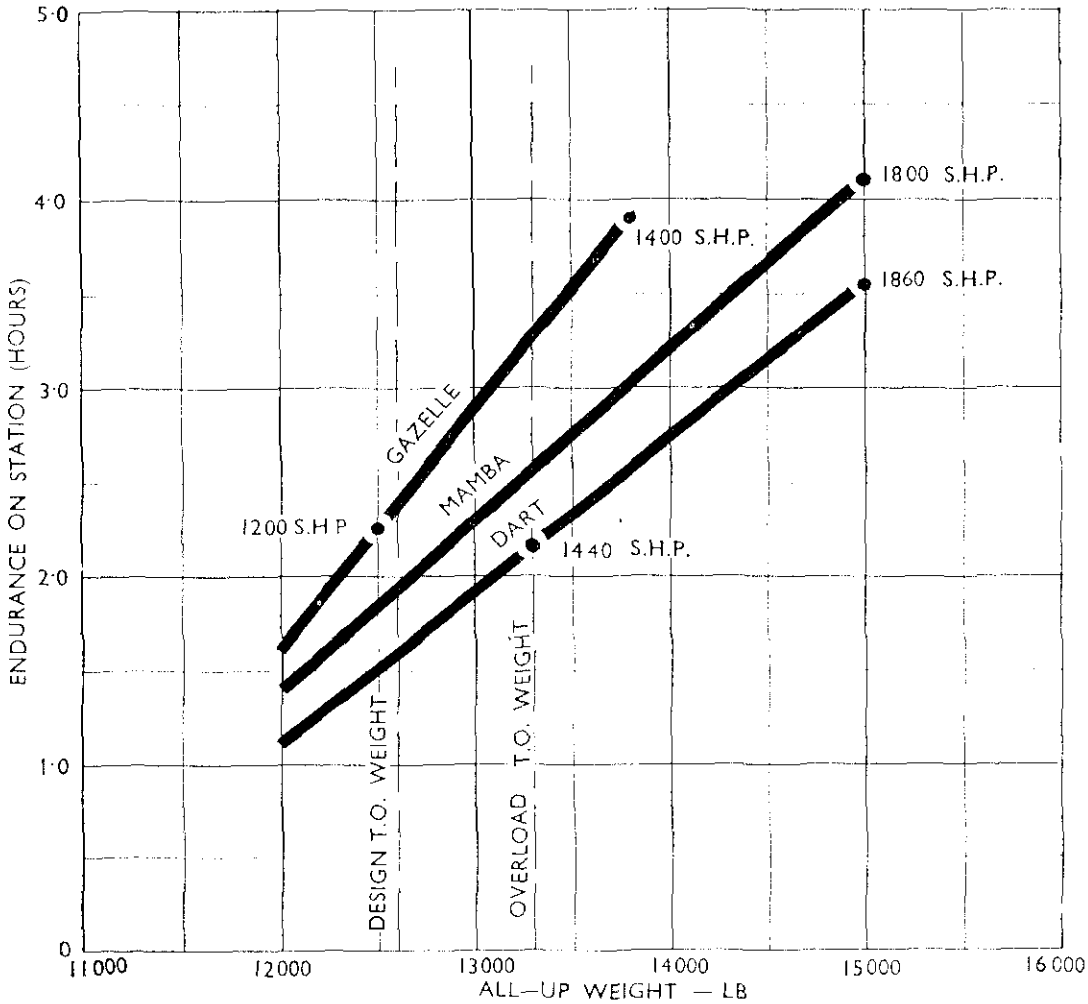

FIG. 5—THE WESSEX IN THE SEARCH ROLE. COMPARATIVE PERFORMANCE FOR THE THREE DIFFERENT ENGINES AS ESTIMATED IN 1955

These figures are comparative only. The absolute endurance figures depend on many assumptions, some of which are no longer valid

The Whirlwind Mark 7 has the lower fuselage, or 'bathtub', modified to carry an anti-submarine weapon, and has an Alvis Leonides Major engine instead of the American engines of earlier Marks of Whirlwind. Airborne Asdic can be carried instead of a weapon. It was hoped to obtain a C.A. Release for the Whirlwind Mark 7 in April, 1957. In fact, a full C.A. release was issued in August, 1957.

THE WESTLAND WESSEX HELICOPTER

A Westland version of the Sikorsky S.58 was the Navy's alternative to the Bristol 191, and was under consideration during much of 1955. Negotiations had already commenced between Westlands and Sikorsky for the necessary licence agreement, which was finally signed on 11th January, 1956.

Choice of Engine

The first big problem was to find a suitable British engine to replace the Wright Cyclone 1820. This engine has a take-off horse-power of 1,525, with 128 h.p. absorbed by the cooling fan, leaving approximately 1,400 h.p. at the gearbox. Admiralty policy required a gas turbine engine for carrier-borne aircraft, so that the use of Avgas could be eliminated, thereby reducing fire risk. In any case, there were no suitable piston engines available in the power range required.

FIG. 6—THE SIKORSKY S.58 WITH WRIGHT CYCLONE ENGINE. POSITION OF THE INTAKES CAN BE COMPARED WITH THE GAZELLE INSTALLATION

Three possible gas turbine engines were considered : the Armstrong Siddeley Mamba, the Rolls Royce Dart, and the Napier Gazelle. All these engines were expected to provide the necessary power, but the Gazelle was the obvious choice on several counts.

Firstly, as far as the actual installation was concerned, the Dart was unattractive, being a fixed turbine engine necessitating a rigid coupling between engine and rotor. Of the Gazelle and Mamba, both free turbine engines, only the Gazelle could be installed within the existing airframe contour. (A comparison of fixed and free turbine engines in the helicopter application is given in Reference 2.)

Secondly, the Gazelle promised the best performance, having both a lower specific fuel consumption and a lower installed weight. The Mamba would give about 80 per cent, and the Dart 67 per cent, of the Gazelle performance at identical all-up weights. This is shown graphically in FIG. 5.

Thirdly, on timescale, the Gazelle would meet Westland's forecast requirements. It had been designed specifically for the helicopter application and was already performing satisfactorily on test. The other engines could not satisfy Westland's requirements, since 18 months to two years would be needed to develop a version suitable for a helicopter from the basic engine.

So the decision was made to go ahead with plans for fitting the Gazelle engine in the Wessex.

The Advisory Design Conference

The new issue of the Naval Staff Requirement N.A.43, written round the Gazelle-engined Sikorsky S.58, was received by the Ministry of Supply in February, 1956. The requirements for the minor roles remained similar to those contained in the original Staff Requirement, but the anti-submarine role

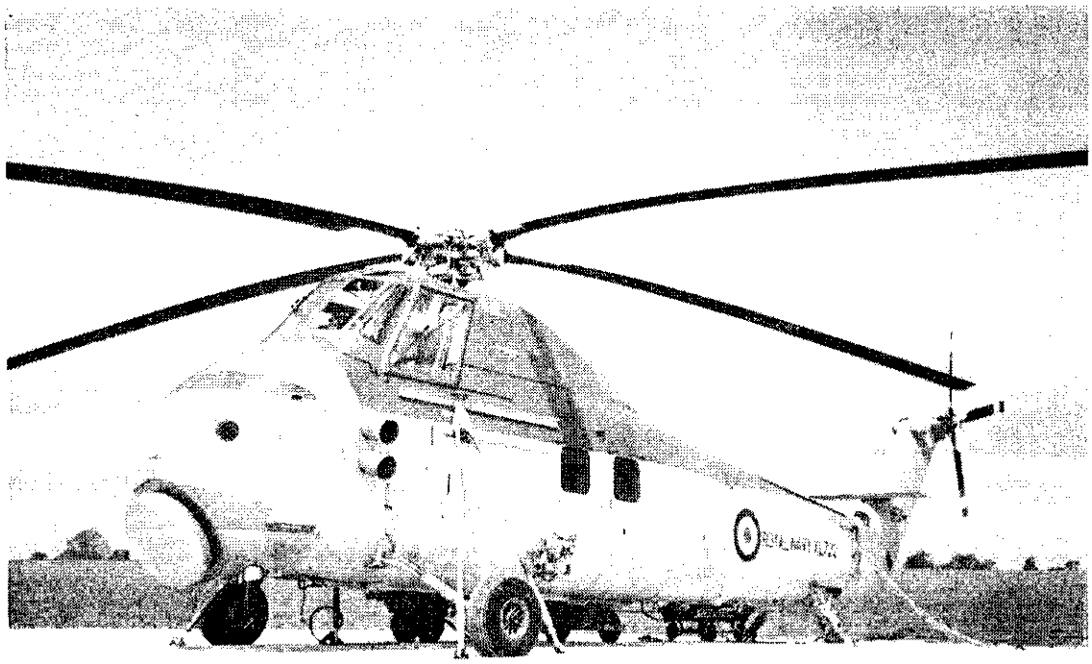

FIG. 7—THE GAZELLE-ENGINED SIKORSKY S.58 WITH THE ORIGINAL INTAKE. THE AIRCRAFT IS SHOWN TETHERED FOR GROUND RUNNING

requirements were reduced to what was possible with a smaller aircraft than that which was previously envisaged. It was to be a ' single package ' aircraft, i.e. it was to carry both an Asdic set and weapons at the same time, thereby enabling it to carry out the job of two Whirlwind Mark 7s. Draft Specification No. H.A.S. 170D, based on the new Requirement, was prepared for consideration at the Advisory Design Conference. This was held in April, 1956, when the Specification was agreed by all concerned. Two months later the Specification was formally issued and the development batch contract placed. This contract covered the manufacture of three aircraft and the ordering of long-dated materials for a further nine.

