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IN THIS ISSUE:

Speed Without Tears or Fears

HOW pleasant and flattering it is to hear the thoughts of a great scientist revealed—to be taken into his confidence, as it were—in such a way that one can follow his arguments and understand clearly and without difficulty the points made. So many aviation matters of general interest today, if examined more than superficially, seem to blind the average man with science. The faculty of describing a complicated subject in simple terms is generally a good indication of the real stature of the authority concerned.

Sir Arnold Hall, Director of the Royal Aircraft Establishment, is unexcelled in his ability to marshal scientific facts, to produce them both related and in their true perspective and, as a result, to present a clear, concise exposition of his subject. No better example could be found than that provided by his Brancker Memorial Lecture, recorded on pages 211-214 of this issue. This paper sets out—more thoroughly yet more plainly, we believe, than any before it—the considerations and possibilities with which designers are concerned in their preparations for the next generations of airliners. It may help a great many people to form a truer picture of the future of air transportation because, as we have indicated, it is a review at once readable and instructive for anyone interested in aviation—as, in fact, all must be to some extent in view of the influence of aviation upon their lives.

We have been privileged to discuss some of Sir Arnold's views and calculations with him, and have noted that some other authorities are not entirely in agreement with his predictions. We believe we detect in his lecture a slight (a tactful, perhaps) toning-down of his opinions on the advantages of pure-jet transport; but there is no doubt that he has been very little influenced by the tremendous swing of American opinion—and in fact, world opinion—in favour of the more conservative turboprop type. At the beginning of his lecture he says: "Apart from remarking that I believe that the turbojet type can be designed for comparably cheap operation at speeds substantially higher than the turboprop type, I will leave the argument as to which layout and powerplant is to be proclaimed the best to the protagonists of particular arrangements . . ." It is perhaps pertinent to recall Sir Arnold's confidence during his evidence at the Comet Inquiry (a summary of the Inquiry report appears on pages 193-195) that the Comet problems could be resolved and that the aircraft would fly again. The re-establishment of Comets (2s and 3s) in passenger service—most welcome in itself—will, we believe, prove the setback suffered by the jet airliner cause to be no more than a temporary one.

Of supersonic transport aircraft Sir Arnold says in his lecture: "It seems to me likely that the development of long-range supersonic aviation will follow the exploitation of the high-subsonic possibilities. The influence of the higher annual earning capacity which increase of speed represents is a potent one; and whilst, on present knowledge, it is offset in the overall economic picture by lower aerodynamic efficiencies in supersonic, as compared with subsonic, conditions, only small changes in the aerodynamic position are needed to allow it to reassert its dominance." To the often-asked question "Why faster?" Sir Arnold therefore gives the convincing answer, "A better service at a lower cost."

Before recommending readers to study this lecture for themselves, we may draw attention to certain other very important points, the soundness of which will appeal to the general public, the aircraft industry and the operators alike, even though the last-named may find it difficult to choose precisely between revenue and popularity at a time when it is most difficult to show operating profits. Sir Arnold states: "Some part of the inherent economy should, I think, be given to features which will increase reliability and safety, rather than that the last ounce should be taken in cruising economy. I think that the most important of such features is the reduction in the landing approach speed of aircraft . . . This has a considerable influence on the ability of the aircraft to land safely in conditions of bad visibility." He adds, "It is likely to prove good business—in terms of reduction of bad weather diversion and accident rate—to design for lower approach speeds."

While some of us feel, like Sir Arnold Hall, that approach speeds should be reduced, others think that it is sufficient to peg them at present figures; on the other hand, competition may sorely tempt operators to "misuse" impending lift-increase devices in order to carry greater payloads at higher wing loadings.

FROM ALL QUARTERS

More Britannias?

NO harm has come of recent criticisms (direct or implied, and mostly unjustified) of the Bristol Britannia airliner and its progress. In fact, the answering of questions and the discussion of planning and progress have helped the aircraft and placed it in a stronger position in the public esteem. There now seems less reason than before for B.O.A.C.'s proposal to order Douglas machines. Each additional large aircraft ordered from America means one fewer bought in this country, for it is not extra to the total of such machines which the airlines of the world can absorb.

Present orders for Britannias—25, plus ten on option, for B.O.A.C., and six at letter-of-intent stage for Qantas—must now be increased if production is not to be interrupted later on. Thus a decision is likely to be announced in a day or two to order materials and proceed with the manufacture for an additional batch of Britannias. A small pilot order of perhaps two or three aircraft is likely to be placed by the Ministry of Supply, and the Bristol Aeroplane Company and Short Brothers and Harland, Ltd., will show their faith in the Britannia by backing the remainder against new orders expected by the time the aircraft are taking shape. It will be recalled that in August, last year, Bristols acquired shares in Shorts, nominated two extra directors, and embarked on a programme of mutual collaboration.

The Ministry's order for Britannias would no doubt be for the Mk 250 L.R. for troop transportation. This is the type for which manufacturing plans are in hand at Belfast. In round figures, a Britannia, according to mark and without spares, costs between £650,000 and £850,000.

Bell's Convertiplane

EARLIER this month, as we recorded last week, the Niagara Division of the Bell Aircraft Corporation unveiled their vertical-jet-lifting prototype. On February 10th it was the turn of the company's helicopter division at Fort Worth, Texas, to reveal a wholly new development—in this case the Bell XV-3 convertiplane.

The company president, Larry Bell, visualized such an aircraft as long ago as 1943, but it was not until 1951 that the company was enabled to start actual design. In that year Bell was awarded a joint Army/Air Force contract for the development of a convertiplane for the Army. This machine has now materialized as the XH-33 or, as it is now designated, XV-3.

Basically the Bell XV-3 is a combination fixed- and rotating-wing aircraft combining many of the advantages of the fixed-wing aircraft with those of the helicopter. It is powered by a single Pratt and Whitney engine (probably a Wasp) mounted just behind the small constant-section wing. The engine drives a gearbox and transmission supplying power to a pair of airscrew/rotor units mounted at the wing tips.

For vertical take-off the screws are used as rotors with their axes vertical, and the aircraft takes off and gains altitude in normal helicopter manner. It is then accelerated horizontally in the usual way and, at a given basic forward speed, the rotors are tilted forward through approximately 90 deg until they are acting as conventional airscrews. During this conversion process, which requires 10 to 15 seconds, the lift is transferred from the rotors to the wing. In full forward flight the pilot changes the gear ratio between the engine and screws, thus making possible improved high-speed performance.

It is claimed that there are no abrupt changes in attitude or flight characteristics during conversion from vertical to forward flight and that full control is maintained throughout. Transition to forward flight can be stopped and reversed at any time and, in the case of engine failure, a return to helicopter configuration can be made preparatory to an auto-rotative landing.

The XV-3 is a four-seat aircraft which should be capable of performing a multiplicity of Army duties including all those at present undertaken by helicopters. The speed limitation of the XV-3 is predicted as greater than 175 m.p.h. and, in commercial use, Bell foresee the convertiplane (as a class) becoming supreme over stage-lengths from 100 to 750 miles. The XV-3, which measures 30ft in length and span and is 13ft high, is looked upon as a valuable prototype which may precede more advanced variations on the same theme. The present prototype, which is illustrated on page 202, is scheduled for exhaustive tied-down testing prior to flight testing in the spring.

America and Air Superiority

THREE pitfalls to be avoided in planning the maintenance of qualitative superiority in air weapons were enumerated by the Hon. Roger Lewis, U.S. Assistant Secretary of the Air Force (Material), in a speech at the recent honours night dinner of the Institute of the Aeronautical Sciences. The first, he said, was poor conception, and by this he meant the technical results of *inadequate military requirements*. The second was *indecision*; here he referred to the absolute necessity of ruthlessness in terminating sterile or outdated projects. The third was unstable weapons planning and control; Mr. Lewis pointed out that the U.S.A. would never be ready for an emergency if planning was done on the basis of the ebb and flow of political events rather than on fundamental technical developments.

The Assistant Secretary proclaimed his faith in the weapons-system concept, which he thought was an essential policy in view of the great complexity of modern weapons. He went on to say that the rapid rate of change of the technical situation presented the greatest problem to defence planners, whose minds were continually exercised by the possibility of unforeseen development. Pointing out the great difficulties of the rapid exploitation of research, he quoted the example of the steam engine, the fundamental concept of which was born in 1736 but was not applied to locomotive traction until 1836 [In the United States—Ed.]. Jet engines were running on both the opposing sides in World War II before the war began, yet effective jet aircraft were not in operation until after the war was over; Germany's failure to exploit her technical developments was one of the outstanding features of this war.

Dealing with the present situation, Mr. Lewis pointed out that the United States possessed only seven per cent of the world's population and six per cent of the world's land mass, and said in this connection that she must not fall into the error of taking comfort from an imagined technical superiority.

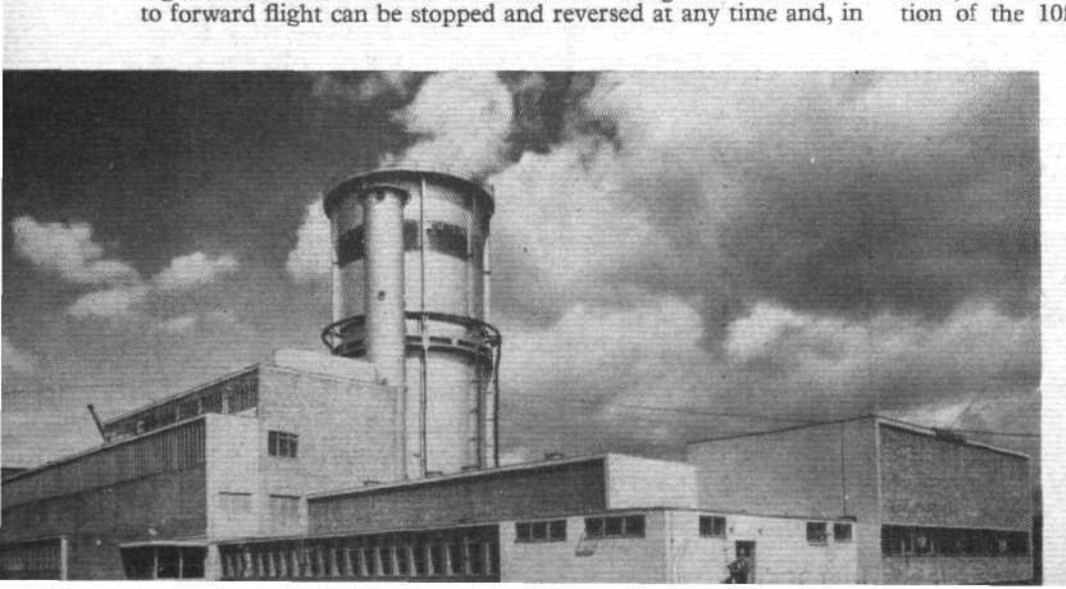
National Wind Tunnels

THIS country's largest supersonic wind-tunnel, with an 8ft × 8ft working section, flexible walls, and absorbing some 80,000 h.p., should begin operation later this year. Designed for airspeeds up to Mach 2.7, it is located at the National Aeronautical Establishment, Bedford, which last week (for the first time) was open for inspection by the press.

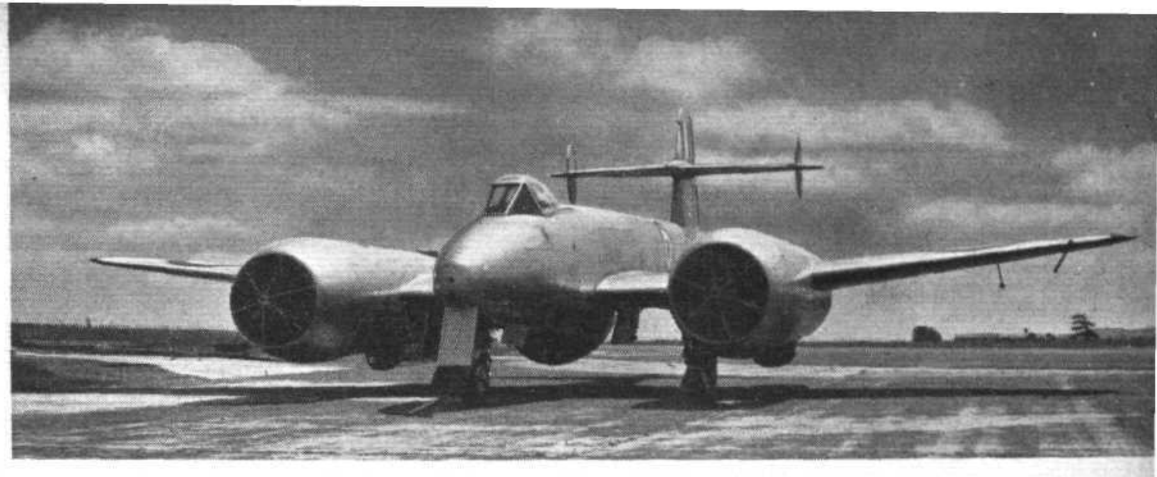
Among N.A.E.'s other facilities are a vertical spinning tunnel, of 15ft working-section diameter, which can be pressurized to four atmospheres; a 3ft supersonic tunnel which has been in use for the last five years; and a 13ft × 9ft low-speed tunnel.

Wind-tunnels at the R.A.E., Farnborough, were also visited. Here, one interesting development in progress was the modification of the 10ft × 7ft "high-speed tunnel" (used since 1942 for speeds up to Mach 0.95) to form an 8ft × 6ft transonic tunnel capable of Mach 1.2.

The highest speed attainable in the tunnels visited was Mach 4.8, approximately the limit of conventional-type tunnels due to the liquefaction of air at those speeds. Tunnels capable of speeds up to Mach 9 (using air heated to 600 deg C) are now being designed, however, and shock-tube and other techniques are expected to reproduce conditions of flight at Mach numbers of from 10 to 20. A full description of the Farnborough and Bedford facilities will appear next week.



***BEDFORD BLOW-TUBE:** Rising above the high-speed laboratory at N.A.E., Bedford, the new vertical spinning tunnel is typical of the establishment's impressive facilities (see "National Wind Tunnels").*



***FIRST WITH DEFLECTION:** Westland-converted to M.o.S. order, this experimental Meteor is the first British machine to employ jet deflection. It flew nearly a year ago, with S/L. L. de Vigne at the controls. The turbojets are R-R Nenes, and the deflected jet-pipes, just visible under the nacelles, exhaust beneath the cs. of g. (Another photograph appears on page 214.)*

Jet-deflector Meteor

IT may now be revealed that a jet-deflection aircraft has been flying in this country for ten months past; the machine concerned is an experimental Meteor fitted with Rolls-Royce Nene turbojets. The work of conversion and installation of the deflection units was carried out by Westland Aircraft, Ltd., under a Ministry of Supply contract, and it was a Westland pilot, S/L. Leo de Vigne, D.S.O., D.F.C., A.F.C., who first flew the aircraft at Boscombe Down last May and subsequently completed ten hours' testing.

The deflection boxes themselves were designed and constructed at the National Gas Turbine Establishment at Farnborough, whither the aircraft has now returned. The R.A.E. will continue with the experimental flying and development work. In the accompanying photograph it can be seen that the deflector jet-pipe protrudes from beneath the engine nacelle at approximately the mid-way point. This is to enable the thrust to act through the centre of gravity. The normal engine jet-pipe is also, of course, retained.

Some readers may recognize this particular Meteor, serial RA490, as a much-converted Beryl flying test-bed. The tail is now, however, that of a Mk 8, to which has been added small extra fin surfaces reminiscent of the Wyvern and the Trent-Meteor in earlier days.

In the course of his experimental flights, S/L. de Vigne has discovered that the deflection of the jet stream considerably reduces the stalling speed of the aircraft and, for example, with 60 per cent of full thrust deflected on the approach, the safe speed can be reduced by as much as 20 per cent. The pilot has a selector switch, on the port side of the cockpit, for operation of the deflector mechanism under hydraulic power.

Advantages to be gained from jet deflection have been listed as follows: (1) an aircraft can take off and land using shorter runways than hitherto; (2) the speed range can be substantially improved; (3) it is possible to produce an aircraft of smaller dimensions for a given all-up weight (saving structure weight, cost and raw materials); (4) for the pilot, it is easier to carry out an approach without changes of airspeed or attitude; (5) rate of descent can be quickly checked, or converted to climb, with little tendency to increase forward speed.

No Monopoly in Trouble

ALTHOUGH the proverbial blacks do not make a white, it is worthy of note that two of *America's* finest and most important new military aircraft have both been in trouble recently. One is the Boeing B-52A strategic heavy bomber, which is in production at Seattle and will be produced at Wichita. The chairman of the Senate Armed Services Committee, Mr. Richard Russell, testified on February 10th that the B-52 had "developed faults which have slowed down its delivery to the U.S.A.F."

The other is the North American F-100A Super Sabre. Last autumn a number of F-100s were completely destroyed, one such occurrence resulting in the death of A. Cdre. G. D. Stephenson, Commandant of the R.A.F. Central Fighter Establishment, and another killing George Welch, the test pilot principally responsible for the F-100. It was possibly the latter accident which provided the key to the problem: the machine concerned had dived from 40,000ft to 23,000ft (near Los Angeles) when it disintegrated in the air.

Early in November an order was issued grounding all F-100As in U.S.A.F. service, while weeks were spent collecting and examining fragments of the stricken machine and its instrumentation. Only when a slightly-damaged oscillograph film record was recovered was the solution exposed: the F-100 had experienced what Mr. Ray H. Rice, North American's engineering vice-president, described as "a high, nose-dive yaw" to an unprecedented angle, resulting in accelerations of at least 7g at a true airspeed of over 800 m.p.h. This condition, described by Mr. Rice as due to "aerodynamic phenomena never before experienced by man" exceeded the design limit of the aircraft.

North American have now designed a number of important modifications, which are being retrospectively made to the 100-plus machines already built. Early this month the grounding order was lifted and, following the alterations, the F-100A is claimed to be "on the brink of new high performance".

Even the well-tried Martin B-57 (Canberra) has just been grounded—by the makers—following two recent accidents.

REPORT OF THE COMET INQUIRY

THE report of the Public Inquiry into the accidents to Comets G-ALYP and G-ALYY was published* last Saturday, February 12th. Both accidents occurred over the Mediterranean, G-ALYP being lost on January 10th, 1954, and G-ALYY on April 8th, 1954. Simultaneous public inquiries into the accidents were held in London between October 19th and November 24th, with Lord Cohen as Commissioner and Sir William Farren, Professor W. J. Duncan and A. Cdre. A. H. Wheeler as assessors. Lord Cohen's report was submitted to the Minister of Transport and Civil Aviation on February 1st, 1955; it bore the signatures of all three assessors, indicating their agreement with its contents.

The major findings of the Court were that the cause of the accident to G-ALYP was structural failure of the pressure cabin, brought about by fatigue; that the cause of the accident to G-ALYY could not be definitely established, but that the explanation offered for the first accident appeared to be applicable to the second; and that neither accident was due to wrongful act, default or negligence.

The greater part of the report deals with the accident to G-ALYP, which, while operating a scheduled B.O.A.C. service from Rome to London, descended into the Mediterranean off Elba with the loss of all 35 persons on board.

Dealing first with the history of the Comet project, the report notes that in order to provide the aircraft with an economically satisfactory payload and range it was essential that its cruising height should be upwards of 35,000ft—double that of airliners then current—and that the weight of the structure and equipment should be as low as possible. The manufacturers gave special attention to the structural integrity of the pressure cabin, since the difference ($8\frac{1}{4}$ lb/sq in) was about 50 per cent greater than that in general use. For the design of the basic cabin structure they adopted a multiple of the working pressure difference—referred to in the report as P—in excess of current requirements in any country. British and international airworthiness requirements called for a proof pressure of $1\frac{1}{3}$P (under which the cabin must show no signs of permanent deformation) and a design pressure of 2P (at which the material might reach its ultimate strength), whereas de Havillands used a design pressure of $2\frac{1}{2}$P and tested the cabin to 2P. They did so because they believed that a cabin which would survive undamaged a test to double its working pressure would not fail as a result of pressure fatigue, and also to ensure a larger margin of safety against the possible failure of windows, door and hatches.

Two test sections of the cabin were built. The front part, 26ft in length, was pressurized to between P and 2P some 30 times and "rather over P" 2,000 times—not to test the fatigue-resisting properties of the structure, but rather to provide assurance that it would be satisfactory as a pressure vessel. Simultaneously with this design and testing, all other parts of the structure received treatment based on the same outlook—"design to at least the current requirements, coupled with exhaustive tests".

Until about the middle of 1952, the report states, the likelihood that the fatigue-resistance properties of the pressure cabin demanded further precautions than were provided by the current static-test requirements had not been realized. In June 1953 the A.R.B. issued a paper calling for repeated applications of load (15,000 times $1\frac{1}{4}$P) in addition to the static tests; the paper also suggested that such parts as door and window frames might have to be designed to 3P. In July 1953 de Havillands undertook repeated loading tests of the test section previously referred to, which extended from the nose nearly to the front spar of the wing; the working pressure P was applied about 16,000 times. The tests were ended by a failure of the skin due to fatigue in a corner of a window, originating in a small defect in the skin.

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REPORT OF THE COMET INQUIRY . . .

But, says the report, the number of pressurizations sustained was so large that, in conjunction with the numerous other tests, it was regarded as establishing the safety of the Comet's cabin with an ample margin.

Meanwhile (on May 2nd, 1953) Comet G-ALYV had crashed in a tropical storm of exceptional severity near Calcutta. Fatigue failure of the cabin was not then suspected as a cause and, in the Commissioner's opinion, subsequent evidence afforded no reason for doubting the conclusion of the Indian Court of Inquiry—i.e., that the accident was caused by structural failure resulting from severe gusts, or over-controlling or loss of control by the pilot.

The report next considers the circumstances of the accident to G-ALYP off Elba. Immediately on receiving news of the accident, B.O.A.C. had suspended Comets from passenger service for the purpose of making a detailed examination of the aircraft in collaboration with the A.R.B. and de Havilland. To this end a committee was set up under the chairmanship of Mr. C. Abell, deputy operations director (engineering) of B.O.A.C., and composed of representatives of the A.R.B., B.O.A.C. and de Havilland. This committee decided that possible main causes of the accident were as follows:— flutter of control surfaces; primary structural failure with particular emphasis on the possibility of abnormally high loads caused by gusts; malfunctioning of the power controls; fatigue; explosive decompression; and engine trouble, with particular emphasis on possible causes of fire. As a result of the inspections and tests which followed the meetings of the committee a large number of modifications were made. The possibility of wing fatigue was regarded as much more likely than pressure-cabin fatigue, and the only recommendations specifically directed to fatigue related to the wing. One modification and two special inspections were called for. At about the time of the Elba accident, the report notes, cracks had appeared near the edge of the wheel wells on the under-surface of the first prototype Comet wing, which was then under test at Farnborough, after the equivalent of about 6,700 flying hours.

On February 19th, 1954, the chairman of B.O.A.C. forwarded to the Minister of Transport and Civil Aviation a report on the inspections, investigations, modifications and other work carried out as a result of the Abell Committee's meetings; he stated in a covering letter that, on the assumption that no further indication of the cause of the accident emerged before completion of the inspection and modification work, B.O.A.C. considered that all such steps as were possible before putting the aircraft back into passenger service would have been taken. Lord Brabazon, chairman of the A.R.B., wrote to the Minister on April 4th that "when these modifications are completed and have been satisfactorily tested the Board sees no reason why passenger services should not be resumed."