Sikorsky S.58—Wright Cyclone Engine

The aircraft shown in FIG. 6 (XL 722) has played, and is still playing, an essential part in the Wessex development programme. It was the 265th aircraft from the Sikorsky production line, and is equipped to, what was, at that time, the full United States Navy anti-submarine standard, and U.S. designation being H.S.S.1. It was sold to Westlands as part of the licence agreement, both to enable Westlands to evaluate it for themselves, and also to fit a Gazelle engine into it, in order to use it as an invaluable development vehicle.

XL 722 was shipped to England in May, 1956, was assembled at Westlands, and flew for the first time at Yeovil on 24th June. During the next four months performance work was carried out on the aircraft at the firm, and it was loaned to R.N.A.S., Lee-on-Solent, and to A. and A.E.E., Boscombe Down, for evaluation by the Navy and the M.O.S. respectively. In all, over 70 hours flying was achieved with the piston engine still fitted. Then, in November, it was grounded for the installation of the Gazelle.

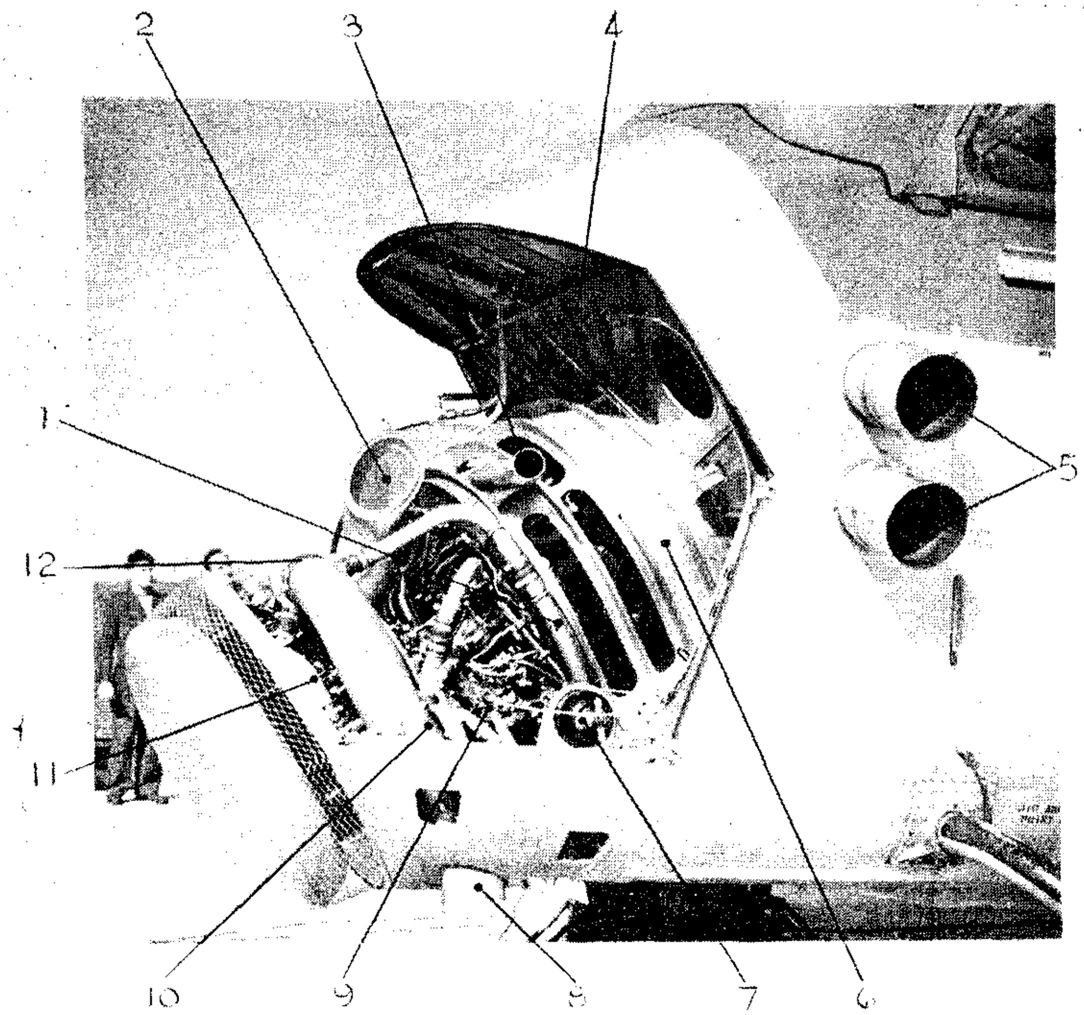

FIG. 8—THE GAZELLE ENGINE INSTALLED IN THE SIKORSKY AIRFRAME. NOSE DOORS AND ACCESS PANELS HAVE BEEN REMOVED

KEY

1—Rear Ventilation Pipe
2—Air Intake in Engine-Driven Oil Cooler Fan
3—Ventilation Air Inlet to Tunnel
4—Front Fireproof Bulkhead
5—Exhaust Pipes
6—Fireproof Tunnel
7—Fuel Recuperator
8—Air Outlet from Oil Cooler
9—H.P. Fuel Cock
10—Oil Cooler
11—Front Ventilation Pipe
12—Engine-Driven Oil Cooler Fan

Sikorsky Airframe—Napier Gazelle Engine

The installation of the Gazelle in the Sikorsky airframe was completed in time for the first ground run to take place in March, 1957. This was so successful, and subsequent progress so good, that on 17th May, after 13 hours ground running, the first flight, which lasted an hour, took place. FIG. 7 shows the aircraft, on the running up base, in the condition in which this first flight was carried out.

The Gazelle, which is a free turbine with rear drive, had been designed to operate at any angle, and could therefore be fitted at the same angle as the Cyclone. Although originally designed with the wrong direction of rotation, as far as the Wessex was concerned, Napiers reversed the direction very simply, by introducing mirror image nozzle vanes and blading for the power turbine. The compressor and power turbines, therefore, rotate in opposite directions, but there is no adverse effect on performance.