Meanwhile, the Minister, who had not revoked the Comet's C. of A., asked the Air Safety Board for advice on the resumption of Comet services. He received a reply on March 5th from Sir Frederick Bowhill, chairman of the A.S.B., recommending that Comets should return to service after incorporation of modifications and flight testing. The Minister accordingly gave permission for flights to be resumed and the first Comet to return to passenger work took the air on March 23rd.

Decision to Tank-test

Comet G-ALYY, operating a S.A.A. service from Rome to Cairo, was lost near Naples on April 8th, 1954, whereupon the Minister of Transport and Civil Aviation, having announced the withdrawal of the Comet's C. of A. on April 12th, instructed Sir Arnold Hall, the Director of the R.A.E., to use all the resources at his disposal to perform a complete investigation of the whole problem presented by the accidents. On April 18th Sir Arnold decided, as one of a number of lines of inquiry, to conduct a repeated-loading test of the whole cabin in a specially built water tank at Farnborough. The R.A.E.'s interest in the possibility of pressure-cabin failure was influenced chiefly by the apparent similarity of the circumstances of the two accidents (each of which had occurred as the aircraft neared the top of its climb) and by the fact the post-Elba modifications seemed to rule out many other possible causes.

Repeated-loading tests on Comet G-ALYU began early in June. Fluctuating loads were applied to the wings and one application of cabin pressure was applied for each simulated flight. At intervals of approximately 1,000 "flights" there was a proving test in which the pressure was raised to 1⅓P (11 lb/sq in). Before the test Comet YU had made 1,230 pressurized flights, and after the equivalent of a further 1,830 such flights the cabin structure failed, the starting point of the failure being the corner of one of the cabin windows. The fact that it failed during one of the proving tests at 11 lb/sq in was not thought to be significant, since the crack would have spread in much the same way after a few more applications of working pressure.

Certain sources of fatigue—e.g., vibration due to irregular airflow, vibration due to engines and jet efflux and fluctuating loads occurring during take-off and landing—could not be reproduced in the tank test. For this reason it was clear that a test fuselage would have a longer fatigue life than one in actual service, and it was estimated that YU's life of 3,060 flights might be equivalent to about 2,500 in practice.

The first inference suggested by the tank test was that the primary failure of G-ALYP was the bursting of the pressure cabin; this was confirmed by a close examination of the wreckage. Experiments were conducted to discover the probable path of fragments after disintegration caused by pressure-cabin failure, and as a result of these experiments the salvage operations off Elba were re-orientated.

The second inference of the tank test was that the pressure cabin had a much shorter fatigue life than previously estimated. Accordingly G-ALYU was repaired and again subjected to pressure, but this time with strain-gauges fixed near corners of typical windows. It was found that the general level of the stress in the skin in these regions was significantly higher than had been previously believed.

Experience suggested that there would be a variation of at least 9 to 1 in the number of cycles necessary to produce failure when the general level of stress was high, and the number of cycles undertaken before failure therefore low. At the time of the Elba accident YP had made 1,290 pressurized flights and at the time of the Naples accidents YY had made 900 pressurized flights. Dr. P. B. Walker, head of the aircraft structures department, R.A.E., did not regard the picture presented by the three failures (on the assumption that all were due to the same fundamental cause) as surprising; the number of loadings applied lay within a range of 3 to 1, compared with the possible 9 to 1 "scatter."

As a result of the new search 70 per cent of the empty weight of the aircraft was recovered by August 21st. Among the last pieces of wreckage to be recovered were fragments giving important evidence about the bursting of the cabin. Marks made by portions of the cabin were found on the port wing, establishing that the cabin burst catastrophically in the neighbourhood of the front spar when the aircraft was flying substantially normally.

The report accepts the R.A.E.'s conclusion that the first fracture occurred near the rear A.D.F. window and spread forward and aft from it. There were two potential starting points for the fatigue crack: a countersunk hole, at a point showing evidence of fatigue, near the starboard aft corner of the window; and a "located" manufacturing crack (i.e., a crack drilled at its ends to prevent spreading) near the port forward corner of the same window. "I do not consider it possible," Lord Cohen states, "to establish with certainty the point at which the disruption of the skin first began"; but since the existence of fatigue near the countersink was established this was the more probable point.

The report outlines the history of the recovery and investigation of G-ALYP's four Ghost engines. It accepts the conclusion of Dr. E. S. Moult, chief engineer of the de Havilland Engine Co., that there was no failure of any part of any engine which could have been the cause of the accident.

Turning to the question of the cause of the Elba accident, Lord Cohen states that he has accepted the main conclusion of the R.A.E., namely that the cause of the accident to G-ALYP was the structural failure of the pressure cabin brought about by fatigue. He then deals with suggestions that other causes might have brought about the accident.

Mr. J. Jablonsky contended at the inquiry that failure of the Redux bonding used in the construction of the Comet might have caused disruption of the cabin. The Commissioner states that for reasons set out in the report he has no hesitation in rejecting Mr. Jablonsky's theories.

The chief technical officer of the A.R.B., Mr. Walter Tye, said at the inquiry that he was not entirely satisfied that fatigue was the cause of the cabin failure. He appears, the report says, to have been impressed by the improbability of both YP and YY failing from fatigue after only 1,000 flights when YU achieved the equivalent of 3,000 flights. He was unable, however, to suggest any alternative cause of failure. Lord Cohen writes that Mr. Tye's caution is understandable, as he will be responsible for advising the A.R.B. when an application is made for a new C. of A. for Comet aircraft; but the report adds: "I have the duty of expressing my conclusion on the evidence . . . I have unhesitatingly come to the conclusion that the R.A.E. were right."

The report also rejects the possibility that the accident was caused by over-pressurization of the fuselage or of any of the defects uncovered in the R.A.E. investigation—i.e., fatigue weakness in the wing skin; weaknesses in the fuel system causing possible escape of fuel during take-off or climb or during refuelling; or possible cracks in the cabin skin caused by buffeting from the jet efflux.

Constructors Absolved

The next part of the report, which has the heading "Responsibility", deals first with suggestions that the de Havilland tests were inadequate to prepare against the risk of fatigue in the cabin structure. Lord Cohen expresses satisfaction that the manufacturers were proceeding in accordance with what was then regarded as good engineering practice; that they could not be blamed for not making greater use of strain-gauges than they actually did; or for believing that the static test that they proposed to apply would, if successful, give the necessary assurance against the risk of fatigue during the working life of the aircraft. These views are endorsed by the assessors in a separate memorandum.

Another criticism of de Havillands concerned the repeated-loading tests carried out by the firm in 1953. Sir Arnold Hall had offered an explanation of the discrepancy between the short life of YU and the results of the 1953 test, pointing out that the latter were carried out with a nose section which had previously been subjected to static tests up to a differential pressure of 16½ lb/sq in; the effect of pre-loading might be to prolong the life of the specimen. Mr. R. H. T. Harper, de Havilland's chief structural engineer, had been aware of this possibility, but considered that the test so amply covered the life of the aircraft both at the time of the tests and for the immediate future that de Havillands could safely accept it as satisfactory. In the then state of knowledge, the report finds, this conclusion was reasonable.

It was also suggested at the Inquiry that some responsibility ought to attach to de Havilland for allowing aircraft containing manufacturing cracks to be put into service since such cracks had been shown to act as foci for fatigue. Observing that public concern may have been aroused by what was said at the inquiry, the report states: "it is important that groundless fears should be allayed". It was general experience that certain parts of aircraft structures developed cracks in service; cracks which occurred during manufacture did not differ materially from those which developed subsequently save that their presence might indicate an unsatisfactory manufacturing process. It would hardly be practicable to insist on a standard of design and construction which would preclude completely the possibility of any crack in the skin.

The report notes that the action taken in locating cracks in YP would have been appropriate had the stresses been as low as de Havillands believed them to be; it was, in fact, inappropriate, as there were high stresses in the region concerned, but de Havillands were not aware of this and therefore no responsibility attached to them.

Commissioner's Recommendations

"The duty is imposed on me," Lord Cohen writes, "of making such recommendations as I think fit with a view to preservation of life and the avoidance of similar accidents in the future." In this task he had been greatly assisted by statements as to future policy made at the Comet inquiry by Sir Lionel Heald, on behalf of the Attorney-General, and by Sir Hartley Shawcross, on behalf of de Havillands. [These statements, published in issues of *Flight* for November 19th and December 3rd, are attached to the report as appendices.]

To ensure a safe life well above the minimum economically acceptable to an operator, methods would have to be devised to ensure that design, combined with a reasonable programme of tests, could guarantee that the pressure cabins of transport aircraft would be entirely safe. Knowledge acquired as a result of the Comet investigations strongly suggested that steps should be taken to determine by calculation, by tests of typical parts of the cabin, and by test on one or more complete cabins, the distribution of stress throughout the structure in considerable detail; and the influences which determine both the highest static load which it will sustain and its life to failure under repeated loading.

"When these methods have been applied," the report adds, "and the tests completed, de Havillands will no doubt ask A.R.B. to recommend the grant of a Certificate of Airworthiness to the re-designed Comet aircraft. It would not be desirable for me to say anything which might in any way limit the discretion of A.R.B. but I may perhaps appropriately express the hope that this procedure will reassure the public as to the integrity of pressure cabins and will justify Sir Arnold Hall's confidence that the Comet aircraft will fly again."

Acting on the advice of his assessors, Lord Cohen adds a recommendation for further Comet tank-testing at the R.A.E., with the most comprehensive exploration of stress distribution. Such a test would serve two valuable purposes: it would clear up such uncertainties as remained from the inquiry and, in conjunction with the tests already made on YU, would provide invaluable information for the design of future pressure cabins.

The report points out that a pre-loaded cabin is physically different from a new one if the pre-loading has exceeded a certain level. This phenomenon occurred when material in the more highly stressed regions was loaded beyond the point where it remained elastic. There were examples of deliberate use of this process to improve resistance to fatigue. It might be used in such structures as a pressure cabin though there were obvious difficulties, not to say dangers, in applying it. Nevertheless, the subject should undoubtedly receive more study, if only to ensure that tests during design were not rendered unreliable by failure to appreciate its significance.

Before giving his answers to the questions submitted at the end of the inquiry by the Attorney General, Lord Cohen dealt briefly with two suggestions placed before the court. The first, dealing with a proposed change in the system whereby the A.R.B. delegates to manufacturers responsibility for the inspection of aircraft parts, is rejected in the report, which concludes that the present system is essentially satisfactory—though subject to human errors, "it has the beneficial effect of creating a sense of responsibility in manufacturers without which aircraft could not be designed and built to the requisite standard of reliability and safety."

It had also been suggested that A.R.B. flight-testing and aircraft approval would be made more effective if an active pilot were appointed to their Council, and if civil aircraft were sent to a Ministry of Supply test establishment for a wider assessment of their flying qualities. Lord Cohen agrees that consideration should be given to the second part of this suggestion, but states that "if an active pilot were to be appointed [to the Council of the A.R.B.] the post would have to be made a whole-time paid employment and it would not be long before he ceased to possess the qualifications upon which those who advocated the appointment laid stress."

In reply to the question "What was the cause of the accident?" the report answers: "The cause of the accident was the structural failure of the pressure cabin brought about by fatigue." To the question "Was the accident due to the act or default or negligence of any part or of any person in the employment of that party?" the report gives a negative reply. Other replies state formally that, except in that the flight engineer was not properly licensed (a point which, the report makes plain, was due to an oversight and had no bearing on the accident) the aircraft was properly maintained and operated in accordance with regulations.

Answers to the question "Upon consideration of all facts disclosed by this Inquiry what steps should be taken to increase the safety of civil aircraft?" are given in the body of the report, as summarized above.

The Naples Findings

The findings on the accident to G-ALYY, lost off Naples with all 21 persons aboard, take up only six pages of the report.

To the Attorney-General's question "What was the cause of the accident?" the report replies: "Owing to the impossibility of salvaging any appreciable part of the wreckage of the aircraft no positive answer can be given to this question, but the fact that this accident occurred in similar weather conditions, at approximately the same height and after approximately the same lapse of time after take-off from Rome as that to G-ALYP, makes it at least possible that the cause was the same as in that case. The state of the bodies recovered was, as in the case of G-ALYP, consistent with the accident being due to failure of the cabin structure owing to metal fatigue." In a previous paragraph, however, Lord Cohen had stated that it was impossible to be dogmatic that the incidental defects disclosed in the post-Elba investigations were not contributory causes to the Elba accident, and that "I am therefore glad to note that the future programme of action outlined by the de Havilland Aircraft Co. includes measures to deal with those defects."

Answering a further question, the report adds: "There was no evidence on which I could attribute the accident to the wrongful act or default or negligence of any party or of any person in the employ of any party."

Another reply notes that on arrival at Rome the aircraft was found to have a number of bolts missing from an inspection panel, and that an equal number of bolts found lying in the port wing were replaced and tightened. This defect did not affect the safety of the aircraft, and in all other respects the maintenance and operation of G-ALYY were satisfactory.

Under the heading "Responsibility", the report includes this passage: "Before deciding to authorize the resumption of the Comet passenger services the Minister of Transport and Civil Aviation consulted A.R.B. and A.S.B. Both of these bodies recommended that consent should be given. When they did so, there had been only one accident to a Comet aircraft for which no explanation had been furnished. According to the evidence it was certainly not the practice either in the United Kingdom or elsewhere to ground all aircraft of a type because of an unexplained accident to one aircraft of that type. The evidence indicated that steps had been taken to deal with what the experts then considered to be all potentially dangerous features. In these circumstances I am of the opinion that no blame can be attached to any one for permitting the resumption of the services."

A.O.P. 9 IN SERVICE HANDS: Auster A.O.P. 9s (Cirrus Bombardier), of which this is one of the first aerial photographs, are now being delivered. Recently, 150 hours' of intensive trials were completed very satisfactorily, in the course of which 1,150 landings were made on rough strips. At one stage the aircraft was given a tremendous hammering in the form of intentional heavy landings, during which the Dowty landing gear proved its ability repeatedly to withstand between 3 and 4 g.

HERE AND THERE

Demon Climber

A McDONNELL F3H-1N Demon single-seat all-weather fighter of the U.S. Navy is claimed to have climbed 10,000ft in 71 sec. As recorded in *Flight* of February 4th, a North American FJ-3 Fury recently attained 10,000ft in 73.2 sec.

Venezuela Negotiates

THE Venezuelan Defence Minister, Sr. Oscar Mazzel, has announced in Carcacas that negotiations have been opened for the purchase by Venezuela of de Havilland Vampires and Venoms. He added that his country wanted to buy British and American military jet aircraft to strengthen its air force, which already has Vampires and Canberras.

Fuel for the "Furnace"

IT is learned that the Leduc 0.22 supersonic ramjet prototype, referred to recently by its new soubriquet "Flying Furnace," will carry 925 gallons of fuel and will fly at a gross weight of seven metric tons. Its ramjet powerplant should permit it to attain a height of 82,000ft in less than 5 min, and to achieve speeds of the order of Mach 2. The first of two prototypes is scheduled to fly in September.

Brazilian Fokkers

FLIGHT trials are under way on the first Fokker S.11 trainer built at the Galeao factory of Fokker Industria Aeronautica S.A., Brazil. Five machines of the type are to be built during the next twelve months for the initial training of Brazilian Air Force cadets. Fokker Industria Aeronautica S.A. is subsidized by the Brazilian Air Ministry under the terms of an agreement between the Brazilian Government and the Dutch Fokker works.

Louis Blériot Lecture

THE Royal Aeronautical Society announces that the Eighth Louis Blériot lecture is to be given in London on March 17th by M. Georges Hereil, honorary president of the Union Syndicale des Industries Aéronautiques, and director-general of S.N.C.A.S.E.; his subject will be *Making Aeroplanes Independent of Runways.* The lecture will be given at 6 p.m. at the Institution of Mechanical Engineers.

Provosts for Iraq

A CONTRACT has been awarded to Hunting Percival Aircraft, Ltd., for the supply of a "substantial number" of Provosts to the Royal Iraqi Air Force. The company points out that in signing this contract Iraq takes the lead among the Arab countries in adopting the training pattern of the R.A.F. They report that the Iraqi machines will be modified to carry a variety of under-wing stores, such as bombs and/or R.P.s, as well as two machine guns, a camera gun and dual sighting equipment.

Inside Story

FOG recently prevented a correspondent from leaving Bodö for Oslo by the normal air service. Offered a lift southwards by the G.O.C. Royal Norwegian Air Force, North Norway, in an R.N.A.F. Dakota, he accepted gladly. The Air Force freighter was carrying as cargo a Klemm Kl 35 two-seater, the wings of which were stacked along the fuselage, so the only vacant space which our correspondent could occupy was in the rear cockpit of the Kl 35 (in the other was a colonel). The flight to Sola, near Stavanger, was completed in five hours, and our correspondent wonders if he is the first civilian to land in two aircraft at the same time.

TAIWAN THUNDERJETS: Republic F-84Gs, like the section of four seen here heading out across the Formosa Strait, form the backbone of the tactical striking power of Chiang Kai-Shek's Nationalist Air Force.

Inter Alia

THERE is to be an aviation equipment section at the Canadian International Trade Fair which takes place at Toronto from May 30th to June 10th.

"Hot Secret"

INFORMATION concerning a D.H. air-to-air missile, published last month, was wrongly attributed to *American Aviation*; another U.S. journal was the source.

Kaman in Canada

FORMATION is announced of Kaman Aircraft of Canada, Ltd., as a wholly owned subsidiary of the Bloomfield, Connecticut, firm of helicopter manufacturers. The new company is located at St. Catharines, Ontario.

Canine Parachutists

MORE than 30 dogs—Alsatians and Labradors—are being trained for war duties with the Australian Army, mainly for detection of approaching enemies, for guard work, and for locating mines. On occasions the dogs will be dropped from aircraft, and for this purpose special harnesses are being developed, though in some cases baskets may be used. The parachute canopies will be of the same size as those used by the troops.

DESERT BATS: Now that restrictions on the supply of weapons to Egypt have been raised, Vampire F.B.52s are once more flowing into the desert airfields. Two are seen here at Hatfield in company with another de Havilland product—a Heron 2 for Turkish Airlines.

ROCKET PROPULSION for AIRCRAFT

Professor Baxter Discusses Prospects and Problems in R.Ae.S. Lecture

THE Saunders-Roe Club House at Cowes was the venue for a Royal Aeronautical Society "main" lecture given before the Isle of Wight Branch of the Society on the evening of February 10th. The lecturer was Professor A. D. Baxter, M.Eng., F.R.Ae.S., M.I.Mech.E., F.Inst.Pet., Professor of Aircraft Propulsion, College of Aeronautics, and his subject was that signified by the title above.

The successful development of the gas turbine for aircraft propulsion, said Professor Baxter, had stimulated much thought, some serious and a great deal speculative, on the possibilities of even more advanced forms of propulsion. The ramjet and the rocket had immediately sprung to mind. The former was a natural development of the turbojet; it could extend the useful field of the turbojet, but the bounds of that extension could be clearly seen. On the other hand, the rocket was not restricted by the same fundamental limitations, and its eventual, although still somewhat remote, exploitation in wider spheres could be prophesied with some confidence.

Before the 1939-45 war, the stage of development of the rocket motor was comparable with that of the internal combustion engine a century ago. Pioneers like Tsiolkovski in Russia, Esnault-Pelterie in France, Oberth in Austria and Goddard in America had laid down the basic theory and had made some small-scale experiments in support, but the first major practical steps had come from the Germans during the war. They had demonstrated the potentialities of rocket propulsion very effectively and had pointed the way to future developments. As a result, post-war progress had been greatly accelerated, but unfortunately much of it had been shrouded in secrecy. Nevertheless, it was probably fair to liken the present status of the rocket motor to that of the petrol engine in the early days of powered flight. The latter, only forty years ago, had been recognized as a practical, but comparatively inefficient, aircraft powerplant; its usefulness had been limited and its future possibilities, except as a weapon of war, had been no more than visions, rejected by the great majority.

It was not surprising, therefore, to find that only two main lectures of the Royal Aeronautical Society had been devoted to the subject of rockets. The first, by Perring, had reviewed the war-time German work, and the second, by Cleaver, had revealed some lines of development with particular reference to assisted take-off. The present paper endeavoured to follow up those earlier ones by considering the possible rôles of the rocket motor in the near future and by putting forward some of the problems which had to be solved before the more ambitious proposals could be achieved. The discussion would be confined to earth-bound piloted craft, although there was much in common both with guided-weapon propulsion and the requirements of interplanetary flight.

To determine the best uses of the rocket motor, said the lecturer, it was first necessary to consider its special features, particularly in relation to the corresponding characteristics of other propulsion units. They could be enumerated as (i) thrust practically independent of altitude and forward speed; (ii) thrust-weight and thrust/frontal area ratios very high; (iii) specific consumption very high.

Prof. Baxter illustrated the first and second features by figures

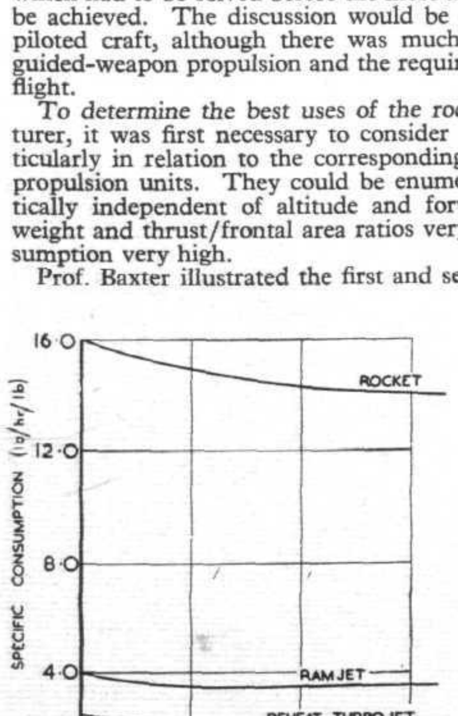


Fig. 1. Specific fuel consumption of high-speed powerplants at Mach 2.0.

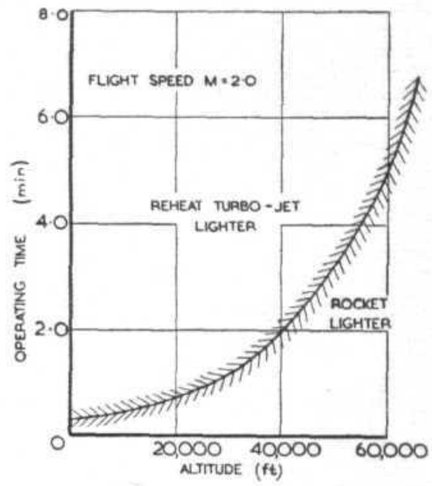


Fig. 2. Break-even times at which weights of rocket and propellant equal those of fully reheated turbojet (at Mach 2.0).

which compared the thrust per square foot of frontal area at varying forward speed and a constant altitude of 40,000ft for, respectively, the rocket and the air-swallowing engine. It was seen that in those circumstances the rocket had almost twice the thrust of the ramjet even at its peak performance, and approaching four times the best the turbojet could give with reheat to the maximum temperature. Another figure gave the same comparison for varying altitude and a constant Mach number of 2.0. The decreasing thrust of the air-swallowing engine became serious above 60,000ft, and very little net thrust was produced; in contrast, the rocket increased its thrust by 15 per cent or more. Near ground level the difference was not so marked, and a well-designed ramjet could give more thrust than the rocket. Generally, however, high supersonic flight speeds near the ground were unlikely, because of aircraft stressing considerations.