FIG. 8 shows the nose section with cowlings removed. It will be seen that

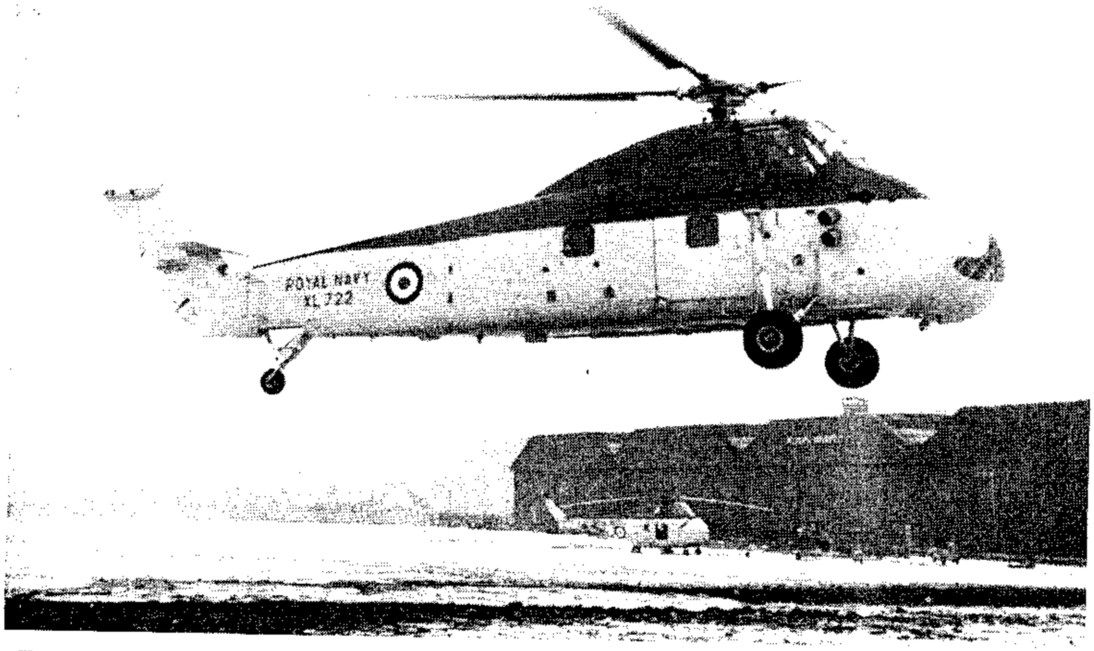

FIG. 9—THE GAZELLE-ENGINED SIKORSKY S.58 WITH THE WESSEX TYPE INTAKE AND NOSE PROFILE

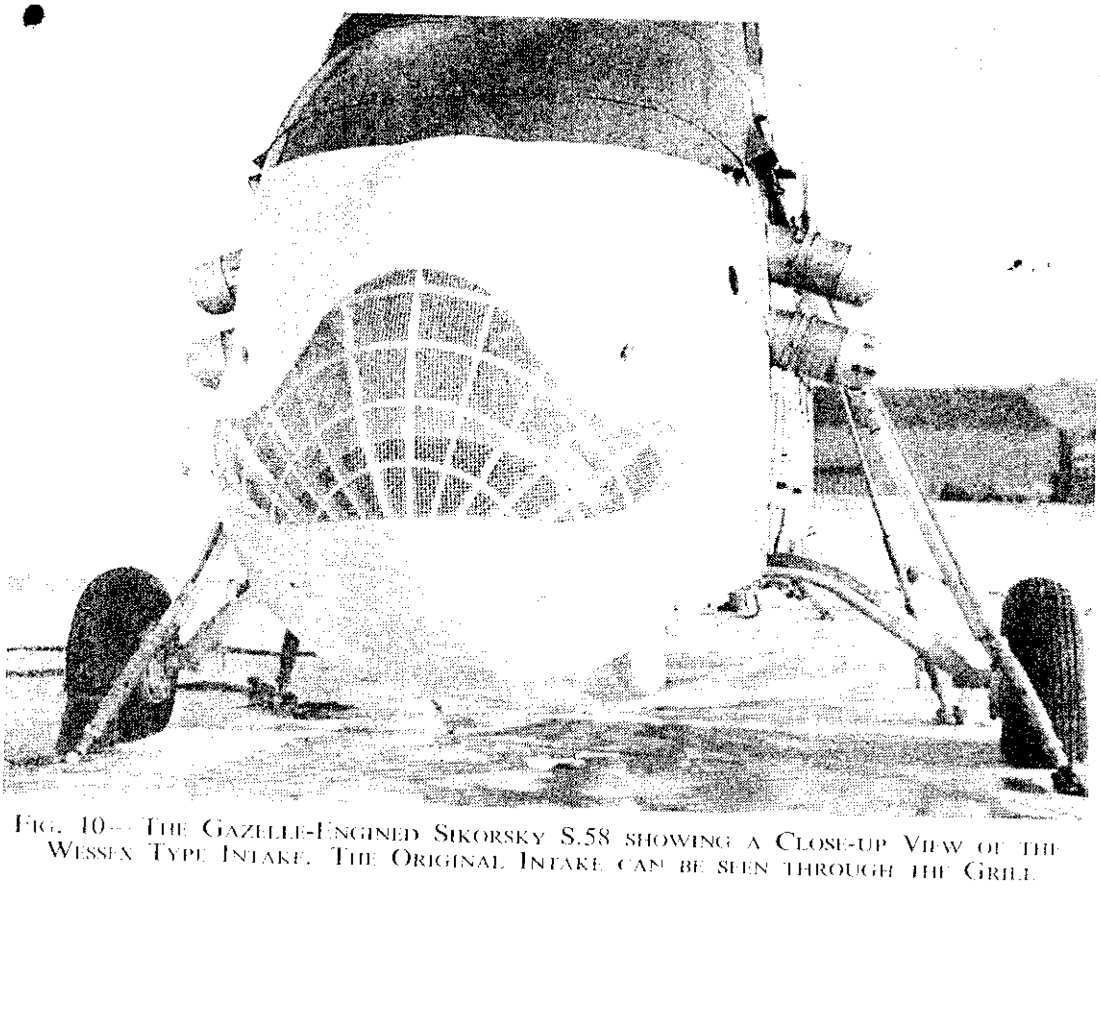

FIG. 10—THE GAZELLE-ENGINED SIKORSKY S.58 SHOWING A CLOSE-UP VIEW OF THE WESSEX TYPE INTAKE. THE ORIGINAL INTAKE CAN BE SEEN THROUGH THE GRILL

the open intake is very near the ground. After a period of ground running some compressor damage was found, thought to be due to entry of foreign matter through the intake. Consequently, a new nose was built on to the machine (FIGS. 9 and 10) similar to the one which was to be fitted on production aircraft. This intake prevented stones being picked up off the ground, and also enabled more representative tests on the airflow round this area to be carried out.

It was thought that there might be some difficulty in leading away the engine exhaust so that there would be no danger to ground personnel moving near the nose of the aircraft, and ensuring that fumes could not affect the pilot when running on the ground. In the event, the initial design, shown clearly in FIG. 8, proved quite satisfactory, and personnel can move safely within a few feet of the four exhaust outlets. The exhaust outlets each incorporate an ejector shroud, which withdraws air from the engine compartments for ventilation purposes.

Naturally, the vibration level in the aircraft is greatly reduced with the gas turbine engine, as compared with the piston engine. Likewise, the noise level, both inside and outside the aircraft, is considerably lower. This reduction in engine noise is such that the tail rotor noise is now much more perceptible.

The only change in the Sikorsky transmission was the deletion of the hydromechanical clutch, necessary with the piston engine, and its replacement by a drive shaft and freewheel unit. The latter is necessary to allow the rotor speed to exceed the drive speed, which is essential during autorotation. The freewheel ensures that the rotor is not slowed down by the drag of the engine, or, in an extreme case, by engine seizure.

The Sikorsky rotor brake was found to be just adequate, but was enlarged for Westland-built aircraft. This was necessary because, in the absence of a clutch, when starting up, the rotor brake is required to hold the rotor stationary against the static torque of the power turbine.

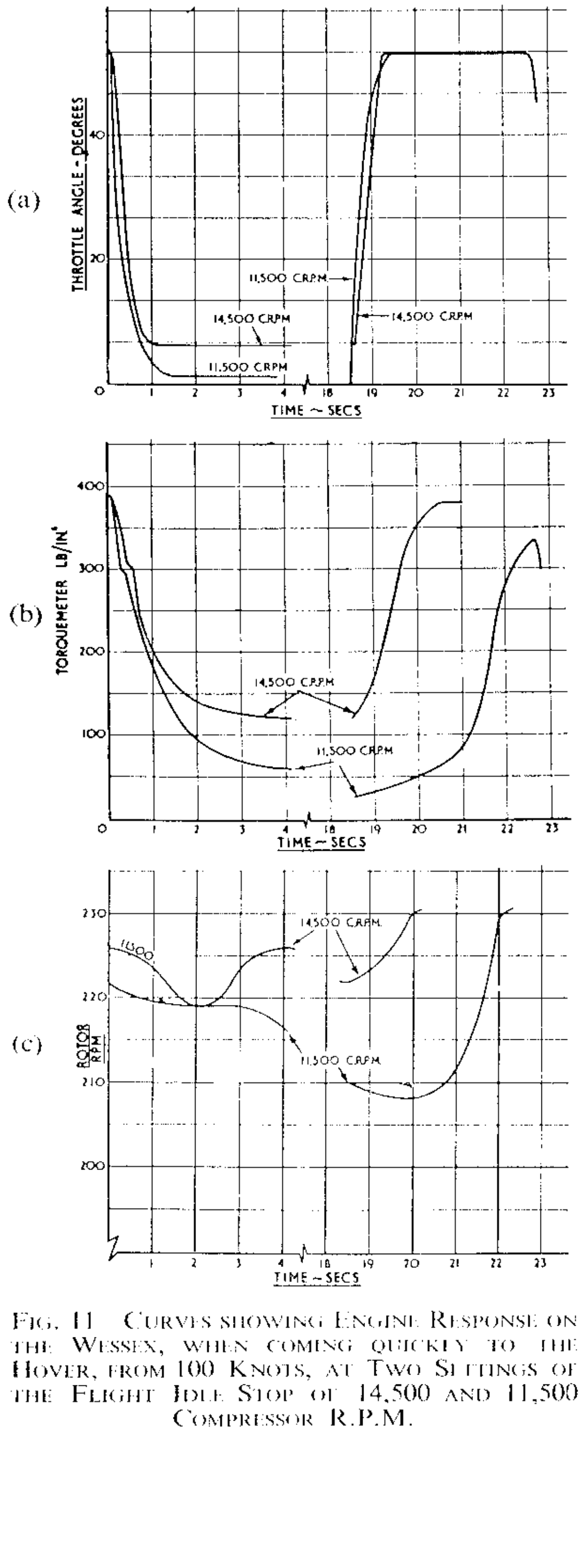

FIG. 11 CURVES SHOWING ENGINE RESPONSE ON THE WESSEX, WHEN COMING QUICKLY TO THE HOVER, FROM 100 KNOTS, AT TWO SETTINGS OF THE FLIGHT IDLE STOP OF 14,500 AND 11,500 COMPRESSOR R.P.M.

Gazelle Engine Response

This initial flight development work on the Gazelle is dealt with in some detail in Reference 2, and it is therefore not intended to pursue this further, except to deal with one other problem—engine response. This is

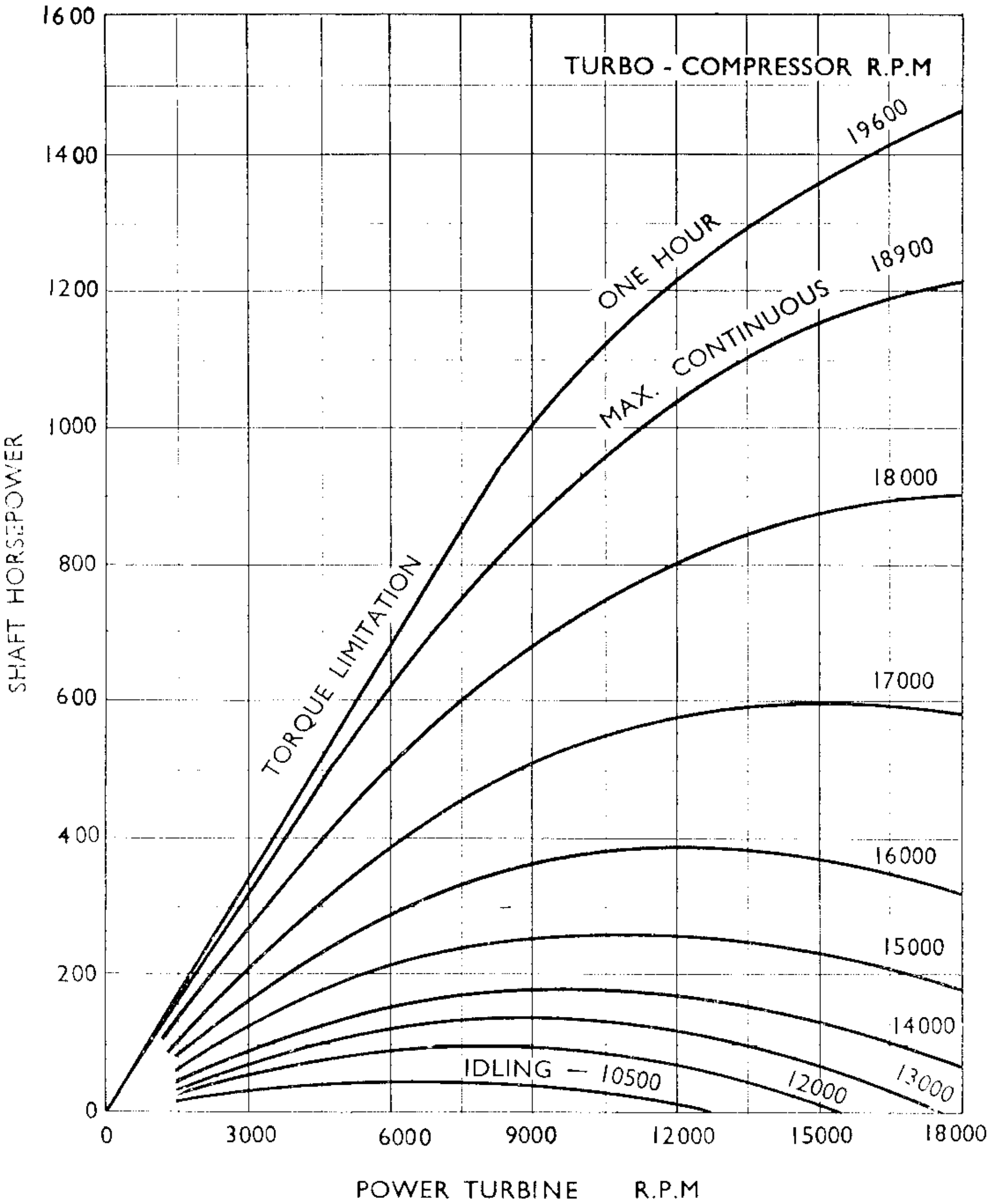

FIG. 12—NAPIER GAZELLE TEST BED PERFORMANCE FIGURES (N. GA. 13 RATING)

very important in any helicopter when coming into the hover, and particularly so in the A/S role, when the pilot is required to fly as rapidly as possible from one dunking position to the next. He requires to reduce height rapidly, and then to increase power quickly to come to the hover. The time to full power from opening the throttle was found to be seven to eight seconds, which was considered to be unacceptable.

The delay was due to the inherently poor acceleration characteristics of a gas turbine at low power. The solution was to provide a flight idle stop to prevent the compressor r.p.m. falling below a certain critical speed. Flight trials were carried out with the necessary instrumentation to establish the position of this flight idle stop. FIGS. 11 (*a*), (*b*) and (*c*) show recordings of the throttle movement, the torque response, and the rotor r.p.m., against time.

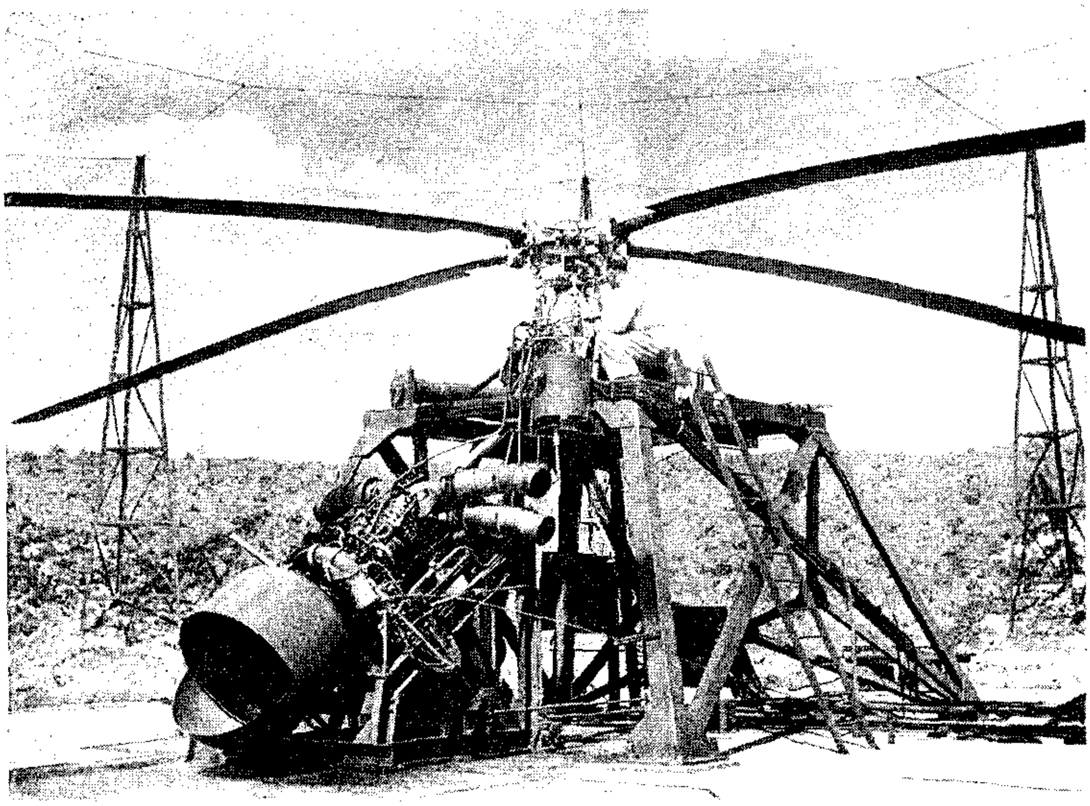

FIG. 13—THE ROTOR TEST TOWER AT NAPIERS (LUTON) WITH GAZELLE ENGINE AND WESSEX TRANSMISSION AND ROTORS INSTALLED

(By courtesy of D. Napier and Son Ltd.)

These tests were done with an adjustable flight idle stop, which was finalized at 14,500 compressor r.p.m. It will be seen that at this setting the time taken to reach maximum torque is reduced to about two seconds, and that the rotor r.p.m. remains more nearly constant.

Engine/Rotor Gear Ratio

The output speed of the Gazelle engine had been originally designed to suit the Bristol 173 rotor system. It was realized that coupling the same engine to the S.58 rotor system would necessitate running the engine at approximately 15,000 power turbine r.p.m. as opposed to a design operating r.p.m. of 18,000. It was thought that this would increase the specific fuel consumption no more than three per cent. Consequently, it was originally proposed to make no change in either the engine output gear ratio, or in the main rotor gearbox ratio. However, test results obtained on the Gazelle, which became available in May, 1957 (see FIG. 12) showed that the three per cent rise in s.f.c. was a considerable under-estimate, the figure being nearer six per cent. This represented a loss of an extra 80 h.p. at one hour power. In view of the concern, prevalent at that time, about the loss of performance due to weight increases, this loss of power was considered unacceptable, and Napiers were, therefore, asked to design a 7/1 engine output gear ratio instead of the existing 6/1. This would enable the engine to run much nearer to the figure of 18,000 r.p.m. already mentioned. The timescale for the introduction of this new gearbox (at least 15 months to fitment on production engines) meant that it would only become available half-way through the development batch. Consequently, this change had to be suitably integrated into the programme.

FIG. 14 THE WESSEX MOCK-UP BEING EVALUATED IN THE RAIDING ROLE. R.M. COMMANDOS WITH EQUIPMENT ARE SHOWN SEATED IN THE CABIN

Rotor Test Tower

Before leaving the subject of engine and transmission development, mention should be made of the rotor test tower at Napiers (Luton). A set of American transmission and rotor blades were bought especially for use on this tower, in conjunction with a Gazelle engine installation. Certain testing which would otherwise have to be done on an aircraft can be carried out here. A photograph of the tower is shown in FIG. 13.

Mock-Up Conferences

While the development work involved in marrying the Gazelle engine to the Sikorsky airframe continued in the experimental shop, in the flight sheds, and in the air, design work directed towards equipping the aircraft for British equipment, and to meet the Admiralty's operational requirements, proceeded apace. The anti-submarine role was given priority, and the mock-up presenting the aircraft in this form was completed for a conference early in February, 1957. A photograph of this mock-up was included as FIG. 3 of Ref. 1.

The mock-up showed the re-arrangement of much of the electrical and radio equipment in the compartments in the nose over the engine. This was necessary in order to restore the centre of gravity after the installation of the Gazelle engine, which weighs some 740 lb less than the Cyclone it replaced.

A separate minor roles conference was held several months later, when the mock-up had been suitably prepared. FIG. 14 shows a party of Royal Marine Commandos, with equipment, seated in the mock-up. This exercise was carried out to verify the maximum number of men which could occupy the cabin. These men were also weighed with their equipment, to make sure that the weight estimates being used were realistic.

The Advantages and the Penalties of ' Anglicization '

Before going in detail into a weight comparison between the Sikorsky and the Westland anti-submarine aircraft, and in view of criticisms sometimes levelled at the latter, it is appropriate to mention here some of the inevitable penalties of Anglicization, as well as the advantages. Some of these points might be equally applicable in other fields, such as the *Dreadnought* project.

The advantages are fairly obvious, the main one being that use can be made of the development work which has been carried out elsewhere. In the case of helicopters this applies particularly to the transmission and rotor system, since it is on these rotating components that most development and testing is required. Almost any sort of cabin may be fitted to a reliable engine/transmission/rotor system. In the case of the Wessex, which in its main role does the same job as the H.S.S.1, advantage can also be taken of the American airframe as a whole, and of their experience in positioning equipment, including such details as aerials, in the optimum position. This last remark does not apply as generally as might be expected, since the aircraft is fitted for the most part with British equipment, but certain major items are American designed.

The disadvantages of Anglicization are less obvious, but first and foremost is the time factor. From the time that it is decided to build in this country an existing design such as a medium sized helicopter, it is inevitable that at least two years will elapse before the first British-built machine is completed.