It should also be borne in mind, continued Prof. Baxter, that to obtain the optimum performance over a range of flight speeds called for variable intake-geometry and exhaust nozzle shape for both ramjet and turbojet. To do this might involve considerable extra weight and mechanical complication, and generally it would be preferable to design for a specified flight speed and accept a reduction in performance at other conditions. The rocket did not suffer intake problems at all, nor were exhaust expansion ratios affected by forward speed.

Present-day turbojets had weight/thrust ratios of about 0.3 at static sea level conditions, rising to 0.75 at 30,000ft and 3.0 at 60,000ft. Rocket motors, on the other hand, should be not more than 0.06 at all altitudes: that is, up to fifty times lighter than the turbojet. With reheat, the turbojet specific weight would be between 50 per cent and 66 per cent less. Little information on the weight of ramjets was available, and they were difficult to compare because of the large variation in thrust with forward speed. At sea level, $M=2$, they would probably be lighter than rockets, but at 60,000ft they would be eight to ten times heavier.

Showing (Fig. 1) variation of specific thrust with altitude for the various engines, the lecturer said it was at once apparent that this was the rocket's one serious drawback, making its use as a conventional powerplant almost impossible. This large propellant-weight penalty was, however, more than compensated by the low motor-weight for short times of operation, and Fig. 2 showed the running times and altitudes for which it had an advantage over the best that a reheated turbojet would give. Without reheat the "break-even" times would be approximately double those shown, and in both cases the time was increasing rapidly with height. Some virtue might be claimed, too, for the rocket because the final weight of an aircraft of the same initial weight would be much less than for the turbojet version.

In view of the limited time of operation for which the rocket gave a lower total weight, it might be asked why it should be considered at all. Unless it had some potential advantages, there was no case for it and, considered merely as one propulsion unit replacing another for straightforward flight, it obviously had a very limited claim. This direct substitution was a trap that, with other forms of engine, had caught designers more than once in the past; it was essential to compare units when each was installed in the most appropriate airframe and was using its optimum flight plan. For the rocket, this would demand new and unorthodox operating techniques.

The rocket's main advantages were that it could develop larger

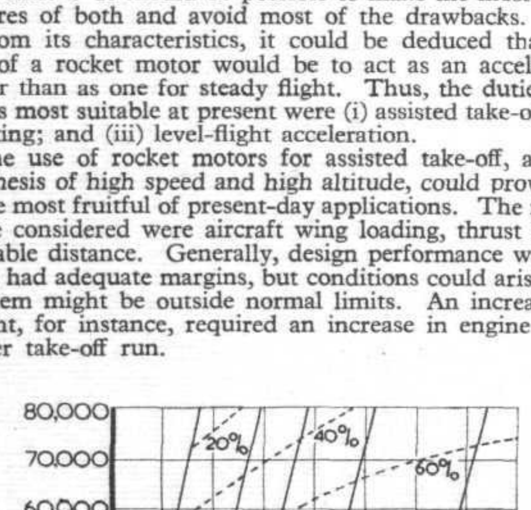
ROCKET PROPULSION FOR AIRCRAFT . . .

thrusts at greater altitudes and higher speeds than any other form of powerplant. There was an obvious military value in this, but it might be questioned whether civil aircraft performance from the earliest days showed how average speeds and operating altitude had followed the continually increasing records set up by specially prepared engines and aircraft. The fighter aircraft speeds had been the record speeds of eight to ten years previously, and bomber speeds had followed the fighters a few years later. In the past, too, civil transport had been close behind the bomber and was still continuing to follow on its tail. Extrapolating from the record curves might be an uncertain way of predicting the future, but there was no reason to assume that higher speeds and altitudes would not be attempted and successfully accomplished. When this occurred it would open the way for others to follow and the upward slope of all the curves would continue.

The lecture, said Prof. Baxter, was not the occasion for philosophical reasoning on the wisdom or foolishness of the constant striving after greater speeds; but he did remark on the trend which had existed since the earliest days, and which still continued, without any sign of stopping in spite of the so-called "barriers" which existed. The sonic "barrier" no longer presented the formidable problems of ten years ago, and no doubt the thermal "barrier" would diminish as it was approached, although the way in which it would be surmounted might involve quite unexpected techniques. For some time to come, the air-swallowing turbojets and ramjets would be able to provide sufficient thrust to drive aircraft at higher speeds, although the prospects for greater altitudes were limited. Eventually a stage would be reached where they would be restricted by stagnation temperature rise or by lack of air for combustion. At this stage a rocket motor would have to take over. This would be the ultimate field for the rocket motor, but many benefits might be obtained from it before that point had been reached if it was used in combination with the other powerplants, rather than in competition. It should be possible to make the most of the good features of both and avoid most of the drawbacks.

From its characteristics, it could be deduced that the main rôle of a rocket motor would be to act as an accelerating unit rather than as one for steady flight. Thus, the duties for which it was most suitable at present were (i) assisted take-off; (ii) climb boosting; and (iii) level-flight acceleration.

The use of rocket motors for assisted take-off, although the antithesis of high speed and high altitude, could prove to be one of the most fruitful of present-day applications. The main factors to be considered were aircraft wing loading, thrust loading and available distance. Generally, design performance was such that these had adequate margins, but conditions could arise where any of them might be outside normal limits. An increase in all-up weight, for instance, required an increase in engine thrust or a longer take-off run.



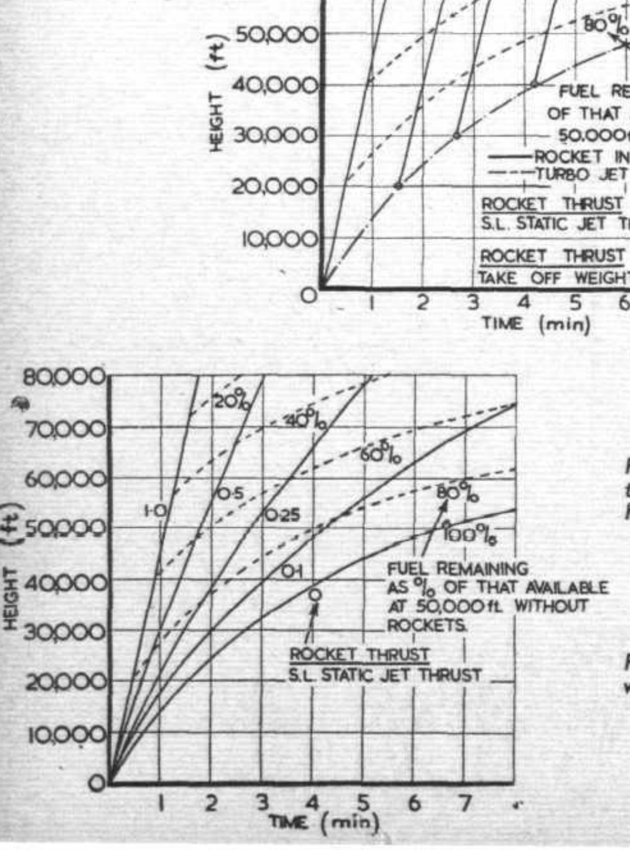


Fig. 3 (above). Climbing times, from various heights, with rocket assistance.

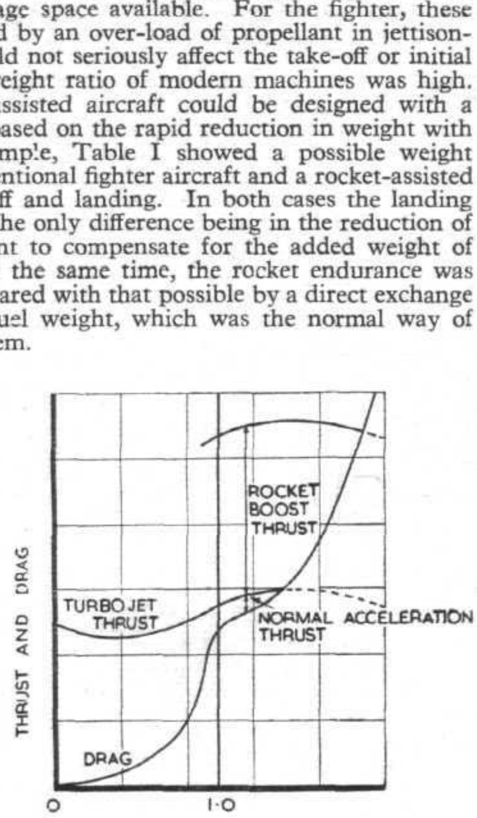
Fig. 4. Climbing times, with rocket assistance, at various thrust levels.

TABLE I: COMPARATIVE WEIGHTS OF SUGGESTED FIGHTER

Component percentage weight	Normal fighter		Rocket-assisted fighter	
	Take-off	Landing	Take-off	Landing
Structure	33	47	27	47
Turbojet	20	29	17	29
Rocket...	—	—	3	5
Fuel and propellant ...	30	—	42	—
Payload and equipment	17	24	11	19
Total	100	100	100	100

The use of the rocket motor for climb boosting might be considered as a prolongation of the assisted take-off case. Its main application should be to enhance the climb of military aircraft. The technique of using such a combination was a matter which, like the assisted take-off, could be altered to meet the requirements. The important consideration was the permissible operating time of the rocket, set either by the weight of propellant that could be carried or by tankage space available. For the fighter, these could be supplemented by an over-load of propellant in jettisonable tanks. This would not seriously affect the take-off or initial climb as the thrust/weight ratio of modern machines was high. Alternatively, rocket-assisted aircraft could be designed with a different philosophy, based on the rapid reduction in weight with flight time. For example, Table I showed a possible weight breakdown for a conventional fighter aircraft and a rocket-assisted fighter, both at take-off and landing. In both cases the landing weight was the same, the only difference being in the reduction of payload and equipment to compensate for the added weight of the rocket motor. At the same time, the rocket endurance was greatly extended compared with that possible by a direct exchange of rocket motor for fuel weight, which was the normal way of considering the problem.

Fig. 5. Effect of rocket thrust on aircraft acceleration and maximum speed.



The advantages of climb boosting were shown in Figs. 3 and 4, which gave typical climb curves and the relative amounts of fuel left with different operating techniques. In Fig. 3, a rocket motor thrust equal to the turbojet sea level static thrust was assumed, and it was started at various points in the climb. In all cases much greater altitudes could be reached than with the jet alone, and the time-to-height was small. As a result, the fuel available for level flight was less, but the reheated jet engine endurance need not be greatly different because the lower thrust at the higher altitude would require less fuel. An alternative boosting technique was given in Fig. 4, where rockets of different thrust ratios were provided and in each case operated throughout the whole climb. There was little difference in the performance between the two arrangements, both of which were assumed to start with a powerplant-plus-propellants weight of 60 per cent of the aircraft weight.

Acceleration in level flight was a function of aircraft weight and excess of thrust over drag. The variation of turbojet thrust (including reheat) and aircraft drag with flight speed was generally of the form shown in Fig. 5. The excess thrust diminished rapidly near sonic conditions and then remained comparatively constant to quite a high supersonic value. Thus, the maximum speed of the aircraft might be high, but its acceleration towards it would be quite slow. If rocket boost was applied during the acceleration, the thrust curves could be temporarily displaced so that the excess thrust available was an order of magnitude greater and, consequently, the time to reach the top speed greatly reduced. The effect of rocket boost in this case was shown in Fig. 6 for an acceleration from M=0.9 to M=1.3 at 50,000ft. Without assistance the jet engines required five minutes to reach the upper speed, but even a small rocket motor would cut the time to one minute. Because of this large difference in time, the total propellant consumption in the second case would be only about twice that of the reheated turbojet operating alone over the longer period.

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In addition to reaching the normal top speed rapidly, a continuation of the boost period would permit a much higher top speed to be attained, but this would, of course, entail a penalty in total consumption.

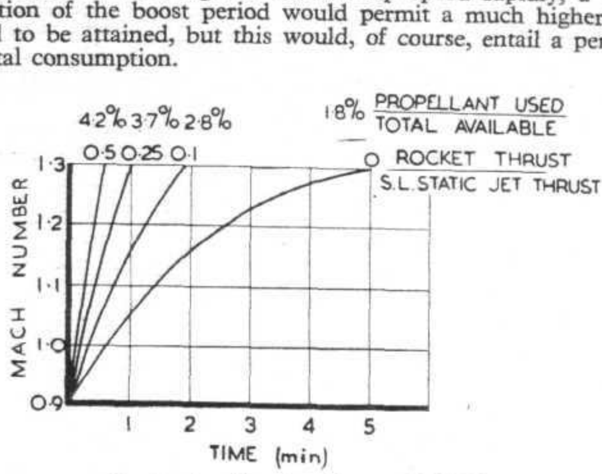


Fig. 6. Acceleration times at 50,000ft.

Near maximum speed, manœuvring was not easy, because of the small excess thrust available; but with a boost rocket operating, relatively tight turns became possible. Fig. 7 showed the influence of rocket thrust on the radius of turn and on the duration.

The lecturer remarked that in all the applications so far discussed in the paper, performance depended upon the ratio of rocket thrust to main engine thrust. This could vary between the two limits of zero and 100 per cent rocket thrust. In the latter case, we had the pure rocket-propelled aircraft, of which the German Me 163 and the American Bell X-1 were examples. Both of these aircraft had a characteristically deep fuselage section in order to store the large propellant supplies required, and both could be operated at reduced thrust for cruising in order to obtain an extended endurance. Although this permitted a longer time of operation, it did not extend the range greatly, and it was interesting to see that much greater ranges could be obtained by a radically different flight plan. This consisted in following a ballistic trajectory from the ground until all the propellant was

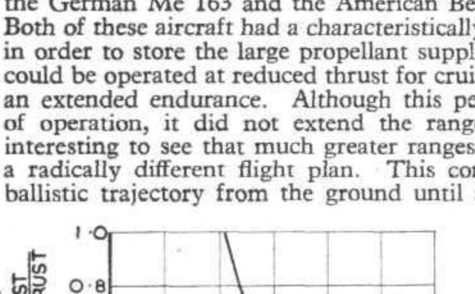


Fig. 7. Influence of rocket thrust on manœuvrability at 50,000ft and 900 m.p.h.

used. By such time it might be assumed that the aircraft had reached very-low-pressure altitudes and the drag resistance was small. At the same time the aircraft had stored in it a great deal of energy, both kinetic and potential. This energy could be utilized to overcome drag, first by conversion of the kinetic energy and later by use of the potential energy. Furthermore, as all the propellant had been used, the aircraft weight would be relatively small and so would the drag.

A V.2 with wings would cover almost 600 miles in 20 minutes and would land at 90 m.p.h. This final subsonic glide and landing could be eased if a small turbojet engine of about 1,500 lb thrust were installed. This would stretch the glide and enable the pilot to make a normal circuit and landing.

While an aircraft of V.2 size would not have a very large payload, there was no reason why much larger designs should not be made in which both propellant and payload were increased. Tsien, at California Institute of Technology, had made a theoretical study of such an aircraft with a take-off weight of 50 tons and landing weight of 10 tons which would make the trans-American trip of 3,000 miles in under one hour. Sänger, in Germany, had made a war-time study of an even more ambitious aircraft which would fly half-way round the world in approximately 2½ hours. This could be achieved by accelerating to a large enough velocity at the beginning of the ballistic trajectory. On re-entering the upper atmosphere after the dragless flight-path, the lift force generated would be sufficient to turn the aircraft back on to a climbing path and the kinetic energy would be re-converted into potential energy with only a small loss, due to the drag suffered while the machine was in the atmosphere. The process would be repeated as the aircraft returned to the atomsphere again and a series of "bounces" into space would occur. In this way, the energy expended for a given flight distance would be greatly reduced, because so much of the path would be in practically drag-free conditions.

Although Sänger's proposal involved many formidable aircraft and motor problems, none of these should be insoluble, and it again emphasized the advantages of an unorthodox flight plan. There could be no doubt that this technique of storing energy in the aircraft, and making as much of the flight path as free of drag as possible, was where the future of the rocket motor as a main powerplant must lie. In the meantime, there were many ways in which the rocket could be used in co-operation with other powerplants. Just as the turbo-supercharger had improved the performance of piston engines, the rocket could be made to improve the performance of turbojet engines or ramjet engines.

Many of the problems associated with rocket motors were similar to those of other propulsion units, but generally they arose in a much more concentrated form. Motor weight and propellant consumption for unit thrust were of primary importance. These were influenced by numerous design factors such as permissible gas temperature, pressure, combustion efficiency, heat transfer, methods of pumping propellants, of ignition, cooling, thrust variation, and so on.

There were two basic reasons for the high propellant consumption of the rocket motor. The first was the fundamental one that the oxidant required for combustion of the fuel was carried by the aircraft and not picked up in flight from the atmosphere. Thus, to provide equal heat energy the rocket must carry at least an additional weight of oxygen sufficient to burn the fuel. For a hydrocarbon fuel this was approximately three-and-a-half times the weight of fuel and so the overall consumption must go up to at least four-and-a-half times that of the equivalent air-swallowing engine. The second reason for high consumption was the inherently high jet velocity of the rocket. For a given available kinetic energy of the exhaust gas, the thrust produced varied inversely with the jet velocity, which was almost four times as great as that of the turbojet engine. Combining these two factors gave consumptions of nearly eighteen times the turbojet figure, and the question arose whether anything could be done to reduce this ratio.

An examination of the parameters would reveal the answer, but first it should be noted that it was more usual with rockets to consider specific impulse, which was the inverse of specific consumption. It was defined as the thrust produced with unit rate of propellant consumption, and it could be written as

$$I = \frac{3{,}600}{q} = \frac{v}{g} = \sqrt{\eta \cdot \frac{2}{g} \cdot \frac{\gamma}{\gamma-1} \cdot \frac{KT_1}{M} \cdot \left(1-\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right)} \quad (1)$$

where:—

- I specific impulse (lb/lb sec)
- K universal gas constant = 2,778 ft lb/°C lb mole
- M molecular weight of combustion per lb
- P_1 combustion gas pressure (lb/sq ft abs.)
- P_2 exhaust gas pressure (lb/sq ft abs.)
- q specific propellant consumption including turbo-pump consumption (lb/hr/lb)
- T_1 combustion gas temperature (°K)
- v jet velocity (ft/sec)
- γ ratio of gas specific heats at constant pressure and volume
- η an empirical efficiency factor = 0.9

In practical motors I lay between 200 and 250 lb/lb/sec and improvements depended upon improving the parameters in the foregoing expression. T_1, M and γ were functions of the propellants used and their mixture ratio, while the ratio $P_1 : P_2$ was set by the designer. It was usually of the order of 20 : 1 or 30 : 1, and was the main factor determining the thermal efficiency. The more it was raised, the better the specific impulse became, but the rate of improvement fell off rapidly above 20 : 1 and even an infinite pressure ratio would only raise it by 50 per cent. Also, the gains must be balanced against the disadvantages of increased nozzle weight, which would be referred to later.

The other possibilities for improvements appeared on first sight to be an increase in gas temperature T_1 and a decrease in gas molecular weight M. These two factors were not, however, independent and the objective must be to make T_1/M an optimum. [In an illustration, the lecturer showed the variation of these parameters for a liquid oxygen/petrol propellant combination against mixture ratio.] Because of dissociation the maximum gas temperature did not occur at stoichiometric mixture, but at some 10 per cent fuel rich, beyond which it decreased slowly. Similarly, the molecular weight of the gas tended to fall with rich mixtures, but more rapidly, and the combined effect was to give a maximum of T_1/M at almost 40 per cent rich. This was repeated in the specific impulse curve, although the gas temperature had fallen from 3,400 deg K to 3,280 deg K. While this reduction in tem-

ROCKET PROPULSION FOR AIRCRAFT . . .

perature was a fortunate accident for the designer who had to combat its effects on the combustion-chamber walls, it still left it at values much higher than those found in any other internal combustion engine, and the heat transfer problem was formidable. Thus, even if propellants with higher gas temperatures were available, they might have to wait for improved cooling techniques before they can be used.

A more attractive alternative was the reduction of molecular weight, and this implied a fuel rich in hydrogen. Hydrazine (N_2H_4) and ammonia (NH_3) were good examples, but another consideration must enter at this stage. Not only must a high specific impulse per unit weight of propellant be achieved, but equally important was a high specific impulse per unit volume. The importance of this could be seen by the simple example given in Table II of the combustion of liquid oxygen and liquid hydrogen.

This showed that the fuel rich mixture had 15 per cent advantage in performance on a weight basis, but was 20 per cent worse on a volume basis. For both mixtures the weight specific impulse was much greater than for the average propellants, but the low density of liquid hydrogen resulted in a poor volume specific impulse. By comparison, the liquid oxygen/petrol impulse was approximately 2,370 lb/gal/sec; nitric acid/hydrocarbon 2,780 lb/gal/sec; and 85 per cent hydrogen peroxide/hydrocarbon 2,760 lb/gal/sec.

TABLE II: PERFORMANCE OF LIQUID OXYGEN AND LIQUID HYDROGEN

Mixture	Stoichiometric	100 per cent Fuel rich
Oxygen/Hydrogen by weight	8 : 1	4 : 1
Combustion temperature T_1 deg K	3,525	3,025
Gas molecular weight M	15.5	9.8
T_1/M	227	309
Specific impulse lb/lb/sec	306	353
Propellant mixture density lb/cu ft	25.5	17.6
Specific impulse lb/gal/sec	1,250	1,000

The three oxidants mentioned were those in most common use, and much controversy had raged round their respective merits and faults. Cleaver had discussed them in detail, and there was little to add to his review, except to note that whereas on a volume basis nitric acid and hydrogen peroxide were practically equal, the latter had a combustion temperature of only 2,600 deg K compared with 2,950 deg K for nitric acid and nearly 3,300 deg K for liquid oxygen. For this reason alone, hydrogen peroxide must be very attractive to rocket motor designers; and when coupled with its ability to provide energy directly for driving the turbo-pumps and accessories, it became, in the lecturer's view, pre-eminent.

The remaining factor in the specific impulse equation was the efficiency η with which the propellant chemical energy was converted into gas kinetic energy. It corrected the theoretical impulse to practical values, taking into account combustion efficiency, heat transfer losses, imperfect gases, friction losses and other expansion nozzle losses. These could account for some 5-10 per cent reduction in impulse and any improvement must be mainly a matter of improved mechanical design.

It could now be seen that the answer to the question of improving specific consumption was that the prospects were not very bright for any major reduction, but a number of minor reductions might be possible. These should not be neglected, as they could give a more than proportionate improvement in performance. In a ballistic flight-path, for example, the range varied as the square of the specific impulse, so that a 10 per cent improvement in impulse would give 21 per cent increase in range.