In the first place, the foreign drawings themselves have to be Anglicized to call up British materials, and where necessary they have to be adjusted to British practice. When aircraft are concerned, a mock-up is also required showing British equipment fitted, and laid out to meet the British specification. This naturally involves a considerable amount of original design work. In the case of the Wessex, with the change of engine, additional fuel tankage, and re-designed aircraft systems, there was far more of such work. The material and equipment have to be ordered, the jigs and tools built, and the parts manufactured, assembled and tested. All this is bound to take upwards of two years. A further one or two years will be required to test and produce the British version, so that, if the foreign aircraft was already in service when British work started, the British aircraft will be three to four years behind the foreign one. This is approximately the position with the basic Wessex (i.e. the non all-weather version).

Alternatively, there is the case where a design which is not already in service is Anglicized, when time is saved at the risk of building something which does not prove a success. This is what is being done with the all-weather version of the Wessex. The decision to follow the American lead was made in February, 1958, at about the time when the the first Sikorsky ' H.S.S.-1N ' was completed. Time is being saved by buying with dollars American equipment for development aircraft (and certain items for production aircraft). The release of the Wessex to the ' 1N ' standard may, therefore, lag on the Americans by only one year, but this is dependent both on the success of the original design, and of British development of a complex electronic system.

The above comparisons of time scales are based on the alternative of purchasing a complete foreign aircraft. Of course, if we compare the time scale of an Anglicized design with that of a completely new *ab initio* development, a *gain* of up to two years may be shown (i.e. although it is taking about four years to bring the Wessex into service, it might have taken six years to bring in an *ab initio* design).

A less tangible disadvantage of Anglicization appears when things go wrong in development or in service. It may not be readily apparent why a part which fails is designed in the particular way in which it has been, whereas if it were an original design the necessary investigation could more easily be made. Sending queries by cable to the country of origin is obviously no substitute for original design knowledge.

On the other hand, the investigation of defects on the British-built machine is sometimes greatly assisted by having an example of the original article available for comparative tests or checks. This has been demonstrated several times on the Sikorsky S.58 at Westlands.

As far as weight is concerned, quite apart from the details which follow, there may in certain cases be weight growth due to the change to British material. This is not a reflection on British materials as such, but simply follows from the fact that American and British gauges of material are different. A choice may be necessary between a gauge slightly lighter or slightly heavier than the American one. On the Whirlwind, the policy was to go to the slightly heavier gauge, but this caused an overall penalty of some 300 lb. Consequently, this policy has been reversed in the case of the Wessex.

This is justified because Westlands obtain full information concerning defects on American S.58s in service. Where weaknesses have been shown up on the S.58, an appropriate change is introduced on the Wessex in the initial design. Furthermore, the structure is re-stressed by Westlands, although time prevents this being done before the issue of drawings for manufacture. However, in the rare event of this re-stressing revealing a doubtful point, the necessary modification action is taken. In the long run the basic structure of the Wessex should weigh no more than the S.58, but should also include some improvements. It should be noted that this same problem of different gauges faces the Americans when they copy a British design.

To sum up this section, it may be said that, even when the best possible use is made of the design which is being Anglicized, and of knowledge of its performance in service, there are inevitable penalties. The most important are, firstly, the time lost in producing the British version (a year at the very least) and, secondly, the lack of knowledge of the thought behind some aspects fo the original design, which handicaps the investigation of defects.

A Weight-Saving Exercise

By May, 1957, the equipment standard of the Wessex in the A/S role had been sufficiently well defined that a more thorough weight breakdown than had previously been embarked upon could be carried out by the M.O.S. Detailed figures for the American A/S aircraft (the H.S.S.1) were also available, so that a comparison of the two aircraft, system by system and item by item, was now possible. This showed very clearly where additional weight penalties were being paid on the Wessex as compared with the American aircraft.

Immediate action was taken to remedy this situation as far as possible. The firm and D.A.W. were each provided with a detailed breakdown of items and subsequently a meeting was held to discuss ways and means of improving the position. The items could be broadly divided into three groups :—

(*a*) Those associated with the structural changes involved in fitting the new turbine engine and fuel system. For example, the Wessex fuel system accounted for an extra 83 lb compared with the H.S.S.1, and fire precautions cost 106 lb as opposed to only 9 lb in the H.S.S.1.

It was found that little could be done to reduce the weight of items within this group. The additional fire precautions were associated with the use of a turbine engine, and, in any case, British requirements in this respect are more stringent than the American ones. However, the use of titanium for the fire-proof bulkhead behind the engine bay, instead of stainless steel, resulted in a weight-saving of 20 lb.

(*b*) Those items associated with Admiralty requirements which differed from the Americans. Details of these items are unfortunately classified. However, suffice it to say that Sikorsky have a great advantage over Westlands in that the former produce S58s to three completely different standards for the U.S. Navy, the U.S. Army and the U.S. Marine Corps, whereas one version of the Wessex has to carry out a large variety of different roles.

(*c*) All other items, which do not fall into groups (*a*) and (*b*), for which some other explanation would be required. The major item in this group was the electrical system. This was shown to weigh 625 lb*, nearly double the Sikorsky figure. A separate meeting was held to go into this point alone. Although it is not self-evident, this penalty is partly associated with the change of engine as compared with the Sikorsky H.S.S.1 aircraft. In the Wessex the majority of the electrical and radio equipment is installed in the nose over the engine for reasons given earlier. Since the cabin has to be kept clear for the carriage of seats and/or stretchers in the secondary roles, most of the remaining electrical and radio equipment has to be installed aft of the cabin. In addition, the Wessex has two separate generators, one driven off the engine and one off the rotor gearbox. This provides added safety in case of a single generator failure, but the weight penalty is appreciable. Furthermore, the H.S.S.1, with one gearbox-driven generator, and most of the electrical equipment adjacent in the cabin, had a very compact installation with the minimum of cabling, which accounts for the large penalty on this item in the Wessex.

The power supplies (both D.C. and A.C.) of the two aircraft were not at this time strictly comparable, because in the Wessex the intention was to provide at the outset the power to drive electronic equipments which were not yet available. However, this investigation highlighted the fact that American generators and inverters, which are suitable for helicopters, are considerably lighter than their British equivalents. In fact, no equipment of this sort had, up to that time, been specially designed for helicopters in this country, so that no advantage had been taken of the facts that :—

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* The breakdown of this figure includes three major items as follows :—

Generators and controls—penalty 49 lb (compared with H.S.S.1)

Inverters —penalty 75lb

Cabling —penalty 100 lb

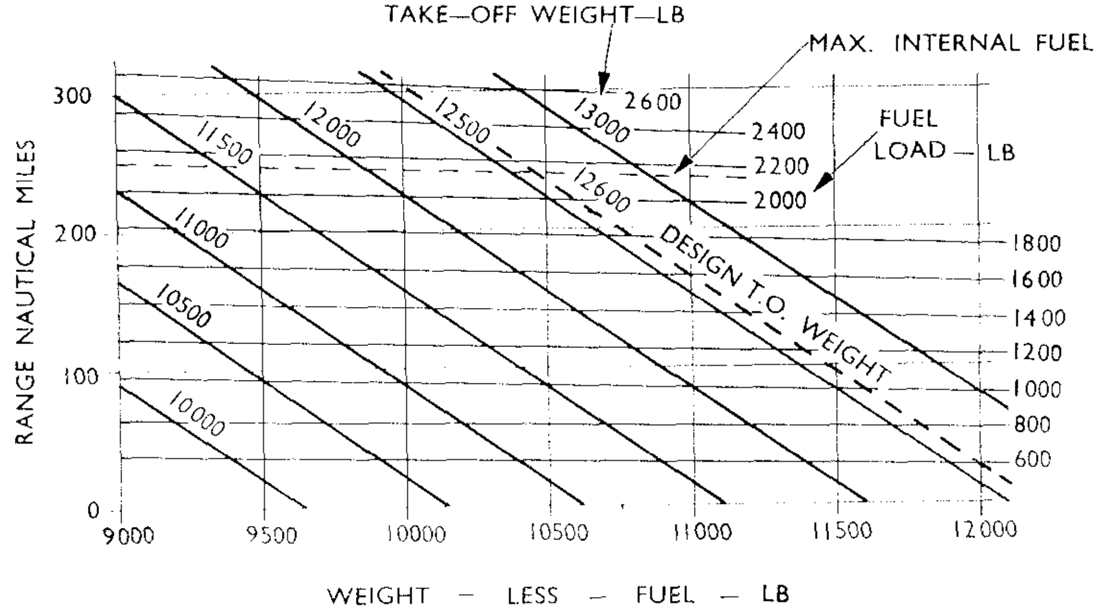

FIG. 15.—WESSEX PERFORMANCE IN THE STRIKE ROLE. FROM THESE CURVES, GIVEN THE EQUIPPED WEIGHT OF THE AIRCRAFT (LESS FUEL), THE RANGE MAY BE ESTIMATED FOR ANY TAKE-OFF WEIGHT

(i) The speed range of a helicopter generator may be much narrower than on a fixed wing aircraft (because the engine speed varies much less) ; or

(ii) There is no great altitude requirement on a helicopter.

It was therefore decided that this situation should be remedied, and Westlands were given approval to develop a 9 kW light-weight generator under the Weapon System Concept. This generator, which would be developed by Rotax, as a sub-contractor to Westlands, would be about 25 lb lighter than the existing one, and would be equally suitable for other helicopters. Two of these generators would be necessary to provide power for the all-weather system now to be fitted. The installation would then be identical in this respect with the H.S.S.-1N.

In the case of the inverters, it was decided to fit a commercially used type in the early stages. This is a non-standard item, but is 60 lb lighter than the existing standard one. Eventually an inverter being developed for the M.O.S. would be fitted. This weighs 25 lb more than the commercial one, but is suitable for supplying a wider range of equipment.

Effect of Weight on Performance

To understand the tremendous emphasis on the saving of every pound in weight, as described above, it is necessary to consider briefly the effect of the basic weight on the performance of a helicopter. The power required to maintain hover in still air is considerably greater than that required to provide forward speed at the same all-up weight. The ability to hover in still air outside the ground cushion or, even more, to achieve a certain vertical rate-of-climb (180 ft/min is the requirement) in these conditions, is therefore the criterion when considering single-engined helicopter performance. (The corresponding criterion for fixed wing aircraft is the ability to clear obstacles immediately after take-off at stated heights and distances from the start of the take-off run.) Since the aircraft we are now considering is primarily employed in A/S work, the reserve power available in the hover is of even more importance.

FIG. 15 shows 'Range' plotted against 'Weight less fuel'. From these figures, it is clear that, if the basic weight of the aircraft is increased by the

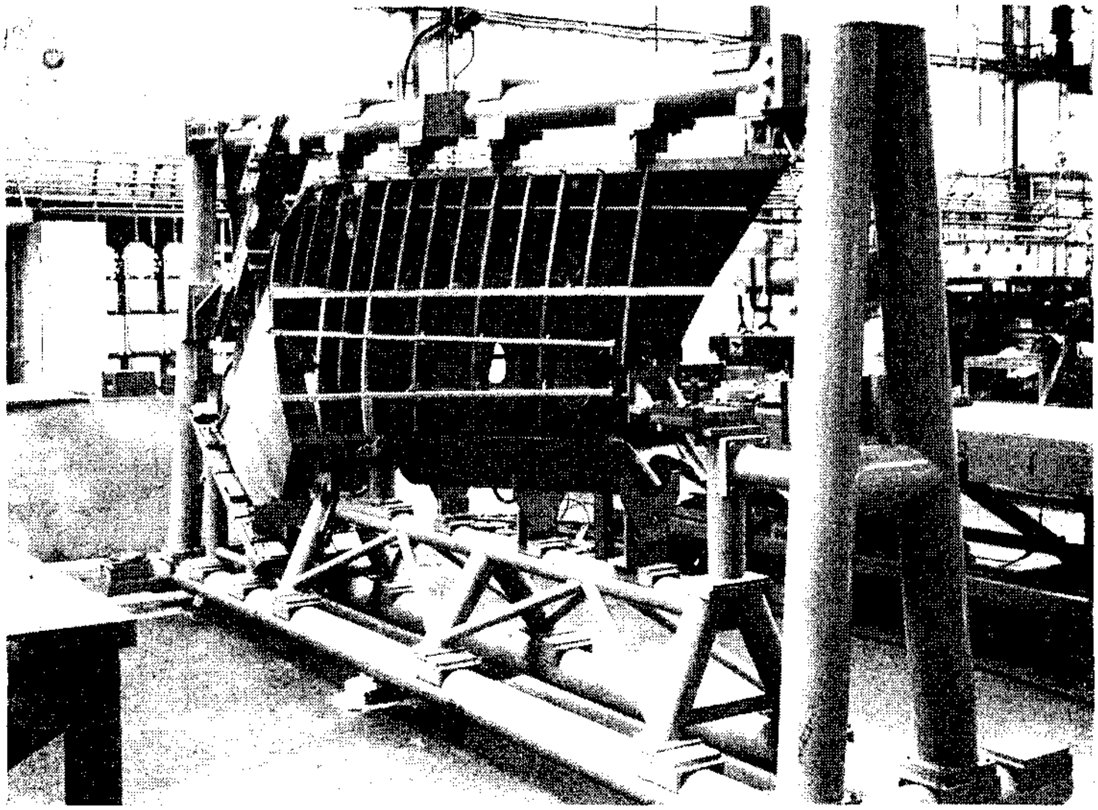

FIG. 16—WESSEX TAIL PYLON JIG

addition of equipment or structure, within a given all-up weight, the fuel load and therefore range and/or endurance must be correspondingly reduced. In fact, 100 lb will decrease the range by 13 nautical miles. This also illustrates the problem which faces D.A.W. in deciding how much equipment should be asked for at the expense of role performance.

The Main Design Stage

In the twelve months following the Mock-Up Conference in February, 1957, the basic design of the Wessex was completed, and the necessary drawings were issued to the shops to enable the first aircraft to be completed on schedule in June, 1958. The firm's Works (Production) Department accomplished no mean feat in completing this aircraft in the four months from issue of the last drawings. Every possible short cut was taken, a typical example being the completion of 90 per cent of a jig, the overall dimensions of which were known from American experience, before the finished drawings were available. Incidentally, jigs and tools to achieve a production rate of two aircraft per month had been authorized from the start. Two of these jigs are shown in FIGS. 16 and 17. The contract for 40 production aircraft was placed in February, 1958, long-dated material for these having been ordered one month earlier. The production rate was then planned to increase eventually to four aircraft per month.

The Test Rig Programme

By this time a considerable number of rigs were in operation, the most important being those for the various gearboxes, the power control system, and the fuel system. Two of these are shown in FIGS. 18 (a) and 18 (b). At the appropriate time, a meeting was held to decide how many hours testing should be completed on all these rigs before the first flight.

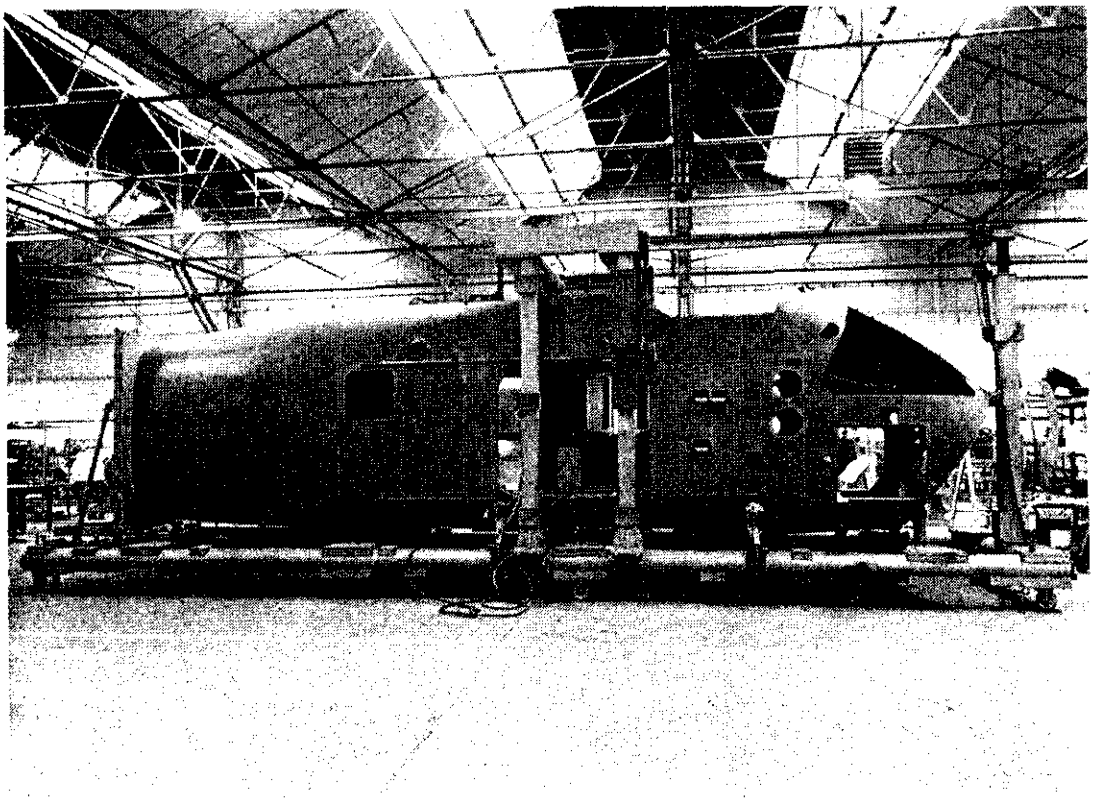

FIG. 17—MAIN FUSELAGE JIG

First Flight of the First Aircraft

A generous allowance of several months had been made on the programme for ground running before flight but, because of the experience already obtained on the Gazelle-engined Sikorsky airframe, the first Westland-built aircraft made its first flight on 20th June, 1958, only three weeks after its completion : the scheduled date for the latter having been met. After gaining confidence in hovering and gentle turns, the Chief Test Pilot was able to put the aircraft through a full range of helicopter manœuvres during a most successful flight lasting over an hour.

The All-Weather System

The Sikorsky H.S.S.1 was fitted with A.S.E. (automatic stabilization equipment) and equipment which enabled the aircraft to hover automatically in certain conditions.

The H.S.S.-1N has an additional range of ' black boxes' which enable the pilot, having descended to an altitude of about 100 feet at 40 knots forward speed, to press a button and allow the helicopter to fly itself automatically into the hover at a pre-set altitude. This system will enable anti-submarine operations to be carried out in all weathers. It has been described in some detail in Ref. 3.

The decision to adopt the 1N system for the Wessex was made in February, 1958. Quite apart from the additional equipment to be installed, it became necessary to re-scheme the cockpit for two pilots. The original cockpit layout is shown in FIG. 19, and may be compared with the H.S.S.-1N layout in FIG. 20.