While the improvements to be expected by changing the propellants or modifying the motor design were limited, one further possibility existed. The use of an air augmentor duct surrounding the rocket jet would give an increase in thrust due to the interchange of rocket jet kinetic energy and momentum with those of air in the duct. Theoretically this increase depended upon the augmentor duct and rocket jet mass flow ratio. It fell to zero as forward speed/rocket jet velocity increased and then once more rose. As an example, for a typical arrangement with a mas ratio of 10 : 1, thrust increase would be 40 per cent at take-off, zero at 450 m.p.h. and 5 per cent at 1,000 m.p.h. To achieve this, the entry to the air duct would have to be shaped as an accelerating or diffusing section according to the speed ratio. This was, of course, similar to the intake problem facing the turbojet and the ramjet. Practically, the amount of augmentation depended upon the friction losses, mixing rates and entry efficiency. In some experiments with a small rocket motor, made at the College of Aeronautics, Cranfield, ducts with augmentor/rocket jet diameter ratios from 7 : 1 to 14 : 1 were tested statically, and thrust augmentation from 17 per cent to 40 per cent was actually measured. In all cases the optimum length/diameter ratio of the duct was between 5 and 7. Duct dimensions were important, too large a duct would be difficult to install, apart from the excessive friction and drag losses introduced. These were likely to be large in any case for high speed flight, and, as altitude increased, the air mass flow would be reduced and the proportionate thrust increase would be less. Thus, the advantage of a simple augmenting device would mainly apply to the low speed, low altitude range, that is, to take-off. For this purpose it need be only a light tube, as pressures and temperatures would not be far removed from atmospheric. It could be easily jettisoned after take-off, either by itself or with the rocket motor.

The rocket-duct combination was studied by the Germans not primarily to improve the rocket performance, but to assist ramjets

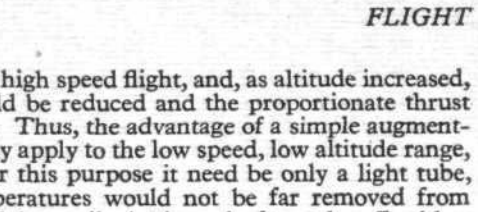


Fig. 8. Rocket/ramjet duct combination.

at low speeds. Fig. 8 showed one of the arrangements adopted. It was effectively a ducted rocket coupled to a ramjet combustion chamber. With it, ramjet static thrust could be developed, although very inefficiently. Its chief merit was that the rocket jet was of decomposed hydrogen peroxide and the oxygen present enriched the ramjet air supply.

Prof. Baxter now turned to a discussion of the weights of rocket motors, quoting (Table III) some actual figures. Weights, he said, depended on combustion pressure, as an increase in pressure involved the use of heavier-gauge constructional material. Figures of 0.05 lb/lb or less should be possible at the present time. Not all the main components would increase in weight with increasing pressure; the dimensions of the combustion chamber would be reduced, so its weight would be lower, though the reduction would be offset by the extra length of divergent nozzle necessary to obtain complete expansion of the gases.

The next sections of the paper were concerned with combustion-chamber design and the arrangement of the burner head, the duty

TABLE III: ROCKET MOTOR WEIGHTS

Motor	Oxidant	Thrust (lb)	Weight/thrust
B.M.W. 109-718	HNO_3	2,750	0.065
V.2	LO_2	60,000	0.035
A.S.M. Snarler	LO_2	2,000	0.107
R.M.I. 6000-4c ...	LO_2	6,000	0.035
H.W.K. 109-509	H_2O_2	3,750	0.100

of which was to ensure the intimate mixing of oxidant and fuel in correct proportions as rapidly as possible. Prof. Baxter illustrated some widely differing examples (Fig. 9). Turning to details of the expansion nozzle, he said that this component was of almost equal importance with the combustion chamber proper, because its weight might be more than 50 per cent of the combined weights, and efficiency decided how much of the gas pressure energy developed in the chamber was converted into kinetic energy.

The lecturer discussed combustion-chamber cooling problems at some length, remarking that water was one of the best coolants available, having a conductance twice as good as that of methanol and four-and-a-half times better than kerosine, at atmospheric temperature. In all cases the conductance improved with increas-

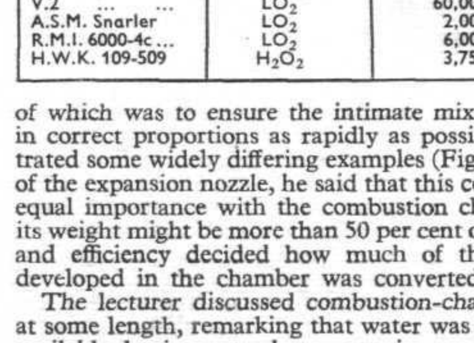


Fig. 9. Typical burner-head arrangements.

ing temperature and for kerosine was about 1.6 times as great at 100 deg C as at 20 deg C, and for water about 2.0.

One method of improving the heat transfer on the liquid side was by nucleate boiling. A large increase in heat transfer could occur without much rise in temperature if the liquid boundary-layer boiled and formed small bubbles which were swept off the wall into the main mass of the coolant. It was a difficult condition to design for and the danger was that the bubbles might coalesce and prevent liquid from reaching the wall. In this case failure would follow very rapidly. Up to the present, probably, very few chambers had been designed for nucleate-boiling heat-transfer, but it might have occurred quite fortuitously in very many others. When it could be properly controlled it would assist the designer to improve the motor performance materially.

Discussing the relative advantages of various wall materials, the lecturer concluded that, on the whole, mild steel was as good a material as any.

In the final sections of his paper Prof. Baxter discussed the control of rocket motors under three headings: propellant supply, starting and thrust control. Under the third of these headings he said that the first question that arose was to what extent variable thrust was required with rocket propulsion. Generally, the objective was to obtain the maximum thrust additional to that of the main engine during some special manœuvre. In such cases, it was unlikely that the pilot would require anything except full or zero thrust from his rocket motor. On the other hand, the ability to select any intermediate thrust gave greater flexibility in aircraft control and was almost a necessity in cases where the rocket was the major powerplant and the aircraft was used in a relatively conventional manner.

Thrust variation might be continuous or in steps. The latter was more simple and could be carried out with a single combustion chamber or by using a number of chambers in combination. Two chambers giving thrusts in ratio 2 : 1 could be used, each operating at full thrust to give thrust steps of 1, 2, 3, and by using more chambers a greater thrust range could be obtained. The motor for the Bell X-1 aircraft was of this type, but had four identical chambers. The motor for the German Me 163 had two chambers but the larger had an almost continuous thrust variation from 100 per cent to 15 per cent. This was achieved by using three sets of injectors, each of which could be cut out in succession and each of which had a range of flow. This large variation produced a change in combustion pressure from 300 lb/sq in to 50 lb/sq in, but combustion at the lower figure was rough and inefficient. Also, with an expansion nozzle designed for 20 : 1, the throttled condition gave a very over-expanded jet near sea level, but at a suitable altitude the nozzle would give correct conditions once more.

It could be seen that, from the combustion chamber end, there was no difficulty about producing variable thrust; all that was involved was a throttle or series of shut-off cocks to regulate the propellant flow. This, however, might not be quite so simple as the statement implied, as a number of separate feed pipes would be involved and it was desirable to keep the oxidant/fuel mixture ratio constant during the throttling. From the pumping end, no special problems arose with mechanically-driven pumps, as a simple throttling of the propellant supply would ensure the delivery of the correct quantity at the appropriate pressure. With the turbo-pump system, rather more care was necessary to match the pump deliveries and pressures with chamber requirements in order to reduce the turbine consumption. A control valve was necessary to meter the propellants required for the gas to drive the turbine. This might take the form of a throttle in the turbine feed line, set according to the equilibrium condition required. If, however, a slight disturbance occurred to the feed pressure, the turbine speed would alter and there would be a consequential change in thrust. Equally, a change in turbine back-pressure would have the same effect. This would be particularly noticeable during a climb, and some form of automatic adjustment of the throttle would be necessary. One method could be by means of a signal from the pump pressure operating against a datum set by the pilot's throttle. In addition, some form of over-speed governor was required to guard against sudden removal of the load, such as might occur if the pumps ran dry.

Prof. Baxter concluded by pointing out that rocket propulsion for aircraft was a very specialized field and that its main applications in the near future would be as an adjunct to other powerplants. In the rôle of a thrust booster for short periods, it could enormously enhance the performance of air-swallowing engines over the whole speed and altitude range. Its value was primarily in military aviation, but such applications as assisted take-off could have advantages for civil aircraft.

In the not-too-distant future there might well be a reversal of the present subservient position of the rocket motor. It would become the main powerplant of special-purpose long-range aircraft, supported by small turbojets which would be used merely for landing purposes. This would be one of the first steps into the region where there could be no question of the rocket's supremacy. When this occurred, it was almost certain that it would not be long before the rocket would open the doorway for humanity to extend its dominion into interplanetary space. Before this came to pass, however, there were many problems to be solved.

FIGHTERS IN THE COMMONS

ALTHOUGH further pertinent questions on details of military aircraft production appeared on the House of Commons Order Paper on February 9th, the edge of Opposition criticism was somewhat blunted by Mr. George Ward, the Under-Secretary for Air, when he suggested in friendly tones that perhaps it would be better to await the contents of the Government's impending White Paper on aircraft production.

Some Labour Members apparently believed that "White Wash" would be a better description of the forthcoming document; but, in view of Mr. Ward's advice to "wait and see", it would perhaps be fitting to confine this brief account of the proceedings to the more salient points elicited.

Thus it was learned from the Under-Secretary that the engine surge noticed on the Hawker Hunter during air firing applied less to the Sapphire version than to that fitted with the Avon. On the question of co-operation between operational commands of the Royal Air Force and designers and manufacturers of new aircraft, he mentioned the existence of Service liaison officers at manufacturing establishments.

Mr. Ward later informed Members—rather grudgingly, according to one who was present—that no Hunter aircraft had yet been modified by the fitting of external link and cartridge containers for the simple reason that these were not yet available.

He said that there had been no redesigning of the Hunter's tail, but added that consideration was being given to the all-moving tail as it was thought this might be an advantage in later development.

Dealing with the Valiant, he said the first operational squadron was now being re-equipped with this aircraft. It was hoped that Victors and Vulcans would be in service next year. He did not comment upon an assertion by Col. George Wigg (Lab., Dudley) that "the tail dropped off a Victor" last year.

HOLLAND'S DEFENCES

AS replacements for the F-84 Thunderjets now in service, quantities of F-84F Thunderstreak fighter/bombers are to be supplied this year to the NATO air forces, among them the Royal Netherlands Air Force. So far as Holland is concerned, the biggest problem associated with this re-equipment is that of finding a factory with the necessary accommodation for assembly, though indications are that the work will be undertaken by Avio-Diepen at Ypenburg, near the Hague (now associated with the Fokker works). This company is already engaged in the overhaul and repair of Thunderjets for the R.N.A.F., and has the advantage that the 1,500-yd runway at Ypenburg has just been completed and is already being used by Thunderjets, which formerly had to make a difficult and costly journey by road. Meanwhile, a new, large assembly shed is nearing completion.

On the naval side, the Dutch aircraft carrier *Karel Doorman* will be withdrawn from service for a lengthy overhaul and for modifications—the latter to include the fitting of an angled flight deck. While the vessel is out of commission Netherlands carrier-borne squadrons—flying Hawker Sea Furies and Grumman Avengers—will be stationed aboard British carriers.

It is also learned that a number of Dutch Fireflies will soon be stationed in New Guinea "in order to guard the coast of that island against Indonesian infiltrations." A squadron of Catalinas is already based in New Guinea, but this has numerous other duties to perform and the "Cats." are in any case too slow, so that the Fireflies will be a welcome reinforcement. The Catalinas, incidentally, will be replaced this year by Martin PBM-5A Mariner amphibians, 15 of which are on order in America. In all, 36 are being converted for the Royal Netherlands Navy.

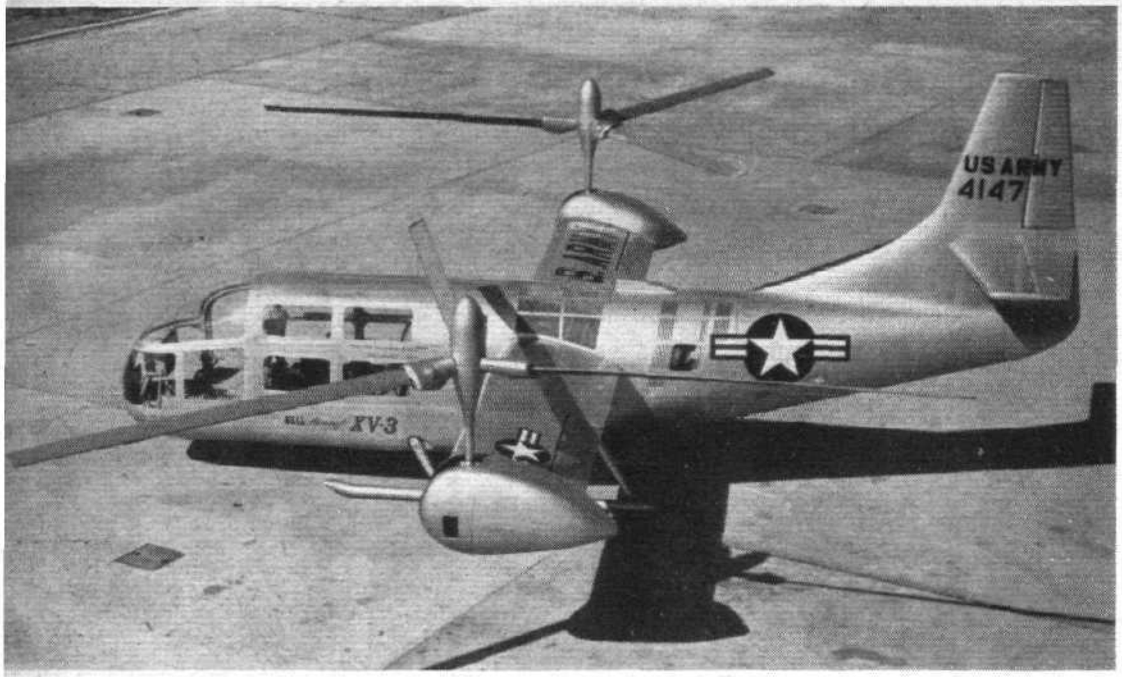
HELP FOR YOUNG GLIDER PILOTS

ASSISTANCE to young glider pilots towards the cost of long-distance soaring and retrieves has now been made possible by the British Gliding Association. An announcement made last week gives details of the new Alex Orde Fund, which is intended to help promising pilots to reach the standard necessary to take part in world championships. Under this scheme, cash awards may be made for certain long-distance flights.

To be eligible for an award, pilots must be under 25 years of age and of British nationality. The minimum qualification is a "Silver C" badge. The qualifying flights—which must start from the United Kingdom—are: (a) Any flight qualifying for either "Gold C" distance (300 km) or a Diamond distance (500 km, or 300 km goal flight); (b) any two-seater flight over 200 miles where neither pilot has a "Gold C"; (c) any flight over 150 miles by a non-"Gold C" pilot (or pilots, in the case of two-seaters).

For flights under (a) or (b), the maximum award is £15; for those under (c) it is £10. Other awards may be granted "as and when the fund permits" by the Flying Committee of the B.G.A.

The establishment of this fund was forecast in *Flight* of January 14th last. Its basis is the major part of the presentation fund established for Mrs. Alex Orde, until recently secretary of the Association. Further contributions would be welcomed and should be sent to the B.G.A. at Londonderry House.



Although it seats only four persons, the Bell XV-3 convertiplane prototype is quite a large aircraft. Powered by a single Pratt and Whitney engine driving the tiltable rotors-cum-airscrews through gearboxes and shafting, it is described elsewhere in this issue.

AIRCRAFT INTELLIGENCE

Great Britain

Olympus-Ashton. Illustrated on this page is the first six-jet aircraft flown in this country: WB493, the fourth Avro Ashton, now being used by the Bristol Aeroplane Company's Engine Division as a test bed for their Olympus turbojet. The very efficient Olympus, which the company believe to be the most powerful type-tested engine in the world (at 11,000 lb rating), has already completed over 700 flight hours in one Canberra and one Vulcan. It is understood that the Ashton may be used to develop afterburning and carry out other trials for which the Canberra is unsuitable; the podded installation permits completely unrestricted engine performance and the size of the Ashton allows a very great range of test equipment to be carried. Meanwhile, the Canberra is fully engaged upon testing at extreme altitudes.

U.S.A.

Allison Test-beds. At present three Convair transports are flying with Allison turboprop engines, not counting the R3Y Tradewind flying boat (which is in production). The original Turboliner was a CV-240 airframe re-engined with T38 engines of 2,750 h.p. each; this machine has now flown approximately 500 hours and has given rides to over 3,700 passengers. The two YC-131Cs of the U.S.A.F. are basically similar to the T-29 crew-trainer and C-131 Samaritan casualty-evacuation transport, but are powered by a pair of T56 turboprops developing no less than 3,750 h.p. each. With both YC-131Cs over 300 hours of engine flight-time have been logged on YT56 engines and both machines are now in the hands of the 1,700th Test Squadron recently established at Kelly A.F.B. This unit will also test other turboprop aircraft including the Boeing YC-97J and Lockheed YC-121F, two of each of which are being built with four Pratt and Whitney T34s.

Bell VTOL. In last week's issue we described the vertical-jet Bell experimental prototype, and commented that it appeared to have been built from parts of other aircraft. It is now known that it embodies the fuselage of a glider (possibly a Schweizer), the wing of a standard light aircraft (perhaps a Cessna), the landing gear of a Bell helicopter and the throttle controls from a motor-boat.

Cessna T-37A. Already in production for the U.S.A.F. as a standard twin-jet basic trainer (two 920 lb thrust Continental J69-T-9), this neat side-by-side aircraft has now also been bought by the U.S. Army. An initial order has been placed for ten machines, for use as observation aircraft "in adjusting surface-to-surface missile fire."

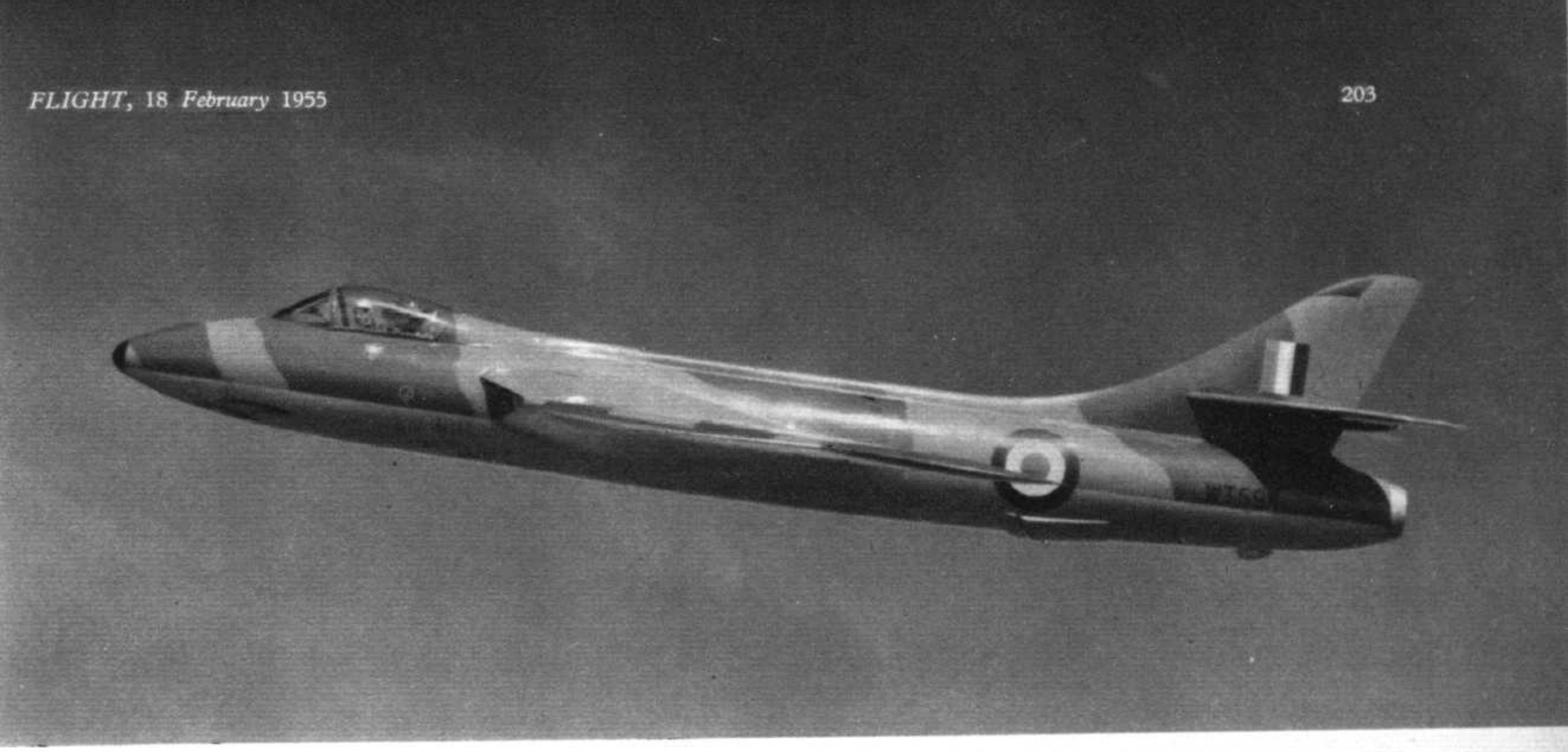
North American FJ-4 Fury. Although it has not yet replaced the FJ-3 on the production lines at Columbus, Ohio, the FJ-4 is doing very well in its prototype trials. This machine is a Sapphire-powered carrier-based fighter developed from the earlier Fury/Sabre family, but incorporating much information gained during development of the F-100. Two prototypes are now flying; both have the required long nose boom, and one is now fitted with wing fences and a revised wing profile. Contrary to reports elsewhere, the tailplane does not have dihedral, but is a level, single-piece slab. The rudder is a small surface similar to that of the F-100, Projects exist for all-weather developments of the FJ-4, which, if carried to completion, may obviate the need for a carrier-based version of the F-100. No F-100 has yet been completed by the Columbus division. but various Super Sabre versions are to be built there.

Australia

Fawcett 120. Hailed as Australia's answer to the problem of replacing the Tiger Moth, the Fawcett 120 is a braced high-wing cabin monoplane with a fixed tricycle undercarriage. Designed by the well-known Italian Luigi Pellerini, it seats four and is powered by a Gipsy Major. The prototype should have flown about one dozen hours by the date of publication of this paragraph.

G.W. Research. Aerodynamic research establishments working on guided missile development in the dominion are to be combined to form the Weapons Research Establishment.

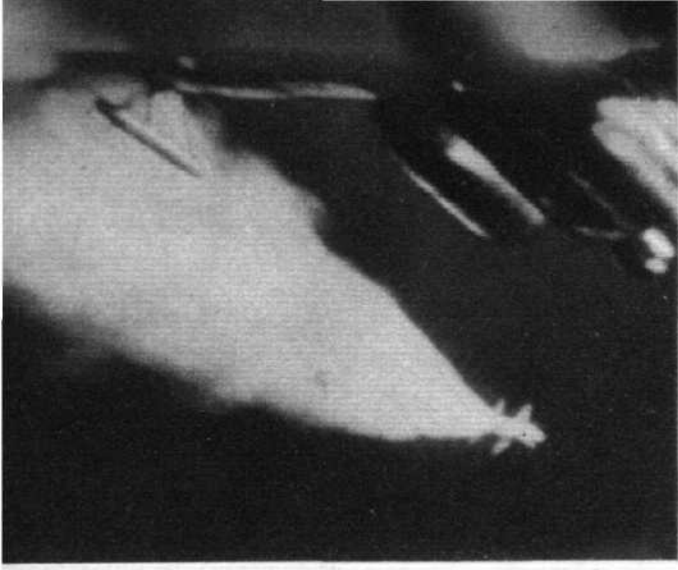
Subject of an item on this page, the Olympus-Ashton is here shown climbing out of Filton in the hands of W/C. W. F. Gibb, D.S.O., D.F.C., one of the Bristol test pilots. He it was who took the Olympus-Canberra to 63,668ft two years ago to establish the present world altitude record.