Automatic Throttle Control

Brief mention should be made of one innovation on the H.S.S.-1N system which is more mechanical than electronic. Moreover, it is the one development

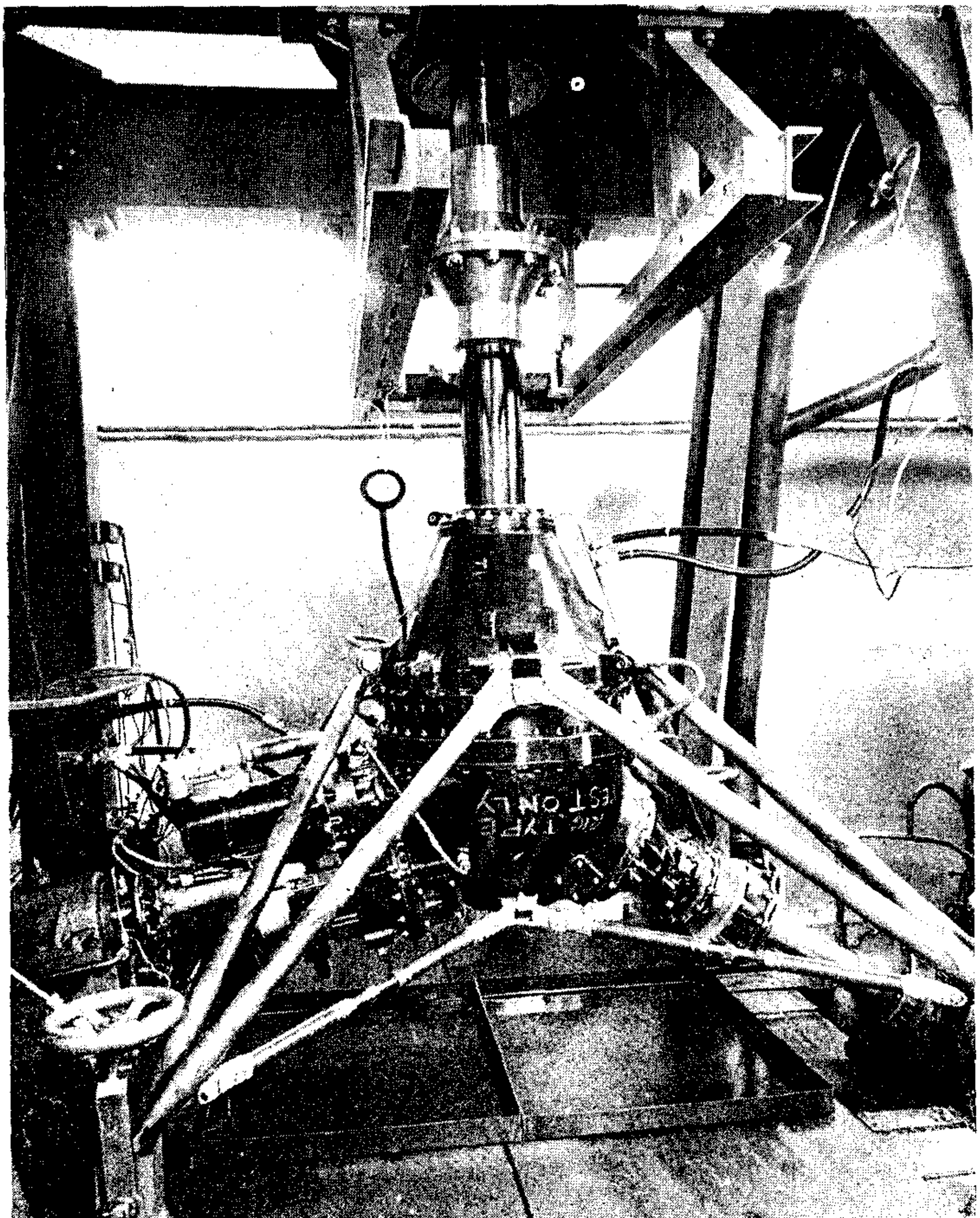

FIG. 18 (*a*)—WESSEX HYDRAULIC SYSTEM TEST RIG

which cannot be a direct copy of the Sikorsky design, because of the change of engine. This is the automatic throttle control.

Motion of a helicopter in a vertical plane is controlled by the collective pitch control and the throttle. The former is normally a lever on the left of the pilot, and the throttle is usually of the twist grip type. Conventional helicopters have a mechanical interlock between the collective pitch stick and the throttle, so that, as the pilot raises the stick, the appropriate engine power to maintain the same rotor r.p.m. at the increased blade pitch is automatically applied. An additional refinement on the Wessex will be an automatic throttle control which maintains a constant rotor r.p.m. as selected on the twist grip for all conditions of flight.

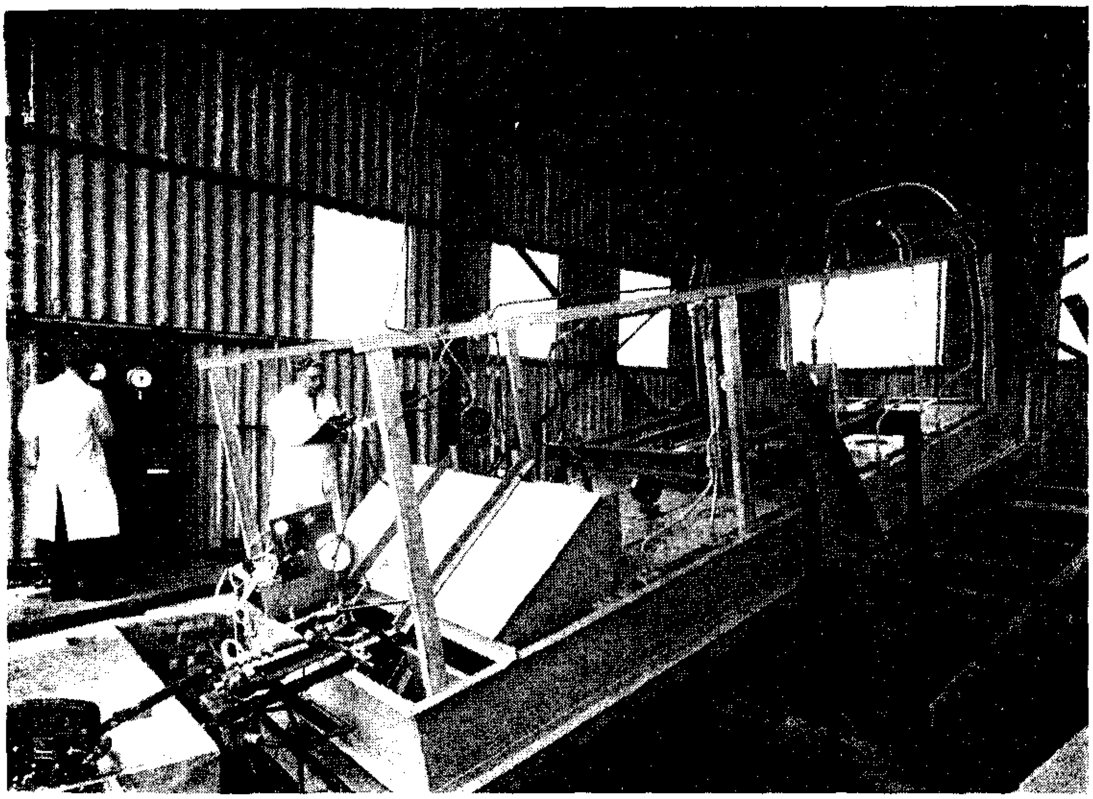

FIG. 18 (*b*)—THE WESSEX FUEL SYSTEM TEST RIG AT FLIGHT REFUELLING LTD. THE AIRCRAFT COMPONENTS ARE MOUNTED ON A STEEL PLATFORM WHICH CAN BE TILTED TO REPRESENT BOTH ROLL AND PITCH. THE METER ON THE LEFT CHECKS THE RATE OF FEED TO THE ENGINE

It is clear that the characteristics of such a control, as applied to a Cyclone engine in the S.58, will be different for a Gazelle on the Wessex. A trial installation of an automatic throttle control is now being fitted in the Gazelle-engined Sikorsky airframe. Several of the components being used are the American ones, while others are specially designed. As a possible alternative, an entirely new Napier-designed, mechanically operated unit is also to be given a trial in the near future.

Mock-Up Conference—All-Weather Standard

By mid-September, 1958, the aircraft had been re-mocked-up with the new cockpit, and with the additional electronic equipment. The decisions of the Conference in February, 1957, were now largely invalidated, and applied only to the first seven aircraft, and ultimately to only the first four. The new target became the completion of the first all-weather aircraft in June, 1959. Of course, the basic aircraft structure and systems remain the same, and the change of standard is being identified as one comprehensive modification. No aircraft will be delivered to the R.N. without this modification embodied. By the end of January, 1959, the new drawings were completed, and it remains to be seen whether the June build date will be met.

Flight Development

The work on the Gazelle-engined Sikorsky airframe has already been described in some detail, and also the first flight of the first Westland-built aircraft. By now (February, 1959) over 50 hours development flying have been carried out on the first four aircraft.

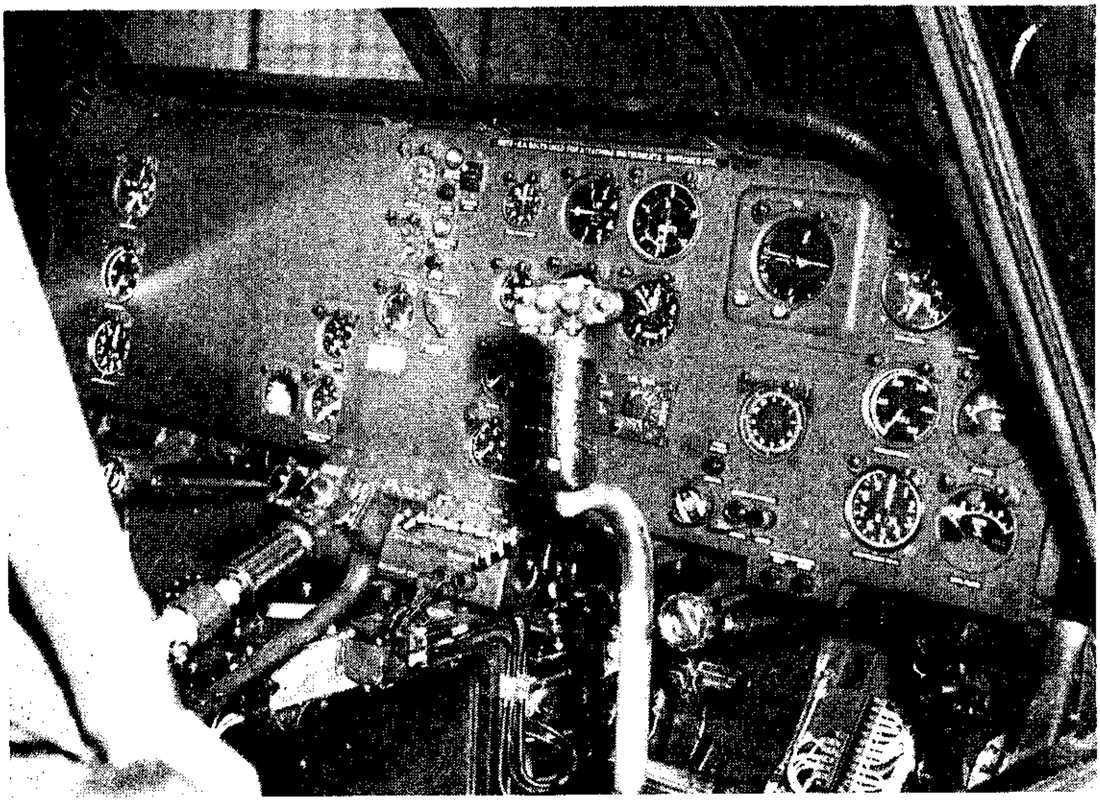

Fig. 19—Cockpit Layout of an Early Development Batch Wessex.

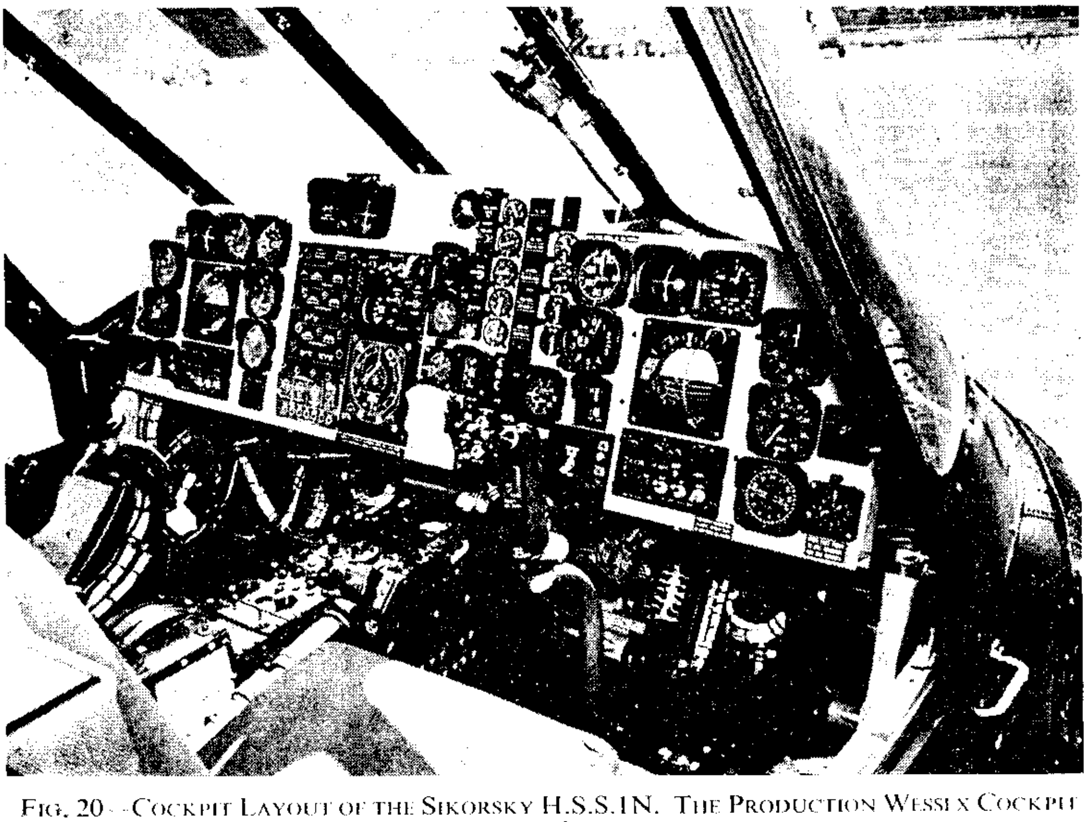

Fig. 20—Cockpit Layout of the Sikorsky H.S.S.1N. The Production Wessex Cockpit will be Similar

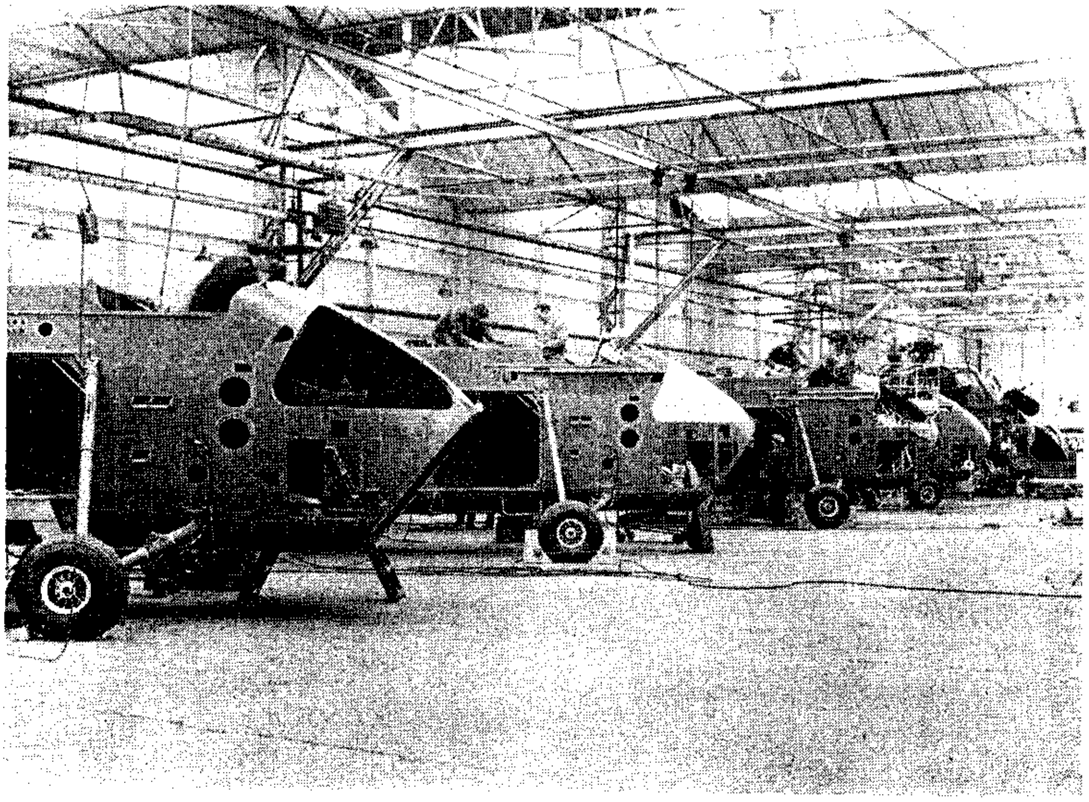

Fig. 21—Part of the Wessex Development Batch Under Construction at Westlands

Fig. 22—The First Development Batch Wessex Painted in Anti-Submarine Colours as at the S.B.A.C. Show in 1958

The first aircraft was used initially for handling and engine development, and is now fully instrumented for a study of temperature and airflows in the radio and electric bays. The latter being directly over the engine, obviously need special attention to keep them at suitable temperatures. The second aircraft is now being used for engine development, and the third is being prepared for delivery to Boscombe Down for a 'preview' after which it will be used for strain gauging and main rotor system.

The fourth aircraft is being used for trials of the I.P.N. starter system. This is to be followed by 100 hours intensive flying with the new 7/1 ratio main gearbox. In addition, XL 722 is being fitted with Westland built transmission, and with a production E.C.U. installation, for a 150-hour ground run, as a form of endurance test. When both these tests have been completed, the standard M.O.S. helicopter type test, consisting of 100 hours ground running and 50 hours flying, will be carried out. All the rotating parts are dimensionally checked before and after the type test to measure the extent of the wear produced during the test. This is both to enable the life of the various components to be assessed, and to show up where modifications may be necessary. Boscombe Down will also have an aircraft for intensive flying. All this will be done before the R.N. Intensive Flying Trial is started, and should help to ensure that the latter is a success.

The rest of the twelve development batch aircraft will be used according to a detailed programme which covers all the aspects of the development up to a full C.A. Release Standard. Nothing comparable with this programme has been carried out on previous helicopters at such an early stage, so that everything possible is being done to ensure that the Wessex achieves a high standard of reliability from the outset of its introduction into service.

CONCLUSION

The foregoing has described, in an inevitably patchy fashion, the present 'state-of-the-art' of producing an all-weather anti-submarine helicopter to meet the Naval Staff Requirement N.A.43. It will be seen that good progress has been made in the last few years, but that there are also many problems still to be overcome. Some of these, such as automatic throttle control, and the electronic aspects of the system, have only been touched on. Others, such as the problem of rotor de-icing, have not even been mentioned. (A trial installation of the latter will shortly be started).

It is not suggested that there is anything essentially new here, either in the type of problem, or how it has been or is being overcome, but it is hoped that it will have given some idea of the broad picture of the project, which it is essential that the Project Officer should have at his finger tips. The remarks concerning Anglicization may also be increasingly applicable to other projects, in different fields, in the years to come.

Acknowledgment

The Author wishes to thank the Westland Aircraft Ltd. for providing many of the photographs and the graphs in FIGS. 11 and 15.

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