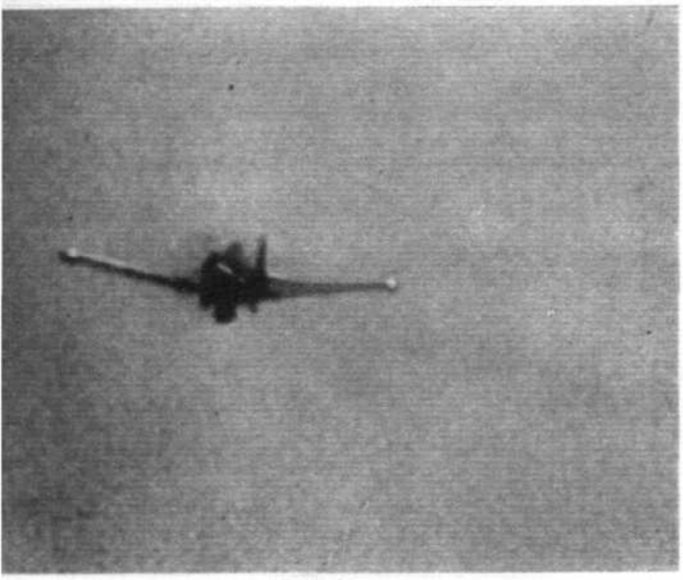
TALLY-HO!

THE Hunters are fast getting into their stride with the R.A.F., and by the time this issue appears it is hoped that *Flight* will have visited the Fighter Command station at Wattisham, in Suffolk, which is one of the first to be equipped with these Hawker intercepters. Both the F.1 (Rolls-Royce Avon) and the F.2 (Armstrong Siddeley Sapphire) are operating and both are armed with four 30 mm Aden guns, installed as a removable "pack." Illustrated here are production F.1s.

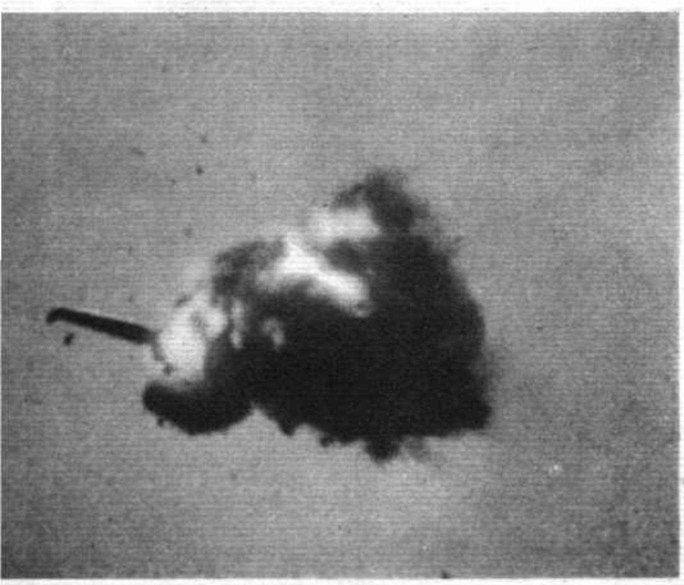
"Flight" photograph



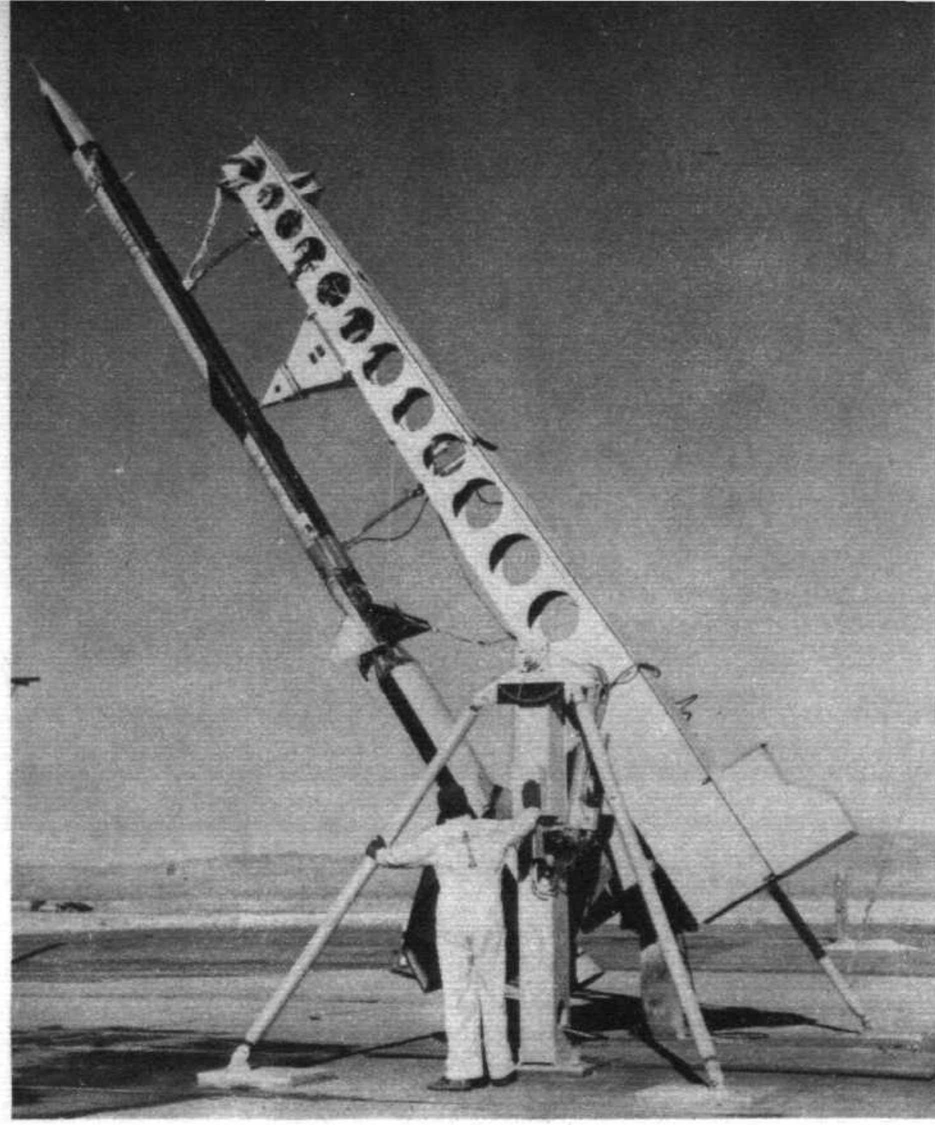
A Sparrow streaks away from a Skyknight . . .



. . . homes on this "drone" target. . . .



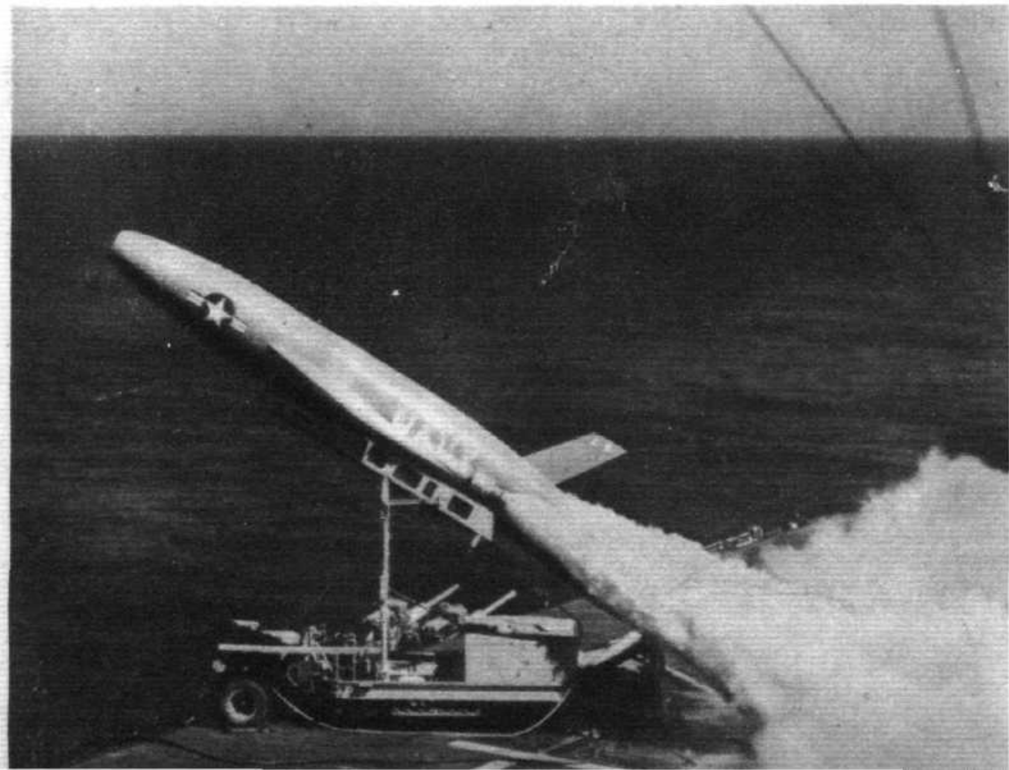
. . . and blows it into smithereens.



A Boeing GAPA research missile, showing that the method of launching is essentially similar to that used for the Oerlikon Type 54, fully described in "Flight" of January 7th.

MISSILE MISCELLANY

THESE spine-chilling photographs show guided missiles of contrasting types, for differing purposes and of various vintages. The new Douglas Sparrow in the three left-hand views (which we reproduce with grateful acknowledgment to Gaumont British News) is an air-to-air weapon, and is shown being launched from a Douglas Skyknight. The intensity of the explosion in the third view is eloquent of the Sparrow's destructive power. The Boeing GAPA research missile (above) is some eight years old, though the photograph has only just been released by the Pentagon. The slinging of the missile from its launching arm is of interest, and it can be said that experience gained from firing more than a hundred GAPAs is being utilized in the development of the Boeing F-99 ground-to-air missile. The Chance Vought Regulus, below, is a U.S. Navy missile, suitable for launching from submarines, surface vessels or land sites. Regulus test-vehicles have been safely landed at Muroc.



A Chance Vought Regulus leaves a portable launcher on the flight deck of the aircraft carrier U.S.S. "Hancock." Two jettisonable JATO bottles help to build up flying speed.

SKYWARRIOR

Designing the World's Heaviest Carrier-based Aircraft

SINCE the end of World War II, the Douglas Aircraft Company have built up a considerable reputation for being producers of essentially sound and efficient aircraft. No other company in the world is in production with so many completely different types of aircraft, and yet Douglas have still found time and resources to enter the missile business on a vast scale.

The development and production of aircraft for the U.S. Navy is the responsibility of the Company's division at El Segundo, and this division's products are particularly indicative of the type of logical engineering which the company have found so successful. Under the direction of their renowned chief engineer, Ed Heinemann, the El Segundo division has now made many thousands of carrier-based aircraft for the U.S. Navy and Marine Corps, the most notable being the Skyraider, Skyknight, Skyray, Skyhawk, and Skywarrior. The last-named machine is especially noteworthy, for it is easily the largest and heaviest aircraft ever planned for carrier operation. It represents the optimum American solution to a singularly difficult specification, and some comments on the evolution of the design form the subject of this article. The account is based upon papers prepared by various El Segundo engineers, notably Harry Nichols (project engineer on the type), and Messrs. Dill, Lamoree, Melching and Stringham.

The conception of a really powerful carrier-based attack bomber took shape in the years following World War II. The U.S. Navy wanted a machine which, although a fully "navalized" aircraft capable of being permanently based on a carrier, could carry a heavy load of all types of weapons to a distant target while having sufficient performance to ensure that it would be no more vulnerable than corresponding land-based aircraft.

Initial discussions between Douglas and the Navy Bureau of Aeronautics started in 1947. Some idea of the difficulty of formulating even the basic specification can be gathered from the fact that the Navy's weight estimates ranged from 62,000 lb up to 200,000 lb, the latter machine approximating to a navalized B-47. Gradually, however, the Navy began to crystallize its ideas, and, as detailed studies progressed, the all-up weights were narrowed to between 100,000 and 130,000 lb.

Even these weights were many times greater than those of any existing carrier-based aircraft, and it was quite apparent that a machine of this size would be too large for operation from any type of carrier with the exception of the then-projected U.S.S. *United States*. Ed Heinemann decided that if the new bomber were to be operated from carriers other than a mythical giant ship not then built, the weight would have to be cut down by at least 30 per cent. The wisdom of this belief was emphasized by the fact that, one year after Douglas started actual design, *United States* was cancelled by Congress (but was later reinstated as *Forrestal*, launched in December 1954 and followed by nine sister-ships).

On page 207 appears a composite three-view drawing of some of the more widely differing forms which the aircraft assumed during its early days. The basic conception was a machine powered by a pair of large turbojets and supported by a slightly swept wing mounted in the high or mid position. Anything approaching a freezing of the design was, however, prevented by the fluidity of the Navy requirements.

One of the most constantly changing factors was the geometry of the weapons bay, which had to be tailored exactly to fit the many highly secret atomic and other stores which were coming into use at that period (1948-9); some of these weapons were long and slim, some were short and fat and others had unusual projections or tail assemblies. Another variable concerned the provision of defensive armament. This was expected to be a single radar-directed barbette carrying a pair of 20 mm guns, mounted at the extreme tail-end of the fuselage. In some versions of the design, however, no armament at all was specified.

The growth factor was found to be roughly 6.4, i.e., for every pound saved in the initial design, the overall reduction in weight produced by the correspondingly lighter structure, smaller wing area, lower power requirement, etc., was 6.4 lb. Applying this factor to the basic project, it was calculated that elimination of the tail turret would reduce the final maximum weight by no less than 12,500 lb, making possible a much smaller aircraft employing engines already well developed (this machine is the smallest of those shown in the composite drawing). But eventually the design was standardized with the tail armament, and the engines chosen were afterburning variants of the Westinghouse J40, which was then considered to be the future standard turbojet for the U.S. Navy. The design was given the Navy designation A3D, following the AD Skyraider and the unsuccessful A2D Skyshark.

Having settled the basic form of the aircraft, the next step was to work out the aerodynamics. During the late 1940s, the design of any aircraft capable of flying well at a Mach number much in excess of 0.8 was, as we in Britain know to our cost, sufficient to occupy the time of a large staff for a number of years. The difficulties facing the El Segundo team, who were attempting to combine such performance with the requirements of carrier operation in a machine with a span approaching 100ft, can perhaps be appreciated.

The wing of the Skywarrior had to be a direct compromise between the conflicting requirements of high and low speed, carrier stowage and efficient cruising at high altitude. The aspect ratio chosen was 6.75; this value is higher than average in the U.S. Navy but less than that employed by U.S. Air Force machines designed for similar purposes. Originally, the figure was placed slightly higher, but the value was brought down owing to aerodynamic pitch-up at high speeds and to the problem of flutter which, of course, largely controls wing weight (the flutter problem is referred to later).

The thickness/chord ratio was fixed at 10 per cent at the root centre-line and 8.25 per cent at the tip. The sweep angle was chosen as 36 deg at the quarter-chord line, since wind-tunnel and flight data available at the time that the wing was finally settled indicated that this value would give satisfactory low-speed characteristics as well as low drag and good control at high speeds. The Douglas Company recently stated that, if the Skywarrior were being designed today, the sweep angle would not differ greatly and would certainly not be more than 40 deg. Dihedral was set at zero, which again was a compromise between high- and low-speed requirements. This factor is of paramount importance in determining the low-speed behaviour of swept-wing aircraft, and, if the Skywarrior were to be redesigned today on the basis of flight experience, Douglas would choose a dihedral angle of −1 deg (i.e., 1 deg anhedral).

As the composite general-arrangement drawing shows, there was no dogmatic acceptance of any particular form of engine

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installation; at least one projected form of the design incorporated units buried in the roots of the wings. It was, however, considered that the engines should be either completely buried or mounted on pylons as long as ground clearance would permit, for any compromise was found to lose many of the advantages of either method. The final configuration was a pair of single pods carried well below, and ahead of, the wing; this made possible the attainment of optimum accessibility, and did not interfere with wing tankage or with the large and continuous flaps. Incidental advantages were that engines could be changed with the use of standard torpedo-lifting trucks without any special hoisting gear, and that—if it became necessary—a change of engine type could be accepted with minimum change to the áirframe. The latter point became very important later.

In the late 1940s the El Segundo engineers began a major programme of investigation on the flutter characteristics of the A3D wing. The load factors to which the aircraft was being designed were considerably lower than those employed in other types of aircraft intended for comparable performance, and it was therefore expected that aeroelastic considerations would be of paramount importance.

Two main investigations were conducted: a preliminary flutter analysis with the analogue computor owned by the California Institute of Technology and a test programme with a flutter model to supplement and check the analogue analysis.

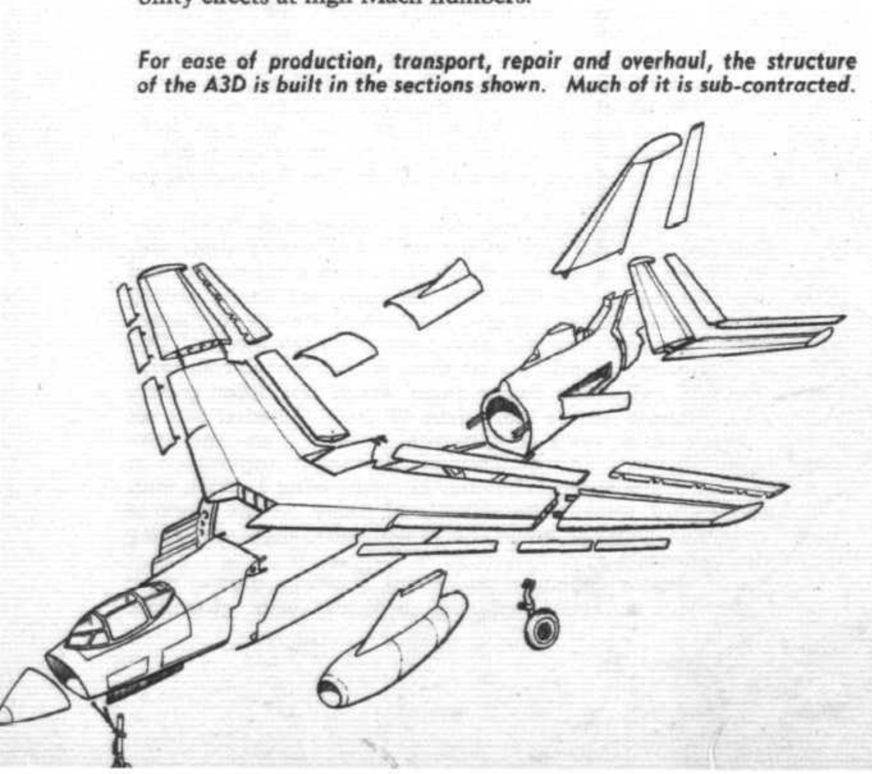
One of the advantages of the analogue computor is that it lends itself readily to the investigation of a large number of distinct cases; in the A3D programme, approximately 1,000 flutter cases were examined. The dynamics of the wing were represented by an equivalent mechanical system which was in turn translated into its equivalent electrical analogue, the force equations being represented electronically. The mechanical system for the wing was a beam in five sections, with coupled bending and torsion degrees of freedom; fuselage and tail masses were included in the inner beam section, rotational inertia and spring terms were used to represent aileron rotation and the nacelle was represented by a suspended mass with a rolling inertia and spring.

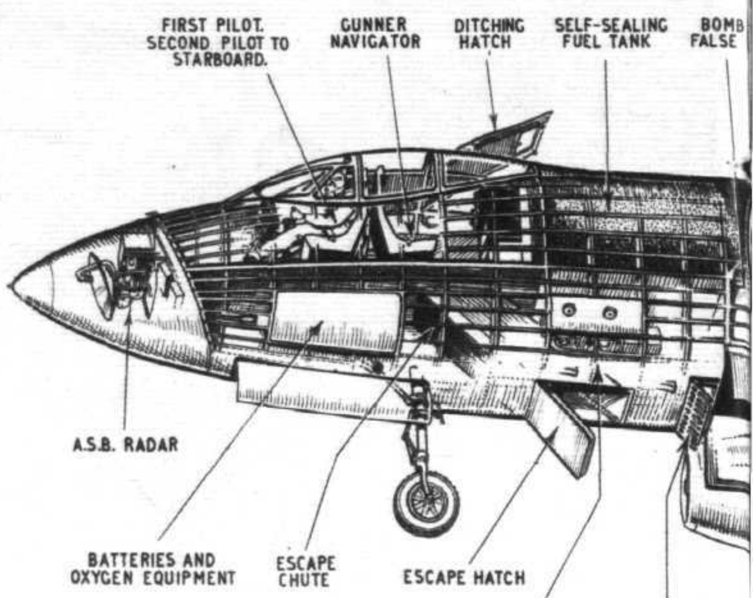
Early in the analogue programme it was found that the flutter speed of the design was *below the maximum design-speed*. This was the type of blow which many design teams have had to face during the past few years, and it probably threw the A3D wing team into turmoil.

The flutter mode was of the bending-torsion type on the basic wing, with or without nacelles (although, of course, the nacelles had a marked influence on flutter speed); the frequency was relatively high. A survey of the effects of various modifications was undertaken and the behaviour of many configurations was balanced against the corresponding increase in weight (diagram, page 208). As a result it was recommended that the nacelles should be relocated rather farther forward and outboard and that both the wing torsional rigidity and pylon rolling rigidity should be increased.

Work on the flutter model was not completed until after the prototype design had been fixed (incorporating the changes resulting from the preliminary analogue analysis). The balsa/lead model was tested first in the El Segundo 40in × 30in tunnel, and then in the GALCIT 10ft tunnel and the variable-density tunnel owned by the Southern California Co-operative organization. Testing in the latter tunnel enabled corrections to be made for compressibility effects at high Mach numbers.

For ease of production, transport, repair and overhaul, the structure of the A3D is built in the sections shown. Much of it is sub-contracted.





The model tests confirmed the analogue analysis for the bare wing, but also showed—disturbingly—that flutter occurred with the J40 nacelles attached, at a speed well within the normal speed range. The critical mode consisted of wing first-bending coupled with inner-panel torsion, nacelle motion also being considerable. Even with the nacelle pylons made as rigid as practicable, flutter became unstable at less than the design limiting speed. But other developments were more favourable: the critical mode developed slowly and was not wildly divergent; the addition of wing-fuel weight either stopped the inner-panel torsion-flutter or raised it beyond the limiting speed; no flutter was met at top altitude within the speed limit; and, fortuitously, a different engine was chosen for the production machine, which permitted stable flight at all speeds and altitudes.

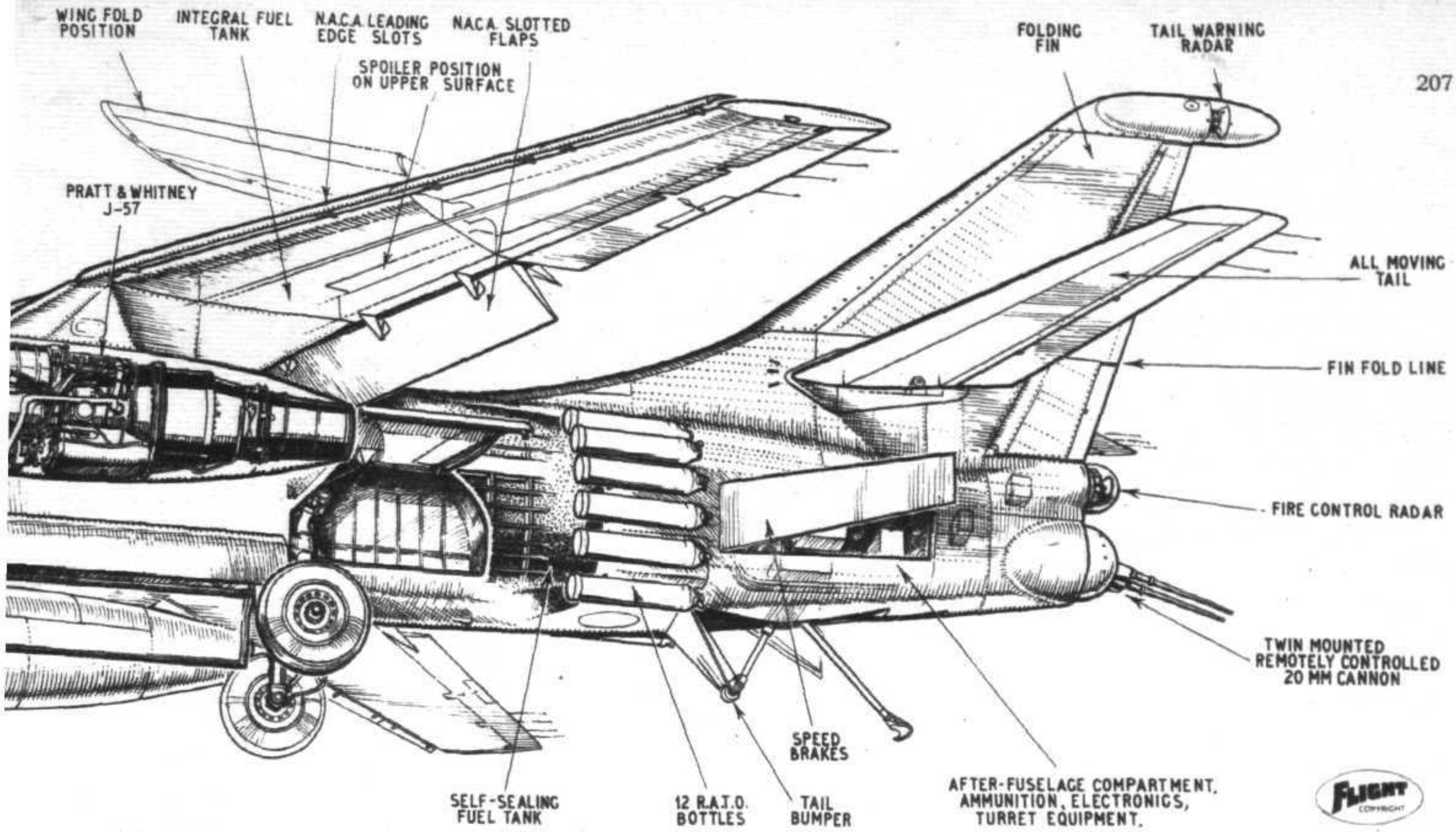
The new engine was the Pratt and Whitney J57 two-spool high-compression engine, giving 10,000 lb thrust without resorting to an afterburner (this engine also took over from the J40 in another El Segundo machine, the F4D Skyray). The increased weight of the J57 and the different nacelle geometry were instrumental in finally overcoming the flutter problem; it was also found, by ground-resonance testing, that the critical inner-panel torsion frequency of the full-size aircraft was rather higher than the model had predicted.

The design of the fuselage was, by comparison, quite straightforward. A very large fuselage was chosen, accommodating all the items normally provided for as well as the main undercarriage and a considerable proportion of the fuel. The chief invariables were the crew compartment, weapons bay and—once it had been decided to incorporate it—the tail gun barbette. The weapons bay occupied the whole volume of the centre fuselage beneath the wing. Ahead of the bay was placed a large fuel tank and a tank of similar capacity was positioned immediately behind the wing. The main undercarriage units were attached to strong frames at the rear of the weapons bay, and were arranged to retract backwards to lie on either side of the rear tank.

Before outlining the design of the internal equipment some notes may be given on the structure itself. The whole airframe was designed to be made in light-alloy stressed skin, there being a high percentage of 75ST material. The fuselage structure was planned around longitudinal and transverse members chosen according to the location of the numerous miscellaneous cut-outs; long, heavy keel members were run from nose to tail, picking up some of the weapons-bay and wing loads as well as the landing gear, catapult spools and arrester-hook attachments.

The wing was designed as a two-spar structure, and the flutter requirements already outlined dictated a skin thickness of no less than ⅜in between the spars all the way from the aircraft centre-line to one-quarter of the span of the outer panels. The outer wings were arranged to fold upwards hydraulically and, in order to save weight, the large lug-fittings accommodating the hinges and locking pins were designed integral with the upper and lower spar booms. These booms were machined from stepped extrusions. The vertical tail also was arranged to fold hydraulically.

On the subject of flying controls, it is El Segundo philosophy that the aircraft should always be capable of being flown manually. Accordingly, the A3D system, although fully powered hydraulically, was given elevator and rudder boost ratios sufficiently low



to ensure that the aircraft could be flown without boost, even in the most adverse conditions, without stick and pedal pressures becoming excessive. On the other hand, it was not found possible to provide a low boost ratio in the aileron circuit, and dual aileron systems were therefore provided. These independent systems, when operating normally from the dual power source, give the equivalent of a 40 : 1 boost ratio, although they are irreversible. Even with one system out of use the ratio power available is reduced by only 50 per cent, providing a satisfactory control; in addition a manual system with a 2 : 1 mechanical advantage was incorporated, and extensive testing and field landings proved that control was adequate for airfield operation. Nevertheless, for landing into the turbulent air behind a carrier it was considered that a higher rate of roll would be needed.

A sketch on page 208 shows the enormous improvement in rate of roll, particularly at the upper end of the speed range, produced by fitting spoilers (these devices have long been standard on U.S. military aircraft, such as the Neptune and Stratofortress). The A3D spoilers are located above the outer ends of the inner wings, immediately forward of the flaps. They sense their required motion from the aileron controls; when aileron control force reaches a given value one spoiler flips open under hydraulic actuation and approximately doubles the rate of roll. The spoilers operate independently and, as they are not actually linked with the flying-control system, their operation causes no feed-back of load on the pilot's control column. The spoilers do not operate when the ailerons are on "manual." It may be noted that, owing to wing twist, the rate of roll on ailerons alone becomes zero at a speed well within the limit for the aircraft (see sketch).

The wings also carry very large high-lift flaps hinged from brackets projecting beneath the lower wing surface. Each flap is continuous from the fuselage to the wing-fold line. On each leading edge is attached a large slat extending in sections from the pylon to the tip. The slat-and-flap combination have been found remarkably effective in reducing the A3D minimum approach and landing speeds, in the face of high wing-loading.

The necessity for rapid deceleration in the air is a fairly obvious requirement for all attack aircraft, and the A3D was provided with a pair of huge speed brakes, one on either side of the rear fuselage. Each takes the form of an unperforated panel hinged at its forward edge and opened against the airstream by a hydraulic jack. As the A3D is not intended to be flown in formation it was found unnecessary to provide for partial brake operation; accordingly, the panels can be selected "on" or "off" by a switch. As both brakes are either shut, fully open, or moving together, it was not necessary to provide any "cross-ship" connection.

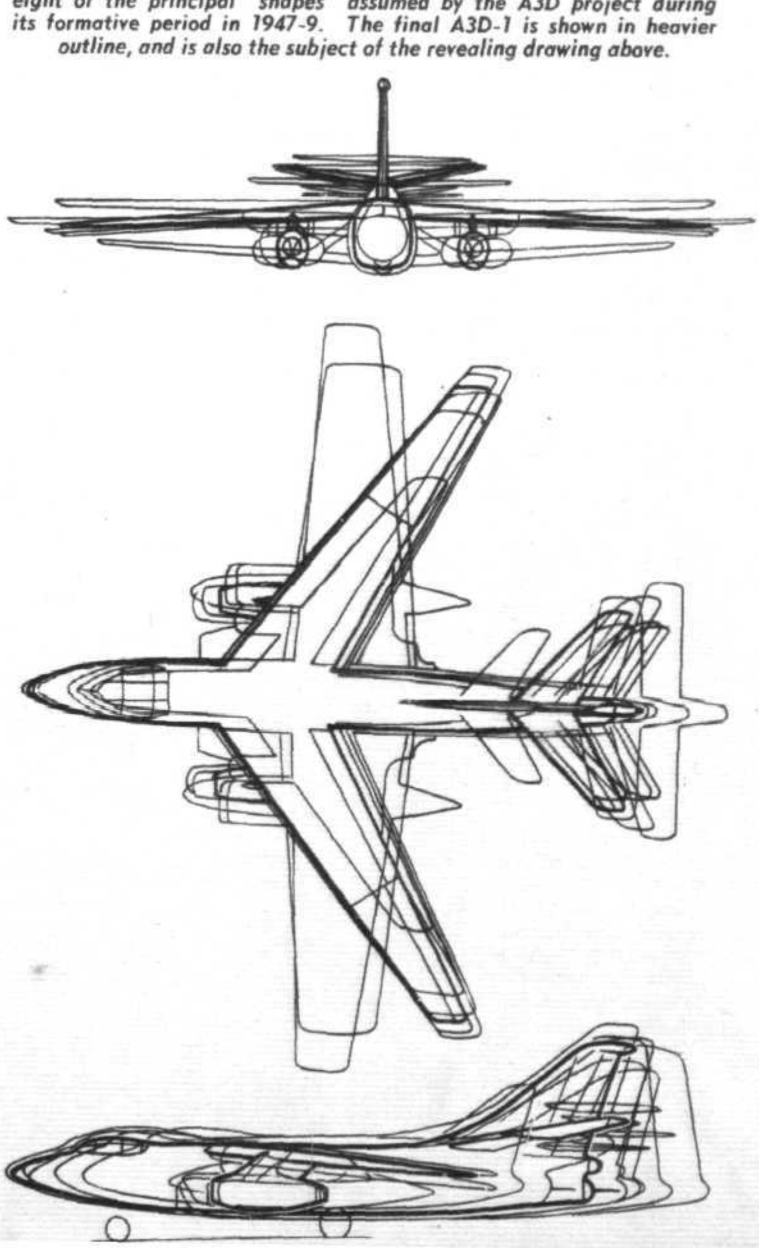
The fuel system of the A3D was made unusually simple for an aircraft of such a size. Fuselage fuel is carried in the two tanks already mentioned, which are of the self-sealing type. In addition, the whole wing forms an integral tank between the spars from the side of the fuselage to the wing fold.

As might be expected, a circuit is incorporated which maintains the aircraft c.g. between the correct limits as fuel is burnt. This consists of an electrically controlled valve which either allows, or prevents, a flow of fuel from the forward fuselage tank to the rear tank. It is governed by a predetermined scheduling of tank contents taking a signal from level-sensing probes located

DOUGLAS A3D-1 SKYWARRIOR: LEADING DATA

Three-seat carrier-based multi-purpose bomber powered by two Pratt and Whitney J57 turbojets of 10,000 lb each. Span, 73ft; length, 74ft 6in; height, 26ft 6in; net wing area, approximately 680 sq ft; gross weight, 70,000 lb; wing loading, up to 103 lb/sq ft; maximum speed, over 600 m.p.h.; operating ceiling, over 40,000ft. First flight of prototype XA3D, October 28th, 1952; first flight of production aircraft, September 16th, 1953; deliveries now being made to U.S. Navy.

The composite drawing below shows, superimposed upon each other, eight of the principal "shapes" assumed by the A3D project during its formative period in 1947-9. The final A3D-1 is shown in heavier outline, and is also the subject of the revealing drawing above.



One of the crew of this A3D-1 is looking out through the roof ahead of the partially-open ditching hatch.

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in both fuselage tanks. Wing fuel can be transferred to the forward-fuselage tank by compressor-bleed air pressure whenever the pilot desires. The wing tanks are provided with carbon dioxide purging.

One of the design features evolved from this system is the manner in which the fuel is consumed. It is intended that the pilot withholds transfer of wing fuel until it has been cooled by contact with the outside wing skin (this cooling is very rapid at high altitude). The fuel is then transferred cold, and greatly reduces boil-off of the lighter hydrocarbon fractions from the fuselage tanks, which was a considerable problem at high altitude with some fuels (not with JP-4). In addition, the fuselage tanks are slightly pressurized (to 2 lb/sq in). This system was much lighter than any equivalent refrigeration system would have been.

As the large drawing shows, the Skywarrior is operated by a crew of three. The provision of an ejection seat for each man would have involved a very serious enclosure design problem, for the entire canopy over the flight deck would have had to be jettisonable. Furthermore, ejection seats would have had to face forward; turning the rear gunner through 180 deg would have caused an aft-shift of the rear flight-deck bulkhead so reducing the capacity of the forward fuselage fuel tank.

The scheme adopted was reminiscent of the earlier Skyknight: all crew-members are enabled to leave the aircraft *via* a bail-out chute running downwards and aft from the cockpit floor. This chute has smooth walls and is sealed at both upper and lower ends by doors, the upper door forming part of the floor and the lower door being part of the fuselage skin. To leave the aircraft, the lower door is opened by means of cartridge-pressurized cylinders, which open and hold the door against the airstream up to the design limit speed. The upper door is also opened through a linkage tied to the lower door. This system has been proved effective and is 550 lb lighter than the best arrangement with ejection seats.

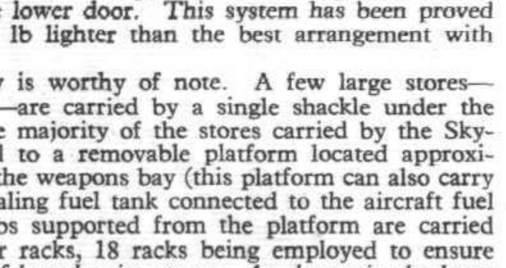
The weapons bay is worthy of note. A few large stores—presumably nuclear—are carried by a single shackle under the centre wing, but the majority of the stores carried by the Skywarrior are attached to a removable platform located approximately half-way up the weapons bay (this platform can also carry an additional self-sealing fuel tank connected to the aircraft fuel system). The bombs supported from the platform are carried on individual ejector racks, 18 racks being employed to ensure positive separation of low-density stores. As shown in the large drawing, an anti-buffet rake is also fitted ahead of the bay; this is opened by a jack tied to the bomb-door circuit and has been found to reduce buffet to an acceptable level under all conditions.

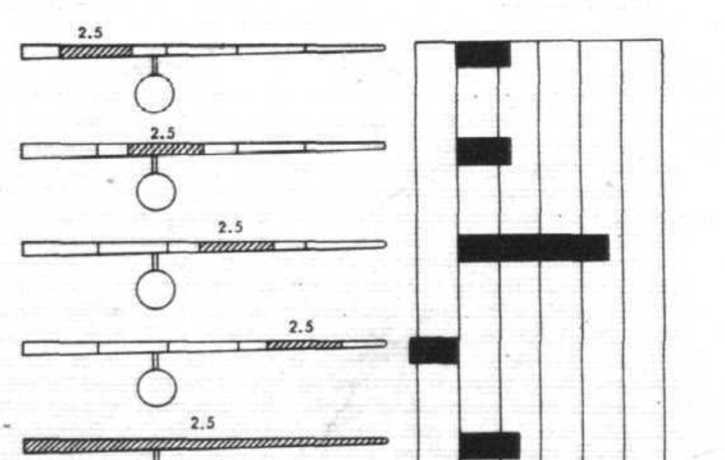
Both hydraulic and electric systems are supplied with power from self-contained units in the fuselage. The power comes, in the first instance, from turbines driven by compressor-bleed air ducted through stainless-steel pipes from the J57s, and controlled by valves which are accessible to the crew. All the voltage relays, batteries, hydraulic accumulators and valving is positioned within a radius of about three feet from the air turbines; as a result the Skywarrior accessory systems are considered unusually reliable and invulnerable to battle damage, and flak curtains are fitted around the drive units for added combat protection. The arrangement also worked out some 125 lb lighter than an equivalent conventional system.

The general layout of the tail barbette, gun-laying scanner, tail-warning radar and main bomb-sight radar is shown in the large drawing. This drawing also shows the location of the Aerojet JATO rocket take-off bottles, which can be individually clipped around a strong frame in the rear fuselage. These bottles provide a total of 54,000 lb thrust for five seconds, and the A3D is, therefore, theoretically capable of flying vertically for this period of time. The acceleration provided is so great that carrier take-offs can be made without the use of a catapult, even at full load.

Altogether the Skywarrior is proving exceptionally versatile, effective and easy to maintain. It is in full production at El Segundo and an aircraft developed from it—the B-66—is in production at Long Beach. The B-66 series are aircraft powered by Allison J71s, and Air Force requirements have resulted in a much heavier machine than the A3D, with a shorter range but carrying rather more equipment.

At far right is a pictorial analysis of the improvement in high frequency wing flutter characteristics resulting from a given weight addition. Right, curves underline the great value of the spoilers at high airspeeds.



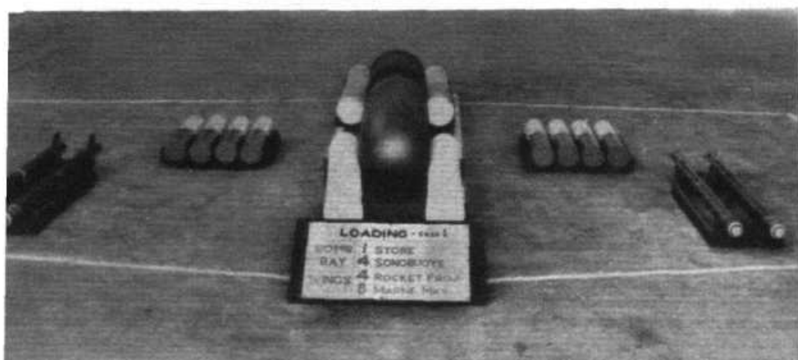


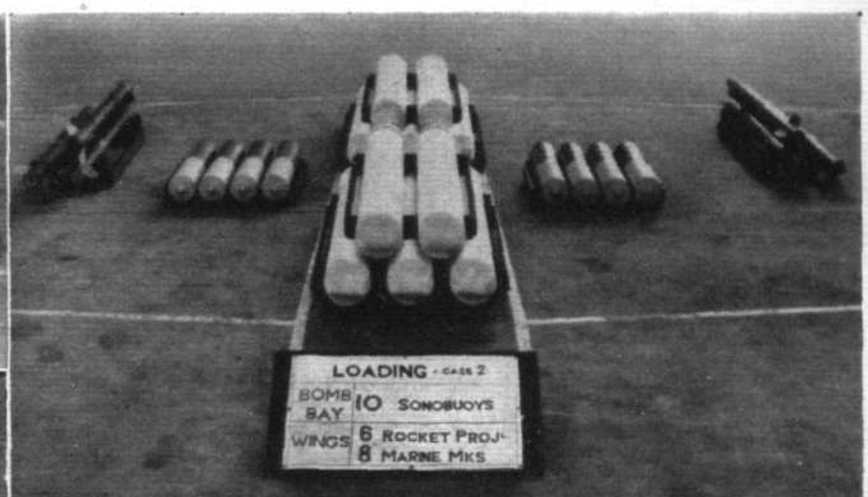
SEAMEW LOADS

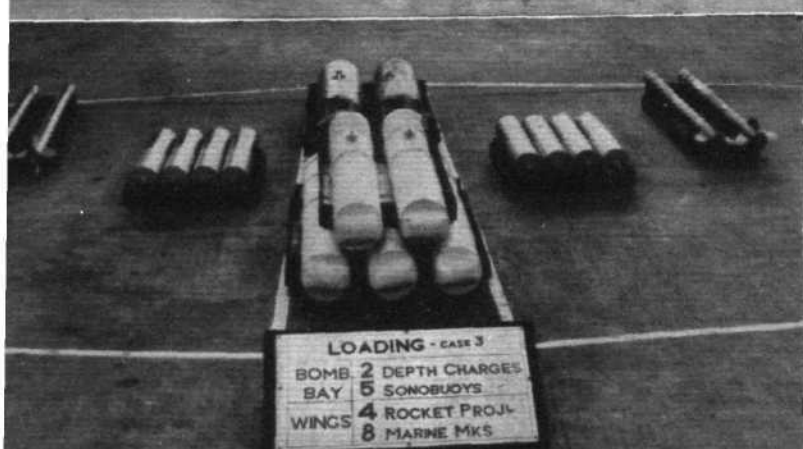
Sonobuoys, Markers, Depth Charges, R.P.s and "a Store"

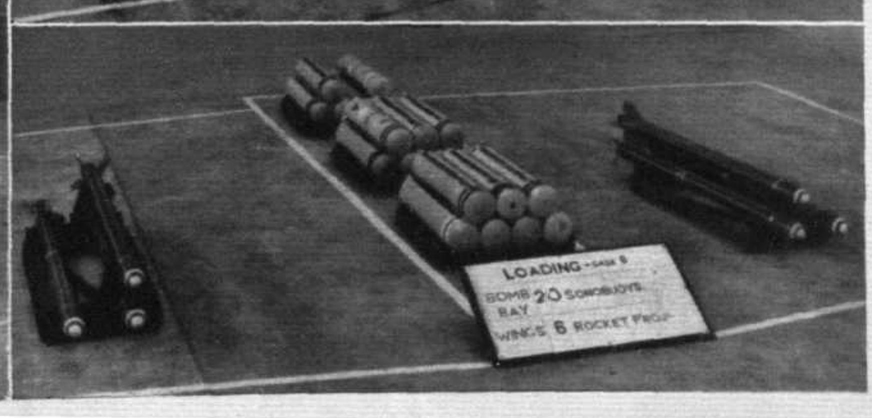
THOUGH having only about half the power of larger and more conventional carrier-borne anti-submarine aircraft, the Short Seamew A.S.1 (Armstrong Siddeley Mamba) has a very favourable structure-weight and a low wing-loading. In consequence, it is able to carry a really worth-while load of munitions, additional to its crew of two and detection equipment. Shown here for the first time are representative loads, disposed in the bomb bay and/or beneath the wings; there is, too, an especially pleasing aerial view, in semi-silhouette, of the Seamew itself. Quite apart from its carrier-borne rôle, this latest Short product is admirably suited for shore-based operations from small and primitive strips, while its handling characteristics (not greatly dissimilar, it would appear, from those of the classic "Stringbag") should allow uninhibited manœuvring in fjords and amid other natural hazards such as might be encountered in narrow approaches. The Seamew offers economy, simplicity and modernity of equipment and armament, all qualities calculated to appeal to NATO countries. Moreover, the operational aircraft can double effectively as an A.S. trainer. Though the various loads illustrated below are all placarded, they are reiterated for convenience and clarity—and by way of emphasizing that, though a gentle flying machine, the Seamew is a sub. hunter/killer of respectable striking power. The "store" which figures in Case 1 could represent a homing torpedo. The various cases are:—

(1) Bomb bay: 1 store, 4 sonobuoys. Wings: 4 rocket projectiles, 8 marine markers. (2) Bomb bay: 10 sonobuoys. Wings: 6 rocket projectiles, 8 marine markers. (3) Bomb bay: 2 depth charges, 5 sonobuoys. Wings: 4 rocket projectiles, 8 marine markers. (4) Bomb bay: 2 depth charges. Wings: 6 rocket projectiles. (5) Bomb bay: 4 depth charges. Wings: 6 rocket projectiles, 8 marine markers. (6) Bomb bay: 20 sonobuoys. Wings: 6 rocket projectiles.



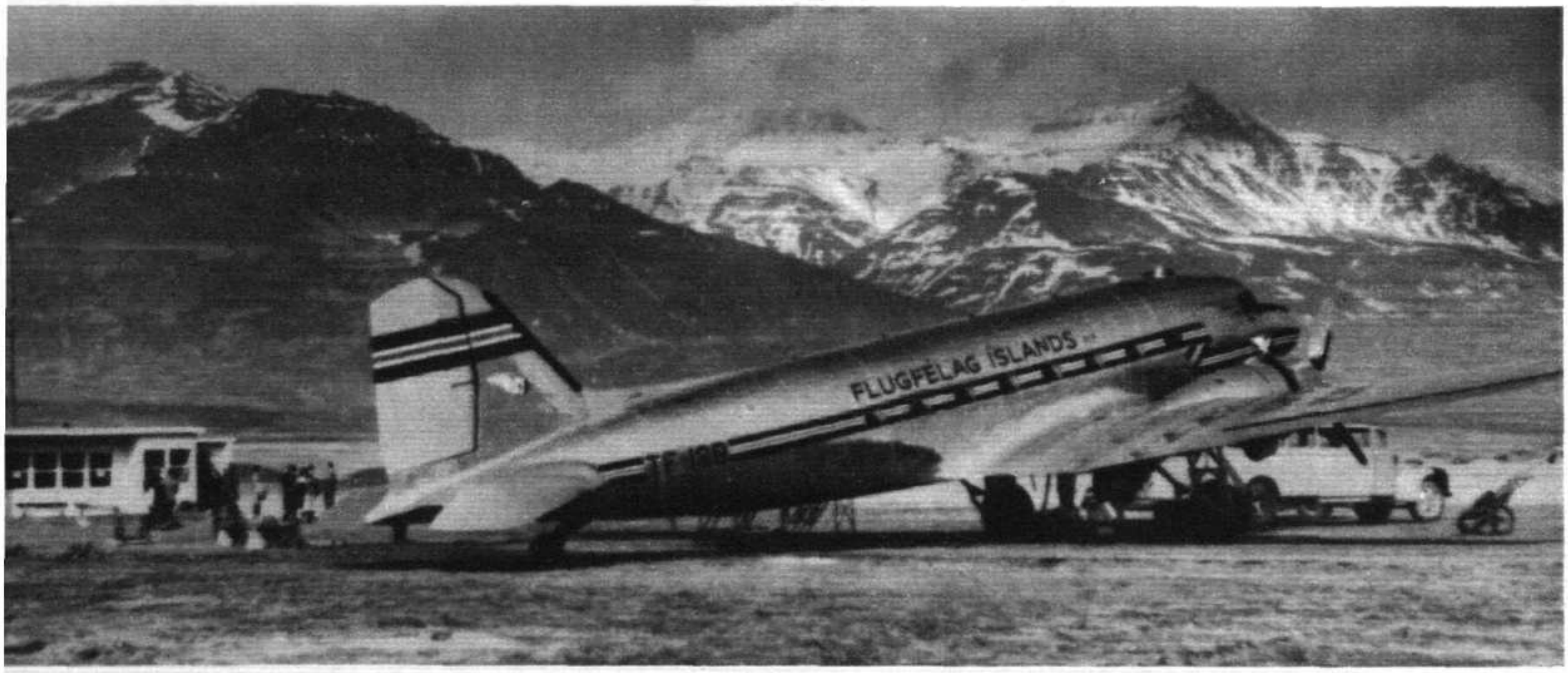






Iceland's Airline

(Left) Latest addition to Iceland Airways' fleet is this brightly marked DC-4, TF-IST "Solfaxi." One of the company's two Catalina flying-boats is seen above at its moorings in Siglufjord, Northern Iceland.



Snow-clad mountains form the accepted background to this study of DC-3 TF-ISB at Akureyri, Northern Iceland. The same aircraft is seen below in flight over Reykjavik, the capital. Last year the airline carried 54,000 passengers—28 per cent more than in 1953.

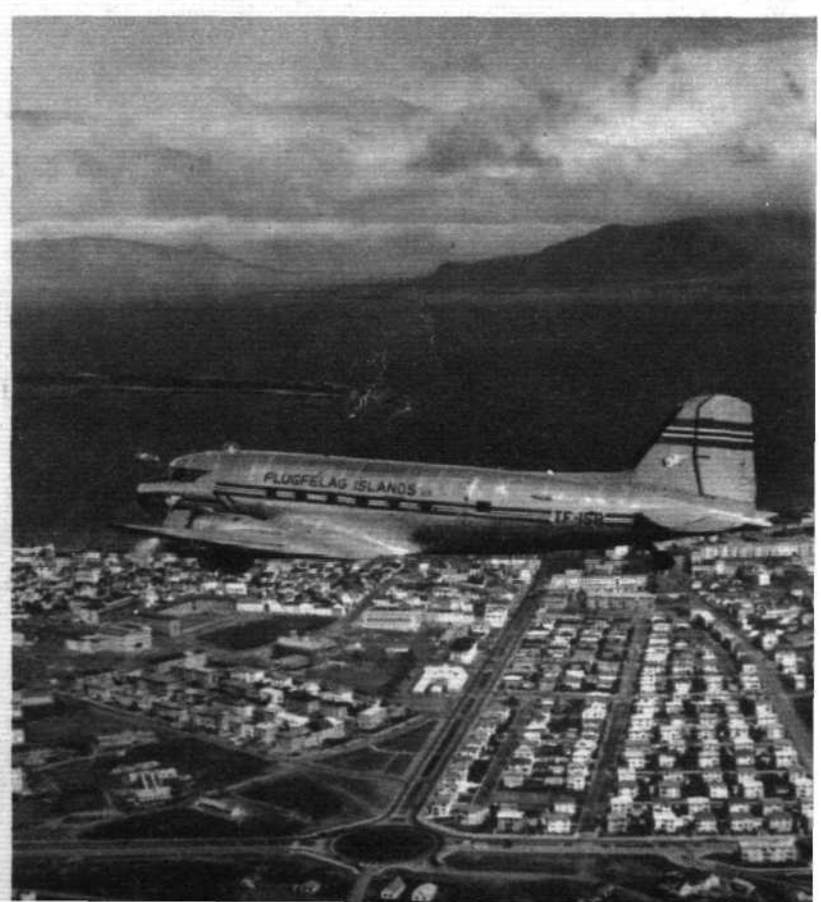
SUBJECT to the approval of the governments concerned, Iceland Airways (Flugfelag Islands H.F.) will operate a greatly increased schedule of international passenger services from May 1st this year.

There will be two services each week to the United Kingdom, instead of one, on the routes Reykjavik-Glasgow-London and Reykjavik-Glasgow-Copenhagen. This represents a major change, as the airline has used Prestwick since it started flying to Scotland nine years ago. The decision to switch to Renfrew—at least during the summer months—follows recent improvements at this airport.

Similarly, there will be twice as many services to Scandinavia as in previous years, with a weekly flight between Reykjavik, Oslo and Stockholm, and three services each week to Copenhagen—one direct, one *via* Glasgow and a third *via* Bergen in Norway. Neither Bergen nor Stockholm has previously been served by this airline. Western Germany also will be linked with Iceland for the first time, with a weekly flight to Hamburg, *via* Copenhagen, and another to Frankfurt.

To make possible this expansion of their services, Iceland Airways have bought a second Skymaster from Fred Olsen of Norway, to supplement the well-known DC-4 "Gullfaxi." After being refurnished at Kastrup Airport, the new machine arrived at Reykjavik from Copenhagen last month. The Icelandic Minister of Communications made a speech, and the Skymaster was christened "Solfaxi" (Sun-horse). This follows the airline's practice of giving all its aircraft names ending with "faxi"—the local name for the Icelandic ponies which were almost the only means of transport in the country until a few decades ago.

Iceland Airways also added a DC-3 to their fleet last year, and now operate two Skymasters, four DC-3s, two Catalinas and a Grumman Goose. The staff totals only 150, including those in offices in London, Copenhagen and Oslo.



TODAY'S RESEARCH for TOMORROW'S TRANSPORTS

Sir Arnold Hall's Brancker Memorial Lecture

THE 1955 Brancker Memorial Lecture was delivered on Monday last, February 14th, at the Institute of Transport by Sir Arnold Hall, F.R.S., M.A., F.R.Ae.S., Director of the Royal Aircraft Establishment, Farnborough. Sir Arnold's paper, entitled *The Influence on Civil Aviation of Some Current Researches,* was particularly concerned with ways of improving not only the performance and economics of transport aircraft, but also their safety and regularity. Lucid in both thought and expression, it promises to receive early recognition as one of the most significant of post-war aviation lectures. The first part of the paper is given below; we expect to conclude our summary next week.

The lecturer began by "confessing to the feeling" that civil aviation, already a substantial influence, needed greater reliability and safety if it was to become, as it should, a great force in world affairs. It was particularly to these matters, rather than the very-long-term possibilities, that attention should be, and no doubt would be, directed. The accident due, for example, to troubles of navigation, to storm, to landing in bad weather, must be totally mastered, and achievement of this aim would be assisted by developments which were now in hand, or which could be foreseen. It was usually the case that advances in the performance of aircraft could be taken in several ways (for example, in lifting greater weight, in reducing operating costs, in lower approach and landing speeds). Improvements representing a considerable potential economy were likely to occur in the next decade, and Sir Arnold hoped that some part of them would be taken in features which enhanced reliability and safety, rather than entirely in economies in the cruising phase. There should be enough in plenty to provide the right service, reliability and safety at the right price.

Saying that he could not hope to cover the subject of this lecture exhaustively, the lecturer remarked that he had chosen topics of general interest, and particularly those in which the Royal Aircraft Establishment had been able to make some contribution.

The Next Generation of Long-Range Aircraft.—During the last ten years [continued Sir Arnold Hall] research has greatly increased our knowledge of the aerodynamic problems encountered near the speed of sound, and has brought the gas turbine engine to a high state of development. As a result, long-range civil aircraft capable of cruising at high subsonic speeds—500 to 600 m.p.h.—can now be designed, and such machines are likely to form the generation of long-range aircraft which will follow the machines now about to come into service. . . .

High-subsonic-speed aircraft can be powered with turboprop or turbojet engines, and the wings can take several forms, typified by the straight wing—for speeds up to 500 m.p.h.—and the swept-back wing of about 40 deg (leading edge), or the delta wing of 45-50 deg, for speeds up to 600 m.p.h. The operating height of this class of aircraft will be in the 35,000-45,000ft altitude band, the turboprop types flying at rather lower levels than the turbojet.

The economic characteristics of such aircraft differ substantially from those of present long-range types and, in particular, their operating costs can be considerably lower. Characteristics are, of course, to some extent influenced by the choice of wing plan-form and propulsion system, but the economic variation between the arrangements is small compared with the change

TABLE

	Cost: pence per capacity long-ton nautical mile	
	Typical present-day long-range aircraft (Payload: 15,500 lb)	Typical high-subsonic-speed aircraft (500-600 mph) (Payload 35,000 lb) (120 passengers)
"Formula" direct operating cost	24.5	11
"In practice" addition to "formula cost"	10.5	7
Indirect cost...	22	20 (assuming present level of overheads)
Total cost	57	38

IN these pages, in very slightly abridged form, is the first part of Sir Arnold Hall's lecture. As all except one of his illustrations (Fig. 5) are included, the original figure numbering is retained in order to assist subsequent discussion.

from present-day standards. Apart from remarking that I believe that the turbojet type can be designed for comparably cheap operation at speeds substantially higher than the turboprop type, I will leave the argument as to which layout and powerplant is to be proclaimed the best to the protagonists of particular arrangements, and attempt to bring out the general characteristics of the class.

As compared with a direct operating cost of about 35 pence per capacity long-ton nautical mile for present-day long-range aircraft, high-subsonic aircraft will show direct costs of about 18 pence, and will, in addition, be capable of operating over considerably greater stage-lengths. Assuming the present level of indirect costs, the total cost (direct plus indirect) of high subsonic aircraft will be about 38 pence, as compared with the present-day 57 pence, per capacity long-ton nautical mile.

In what follows, the "formula direct operating cost" means the direct cost, including the element for annual charges on the aircraft, according to an established costing formula which is detailed in Appendix 1 [see page 214], wherein also will be found the "make-up" of the formula cost in typical cases. Direct costs as they are found in practice differ from "formula costs" by an amount which depends on the route, and type of operation. In quoting the figures in the preceding paragraph, a typical addition, as found in practice on a particular route has been made for the present-day aircraft, and an estimated "in practice" allowance as it might be found in a high-subsonic aircraft operated in similar general circumstances has been added for that case. The general magnitude of the elements making up the total cost in a typical case is shown in Table I, which is intended to do no more than put them in relative perspective.

For comparative purposes, it is convenient to work in terms of the "formula cost," and this is done in what follows.

In Fig. 1 are shown some of the economic characteristics of the high-subsonic class, as typified by aircraft designed for the non-stop London to New York flight, at 550 m.p.h. This is a stage-length of 3,000 nautical miles; the still-air range, to provide normal allowances for wind and fuel reserves, is 4,800 n.m. The figure shows the formula direct operating cost, as a function of the payload and the landing approach speed for which the aircraft is designed. The take-off weight is indicated at particular points. (The landing approach speed quoted is the "speed over the hedge"; some prefer to quote the speed in the early stages of the approach, but the two are usually related in a simple way.)

If the wing of the aircraft is made only sufficiently large to carry the fuel needed for the specified still-air range, the economy of operation in the cruising phase approaches the maximum obtainable, since the wing is then the smallest upon which the aircraft can make the journey. A smaller wing would suffice were fuel carried in the fuselage, a practice some designers prefer to avoid, or if additional fuel were carried in nacelles attached to the wing. Such arrangements, at high design-payloads, result in a fast landing approach speed, which, for reasons I will discuss later, I would prefer to see avoided, though new ideas on obtaining more lift from the wing, or additional lift to that given by the wing, to ease the take-off and landing problem, may allow such additional economy as can be obtained by "podding" the fuel to be taken. Leaving aside these possibilities for the moment, the "wing-full" aeroplane is the design giving maximum cruising economy, and if lower landing approach speeds—and incidentally, better take-off characteristics—than are provided by the "wing full" design are needed, the wing area must be increased, with the adverse effect on economy of operation which is indicated in Fig. 1.

Examination of the influence of designed capacity payload (Fig. 2) shows that there is economic benefit to be derived from increasing the designed payload as compared with that carried by contemporary long-range aircraft, if the traffic available, and frequency of service needed, will permit. The influence of annual utilization can be gauged from Fig. 2 where a comparison is made of the 3,000 hours per annum and 2,000 hours per annum "wing-

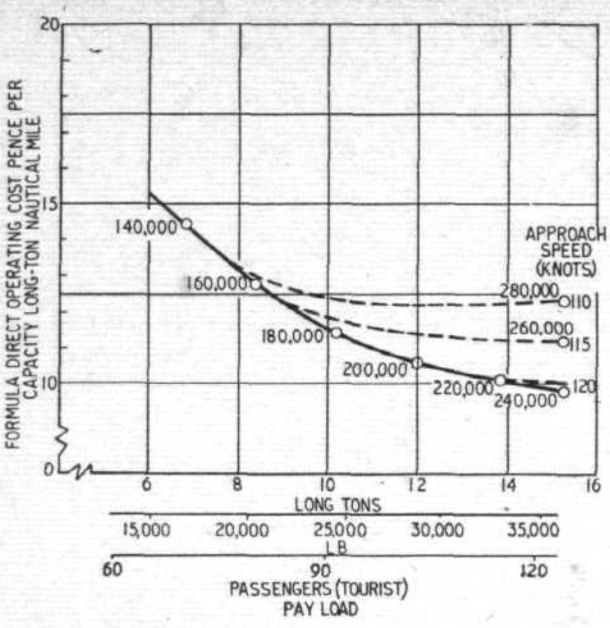
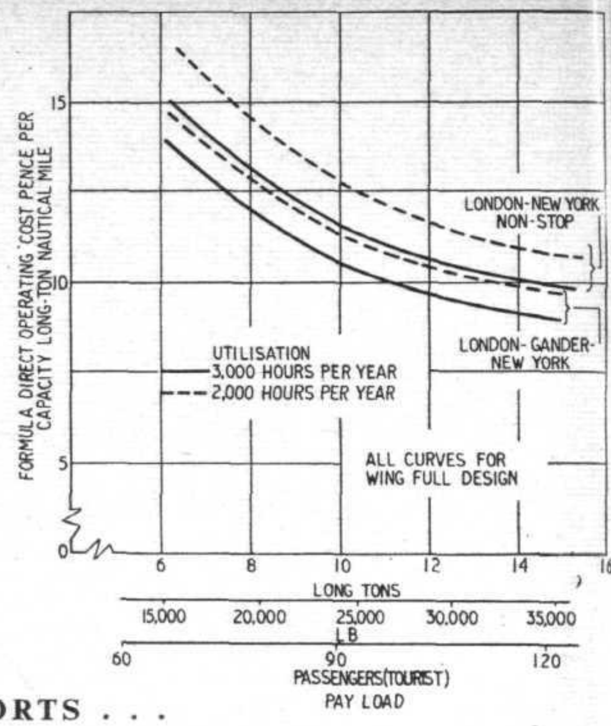


Fig. 1 (left). "Formula" direct operating costs for a swept-wing turbojet transport with cruising speed of 550 m.p.h. (478 kt). Figures on the curves show take-off weight (lb) for a 3,000 n.m. stage, the ordinate being based on 3,000 hr p.a. utilization. The full line is a wing-full design; the broken line a constant-approach-speed design.

Fig. 2. Curves showing the effect of variations in designed range and annual utilization of 550 m.p.h. swept-wing transport.



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full design" curves. The lower utilization increases direct costs by about 6 per cent, which is about 3 per cent on total costs. Within limits, it is evident that there is economic advantage in carrying a given level of traffic in larger aircraft at lower frequency of service. For example, a 60-seat aircraft used for 3,000 hr each year operates at a direct cost some 15 per cent higher than a 90-seat aircraft used for 2,000 hr each year, though the passenger movements provided are the same. It is generally the case that the public expect a frequency of service roughly equal to the journey time, a fact which seems to apply to many forms of transport. This class of aircraft will more than halve the journey-time compared with present standards, and lead to a demand for a correspondingly higher frequency of service. It will be of advantage to the operator to resist this pressure so far as the size of market makes it necessary, and competition permits, in order to obtain the financial advantage of operating aircraft designed for relatively high payloads.

The influence of the range for which the aircraft is designed is indicated in Fig. 2, by the comparison of the "wing-full" lines for 2,000 and 3,000 n.m. stage-lengths, e.g., London to Gander, compared with London to New York. The respective still-air ranges, to provide normal allowances for wind and fuel reserves, are 3,700 and 4,800 n.m. The increase in direct operating costs consequent on designing for the longer stage is about 5 per cent —or less than 3 per cent on total costs—a figure sufficiently low to make it probable that, on the North Atlantic route, operators will prefer the aircraft capable of the non-stop London to New York flight.

The economies in direct operating costs shown by the high-subsonic class of aeroplane, compared with present-day long-range machines, arises mainly from their higher annual earning capacity, due to higher speed. The question "Why faster?" has the answer "A better service at a lower cost." Where the traffic offered justifies it—and, by the time such aircraft are available, the North Atlantic route probably will—a further gain in economy is obtainable by operating larger aircraft, designed for a higher capacity payload.

Some part of the inherent economy should, I think, be given to features which will increase reliability and safety, rather than that the "last ounce" should be taken in cruising economy. I think that one of the most important of such features is the reduction of the landing approach speed of the aircraft. The cost of making a reduction can be judged from Fig. 1, from which it is evident that, though the maximum cruising economy of the class will be obtained only if approach speeds are allowed to increase, as compared with present aircraft, only a small proportion of the saving which will be obtained need be foregone to allow an improvement on present standards. The landing approach speed has a considerable influence on the ability of the aircraft to land safely in conditions of bad visibility. It is likely to prove "good business" —in terms of reduction of bad-weather diversion, and accident rate—to design for lower approach speeds. When this is done, the long-range airline operator will still have a machine capable of operating at a substantially lower direct operating cost than present equipment.

The Supersonic Aircraft.—The question "What price speed?" [continued the lecturer] is answered in the previous section, for long-range aircraft flying at high subsonic speeds, by "It's cheaper." In recent years, we have acquired some knowledge of supersonic aerodynamics and while there is still much to learn, present information is enough to permit an attempt to assess the likely performance of a supersonic civil aeroplane. In doing this, it should be borne in mind that we will acquire much more knowledge in this field in coming years, and it is therefore probable that, in time, we will be able to do much better than now seems possible. In mentioning the supersonic position as it now appears, I do not wish to suggest that we will contemplate building such an aircraft in the near future; all I seek to do is to clothe a not-infrequent topic of general conversation with some reality.

As usual, there are a number of geometrical layouts which can be contemplated, and which have their advantages and defects. But, taking as a starting point a design (Fig. 3) which has characteristics that would enable it to take off from and land on main-terminal runways, I think we will not be severely misled on the operating economics as they can now be contemplated. The figures of Table II emerge for aircraft cruising at 1,300 m.p.h. (Mach 2). No. 1 aircraft is suitable for medium stage-lengths; it could, for example, make the journey from London to New York, with a stop at Gander, in about 4 hr, carrying 50 passengers. No. 2 could fly from London to New York non-stop, in 2¾ hr, carrying 20 passengers. These aircraft would cruise at altitudes between 45,000 and 55,000ft.

Having in mind that when the time comes we shall certainly be able to do better than these figures suggest, and noting that, for the medium-length stage at least, the cost emerging on the basis of present knowledge (being about 20 per cent higher than present costs) is not outrageously high, it seems to me likely that the development of long-range supersonic civil aviation will follow the exploitation of the high-subsonic possibilities. The influence of the higher annual earning capacity which increase of speed represents a potent one, and whilst, on present knowledge, it is offset in the overall economic picture by lower aerodynamic efficiencies in supersonic, as compared with subsonic, conditions, only small changes in the aerodynamic position are needed to allow it to re-assert its dominance. I will be surprised if, in a few years' time, we will not be able to see the economics of the No. 1 aeroplane in machines capable of the non-stop London to New York flight.

A time-table looking something like Table III is not without its attractions. The curious, and perhaps convenient, results of flying "faster than the sun" are evident.

TABLE II

	Aircraft No. 1	Aircraft No. 2
Stage length (nautical miles) (with suitable allowances for fuel reserves)	2,000 (e.g., London-Gander)	3,000 (e.g., London-New York)
Flight time for the stage (including climb and descent)	2 hours	2¾ hours
Number of passengers	50	20
Take-off weight (lb)	270,000	320,000
"Formula" Direct operating cost: pence per capacity long ton nautical mile	35	110
Total operating cost: pence per capacity long ton nautical mile	70	175
Ratio of total cost to present-day long range aircraft	1.2	3

TABLE III

New York		London		New York		London		New York
D 24.00	→	A 08.00						
		D 11.00	→	A 08.00				
				D 12.00	→	A 20.00		
						D 23.00	→	A 21.00
								D 24.00

All times are local times.

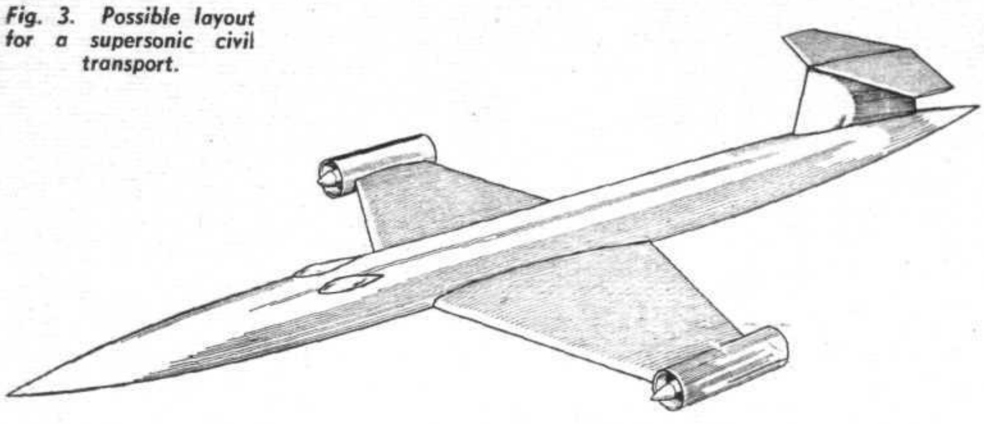

Fig. 3. Possible layout for a supersonic civil transport.

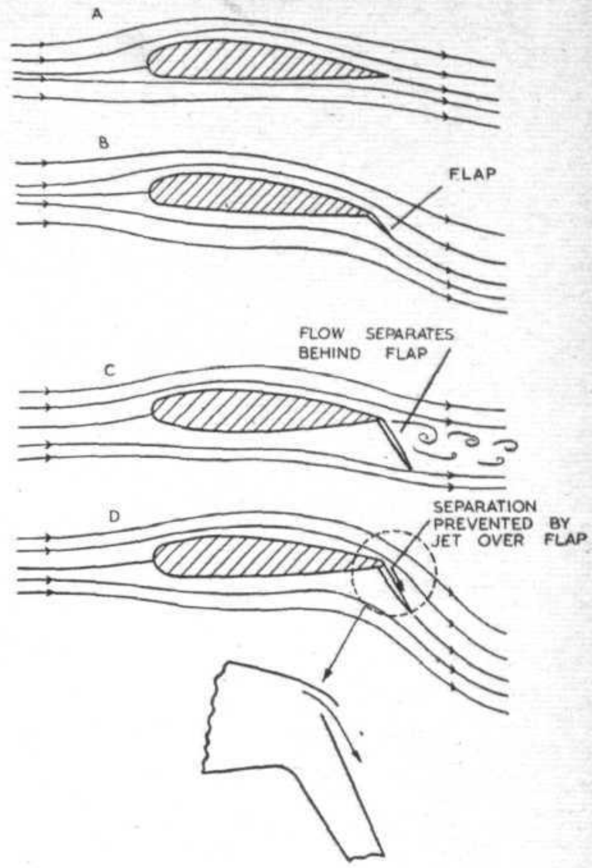

Fig. 4. Flow around a wing (a), showing the influence of a flap (b), the limit of influence of flap caused by separation of flow (c), and the restoration of effectiveness by jet flow over the flap (d).

Take-off and Landing Characteristics.—Were it not for the possibilities with which I will deal briefly in this section, the trend of the past towards increased take-off and landing distance, and increased approach speed on landing might continue in the future, if maximum economy in the cruising phase were demanded. This is shown by the opening discussion of the next generation of long-range aircraft, though it is also clear from that discussion that present standards could not only be maintained but could be improved upon whilst retaining very substantial economic gains. I would feel less concerned with such a trend were it not for the implications in relation to bad-weather landings (which are considered in a later section). It is, of course, popular to criticize the runway—particularly when it gets longer—but the fact is that, for civil aviation, the runway is by no means a bad or expensive way of taking to the air and returning to the ground, and length of runway is one of the best bad-weather landing aids that can be had.

On economic arguments, it would be folly to penalize the efficiency of the aircraft as a flying machine in order to save a little on airport costs. The costs of runways, in terms of money and land, should be considered against a wider background than the critics are sometimes willing to admit. It may be true that there is enough concrete in London Airport to make a road from London to Glasgow, but since this facility forges a vital transport link not just between two cities a few hundred miles apart, but between cities all over the world, is this really too high a price to pay? The civil engineering requirements of civil aviation look far less monstrous if they are considered side by side with the corresponding needs of, say, a railway system. A hundred years ago, our predecessors threw across this country the present network of railway lines; let the critics of runways consider what that feat involved in terms of land, tunnelling, embankments and bridges.

Notwithstanding this defence of the runway, there would, I think, be great advantage to safety and regularity of operations if landing approach speeds were lowered; for civil aviation the reduction of runway length needed should be regarded as a bonus rather than the main aim. Apart altogether from the new possibilities I will now discuss, there is a good case for obtaining reduction of approach speed by such conventional methods as lower loading of the wings and better flaps.

The prospects of significant changes to the trend of the past have brightened recently. The basic reason for this is that turbojet engines are getting lighter every day in terms of their thrust-to-weight ratio, and they will increasingly provide us with the means of pumping large volumes and masses of air at a low cost in weight of machinery.

To explain why this might have a significant impact on the problem, Sir Arnold then discussed how an aeroplane is lifted and propelled, using some effective analogies.

All aeroplanes, from the first [he said], have been jet propelled and jet sustained; the only things that have varied are the means of producing the sustaining and propelling jets. The only way to produce lift on a flying machine (other than lighter than air craft) is by throwing air downwards, so producing an upward reaction on the machine, just as the only way to produce propulsive thrust is to throw air backwards, so producing a forward reaction on the machine. The propeller is a means of producing a backward blowing jet of air—it is of larger diameter, and lower speed than the jet produced by a jet engine, but it is a jet none the less. The wing of a conventional aircraft similarly develops its lift by throwing a jet of air downwards—not a jet in the conventional meaning of the term, but nevertheless a downward motion of a mass of air. The rotor of a helicopter fulfils the same function.

In order to produce the necessary downward motion of a mass of air, the wing must itself move forward, and there is a minimum speed below which it is incapable of providing a sufficient downward "jet" to sustain the aeroplane. The problem of getting more lift for aeroplanes, so that their approach, landing and take-off speeds can be reduced can therefore be approached in two ways—or by a combination of both. The wing itself might be made to throw sufficient air downwards at a lower forward speed, or the lift given by the wing at the landing and take-off phase might be augmented, or even replaced, by lift provided by a downward "jet" generated by machinery.

If this is achieved, in one way or another, another problem must also be solved, and that is the provision of adequate control at the lower flying speeds obtained. The normal elevator and aileron controls depend, for their effectiveness, on the forward speed of the machine—just as does the wing in producing its lift—and as this speed is reduced, so they become the more ineffective. Therefore, if advantage is to be taken of any reduction of flying speed obtained, conventional controls must either be made more effective or be replaced, wholly or partially, by other means.

The conventional way of getting more lift from a wing is to put down a flap at the trailing edge; this, as shown in Fig. 4 increases the downward motion produced by the wing. The limit to what can be done this way is reached when the airflow "breaks away" from the surface (Fig. 4c). It has been known for a long time that if air is blown over the flap (Fig. 4d) this breakaway can be delayed, and more lift therefore obtained. If the machinery required for producing the air to be blown is heavy and bulky, its weight (together with the increase of size and weight of the aeroplane in order that the machinery may be carried) can sufficiently offset the gain of lift to make the process of doubtful value. In a turbo-propelled aircraft, however, it is likely to become possible to provide large volumes of air by tapping the propulsion-engine compressors, at relatively small cost in weight. The specific weight of jet engines is now such that the provision of a small engine as a gas generator, for this duty alone, can at least be contemplated. "Blowing over the flaps," to increase lift from the wing therefore emerges into the field of practical possibilities, and initial work based on this idea is promising.

If the amount of air so blown is increased it begins to make a significant contribution to lift by virtue of its own momentum—not only does it increase the "downward jet" created by the wing, but it becomes a significant additional downward jet itself, and a system emerges which is midway between the "augment-the-wing" and the "machine-generated jet lift" concepts.

"Machine-generated jet lift" can be provided in two forms, in the extreme by the installation of engines for the sole purpose of creating downward jets or by deflecting in a downward direction the jets of the main propulsion engines.

The experimental device which has become known as the "Flying Bedstead" [illustrated by the lecturer, and recently shown in *Flight*] is an example of an aircraft wholly sustained by machine-generated lift. The purpose of this device is not to demonstrate that its two Nene turbojet engines can lift it; that much is clear from simple calculation. Its purpose is to make experiments on the control of a machine by small jets of air, which, in the Bedstead, are fed from the main engines through a suitable control system operated by the pilot. The stability and ease of control achieved are evidence that such a system of control is

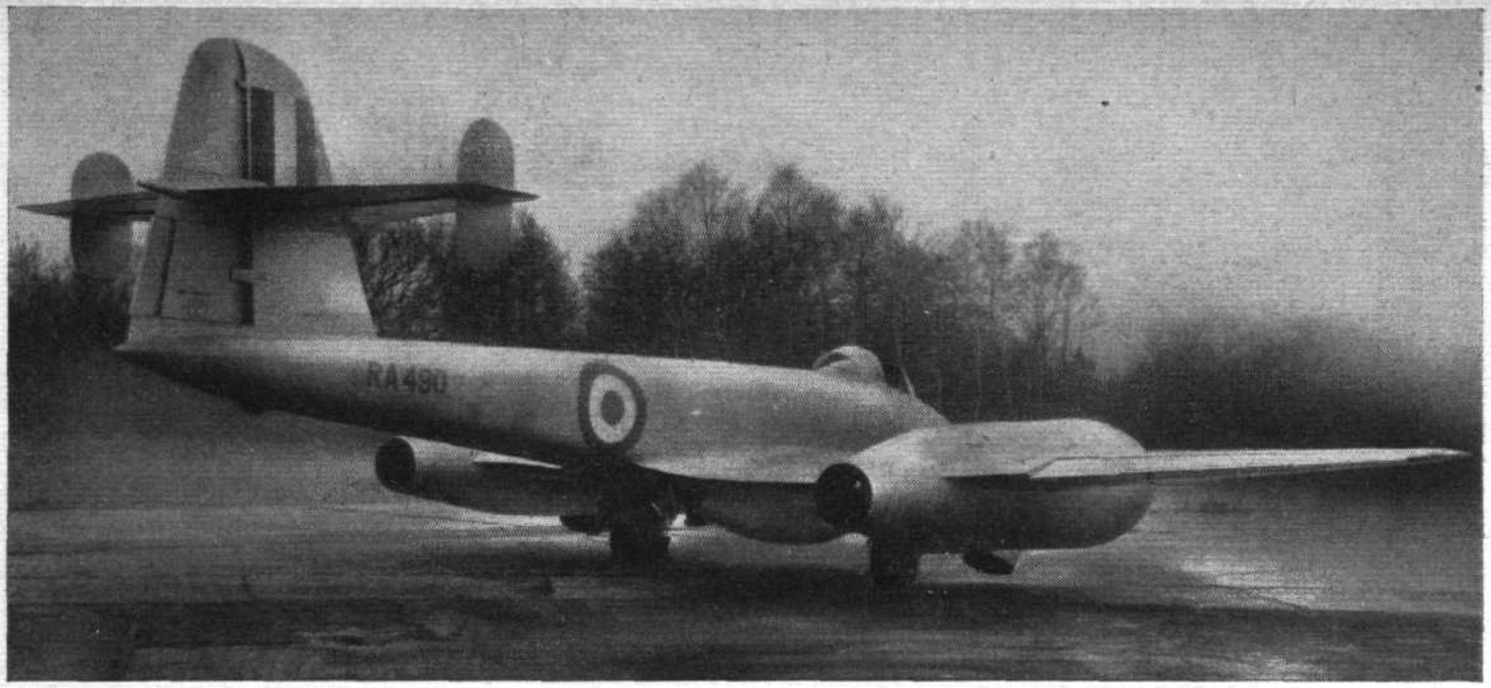

Fig. 6. Beryl-Meteor modified by the addition of under-nacelle jet pipes exhausting in a downward-and-rearward direction. Its minimum safe flying speed was reduced by 20 kt. This aircraft was built as a Mk 4 but now has a Mk 8 tail with auxiliary fins.

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entirely practicable. Such direct lift, so controlled, can, in principle, be used to reduce the lift required from the wing, so reducing the minimum flying speed of the aircraft. In the extreme case it could reduce the distribution needed from the wing to zero, so that the aircraft can land and take-off vertically.

Fig. 6 shows a Meteor aircraft which has been converted for experimental use in investigating the downward deflection of the main propulsive jets. Plainly this type of installation can produce useful effects only if the thrust of the propulsion engines is a substantial fraction of the weight of the aeroplane, a condition to be found in military, rather than civil, aircraft. However, it illustrates another facet of the "machine generated lift" concept. In this aircraft, the propulsive jets can be deflected 60 deg downwards, and the aircraft is capable of a stable minimum flying speed which is more than 20 kt lower than the standard type.

The lecturer concluded this section of his paper by saying it would be evident that the key to the practical application of these ideas was the availability of engines which were very light in weight in relation to the thrust they were capable of providing. We were now entering the stage of development of turbine engines

TABLE IV: ANALYSIS OF FIRST COSTS AND DIRECT OPERATING COSTS

	Present-day long range	High-Subsonic
Cruising speed	230 kt (265 m.p.h.)	478 kt (550 m.p.h.)
Route	London-Shannon-Gander-New York	London-New York direct
Stage speed (still air)	213 kt (245 m.p.h.)	447 kt (510 m.p.h.)
Wing	Straight	35° swept
Powerplant	Piston	Turbojet (by-pass)
Payload (lb)	15,000	35,000
Number of passengers	50	120
Take-off weight (lb)	145,000	239,000
First Costs (£)		
Equipped airframe	350,000	800,000
Powerplant	80,000	145,000
Direct Operating Costs (£) per Flying Hour		
Annual		
Obsolescence of		
Eqppd. airframe and spares ...	13	29
Powerplant and spares ...	4	9
Propeller and spares	1	—
Insurance	8	17
Total	— 26	— 55
Maintenance and overhaul		
Airframe and equipment ...	25	36
Powerplant	22	67
Propellers	5	—
Total	— 52	— 103
Flying		
Cockpit crew	12	10
Fuel	56	109
Landing	5	9
Total	— 73	— 128
TOTAL	151	286
Unit Direct Operating Costs (Pence) in still air with 100% load factor		
Per nautical mile	171	153
Per long ton nautical mile ...	24	10
Per passenger nautical mile ...	2.4	0.95

when the gathering of these fruits of lightness could at least be contemplated. It would turn out, as usual, that the advantages could be taken either in terms of reduced approach and landing speed or in terms of cruising economies, or in a combination of both. He returned to his plea that, in civil aviation, we should use such advances to ensure the safety and reliability of the landing operation before going too far in gathering advantages of other kinds.

In the remaining part of the paper, to be summarized in *Flight* next week, Sir Arnold discussed boundary-layer control; structures; noise; navigation and communication; and problems of bad-weather landing.

APPENDIX I—OPERATING COSTS

When operating costs are mentioned in the paper, they have been assessed using *The Standard Method for the Estimation of Direct Operating Costs of Aircraft* as evolved by the Society of British Aircraft Constructors. First costs have been estimated on the basis of £9 per pound of equipped airframe (basic operation weight less removable powerplant). Powerplant costs (turbojet) have been taken at £7 per pound of removable plant.

Typical cost break-downs are shown in Table IV. The final cost derived from such an analysis has been termed, in the main text, the "formula direct operating cost."

The "in practice" addition mentioned in the main text allows for aircraft utilization shortfall, flight crew utilization shortfall, handling and maintenance facilities at overseas stations and alternates, flying staff training, crews' expenses, overheads of engineering and fleet administration, and provision of licences.

The indirect cost element covers passenger services, station costs, commissions, sales, advertising and interest on capital (other than aircraft).

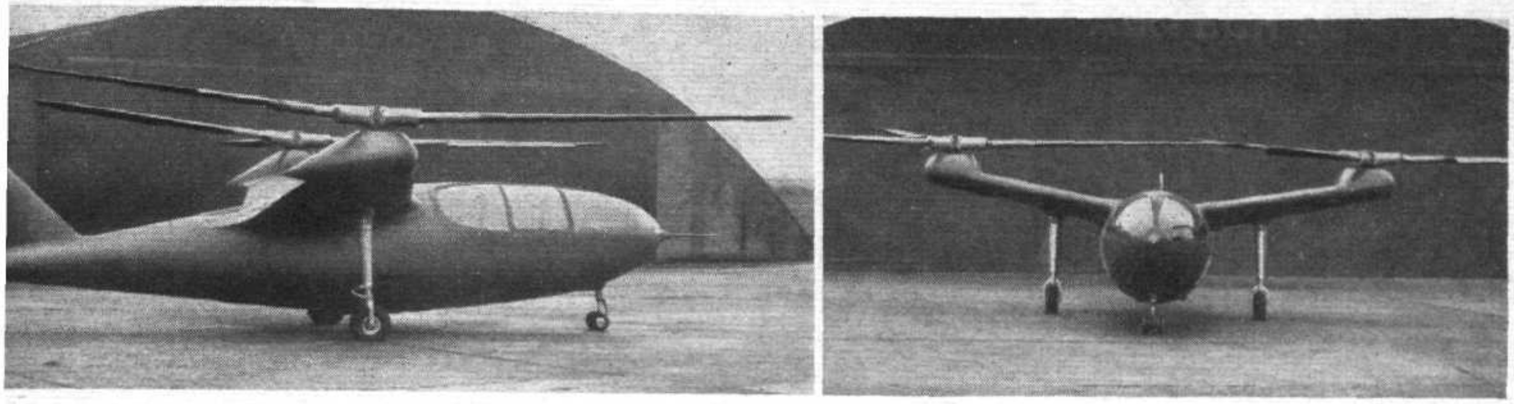
In the case of "laminarized" aeroplanes, the extra weight of surface, suction equipment, ducts, etc., has been taken as 2 lb per square foot of surface laminarized. Airframe maintenance costs have been assumed to be 20 per cent above normal for 20 per cent drag reduction, and 50 per cent above normal for 80 per cent drag reduction. The basic cost of airframe and equipment is taken to be the same for the laminar as for the non-laminar flow aeroplane.

ENGINES IN THE NEWS

TWO new gas-turbine power units have recently been in the news. Of the first, only brief preliminary details are available; it is a new turbojet designed by the French S.N.E.C.M.A. group in the 4,000 lb thrust class for use in fighters, missiles and coleopters [vertical-rising aircraft with annular aerofoils]. The first prototype engine ran on the test bed at the end of December and the new unit is therefore contemporary with the Bristol Orpheus in both output and timing.

The second new unit is the Allison 501 turboprop, now being offered for delivery as a certificated transport unit in March 1957. The 501 is a commercial development of the T56 and has a 14-stage compressor (of no less than 9 : 1 pressure ratio), annular combustion chamber and four turbine stages all on the same shaft. The reduction gear is housed in a cast magnesium box carried forward of the power section to permit the intake to lie under the spinner. The gear ratio is 12.5 : 1 in two stages. The engine drives a single 13ft 6in airscrew with three wide-chord blades.

The 501 delivers up to 3,750 e.h.p. at sea level, with specific fuel consumption of the order of 0.54 lb/hr/e.h.p. The complete engine weighs only 1,610 lb and has a width and length of 27in and 145in, respectively. It is hoped that the overhaul life will be at 400 hr by the time the engine is ready for service in 1957.



The Firth FH-1 helicopter referred to below; it utilized the fuselage of the Planet Satellite, an unorthodox low-wing monoplane of 1947-48.

CORRESPONDENCE

The Editor of "Flight" does not hold himself responsible for the views expressed by correspondents in these columns; the names and addresses of the writers, not necessarily for publication, must in all cases accompany letters.

A Graceful Helicopter

THE photograph in your issue of January 28th of the Firth Helicopter revived nostalgic memories for me. I was Mr. Firth's secretary at the time of its construction, and I watched its progress from blueprint to engine and rotor tests. Flight tests never took place, because modifications to correct slight nose-heaviness were found to be necessary, and, unfortunately, at this point the company ran out of funds.

The FH-1 was, I think, quite the most handsome little helicopter ever built, and it saddened me that its first public photograph should show it in an incomplete state. I am therefore enclosing two others which I hope you will find it possible to print. I am sure Mr. Firth, who, I believe, is now in Vancouver, would not object to their publication.

Letchworth, Herts. JOAN HAGGARD.

Future of the R.Aux.A.F.

IN view of the fact that many keen ex-Service aircrew have been deprived of their flying by the closure of the V.R. is it not inconsistent that the university air squadrons should be preserved?

It seems that these privileged persons can be taught to fly without committing themselves further than an ordinary National Serviceman.

I have spoken to a few members of one U.A.S., all of whom had only one object: to learn to fly at the expense of the taxpayer and consequently to do their National Service as aircrew. Is there the slightest reason why this delightful opportunity should be confined to a few gentlemen at the universities?

Now it seems the U.A.S. are to be kept on while the R.Aux.A.F. is to be dissolved.

Many of us who were pilots in squadrons would welcome the odd 60 hours' flying a year. Or are we too old at 25?

Welwyn Garden City, Herts. W. R. BURROWS.

YOUR contributor's dissertation concerning the future of the Royal Auxiliary Air Force [January 28th, page 128] has been read with interest, and through it one perceives much regret at the passing of the old way of things. Undoubtedly life in the militia in the days of the horse, a sword and a bag of fodder was very pleasant for the part-time soldier. That day has gone for ever and it is no use remembering Auxiliary pilots' ability to handle D.H.9as, Spitfires or even Meteors. The complication today lies not only in the actual pilotage, but in the ancillary aids to air fighting.

However, until the day of complete press-button warfare arrives, and squadrons as we know them cease to exist (horrid thought!), unit *esprit de corps* is an essential. To turn famous units, such as are many of the R.Aux.A.F. squadrons, into part-time training units is to insult them, their illustrious honorary air commodores and the cities and counties from which they take their names.

There are, it would seem, three ways of solving the problem. The first is to bow to the inevitable and disband completely the flying side of the Royal Auxiliary Air Force—this solution would at least have the virtue of the squadrons being retired as honoured fighting formations rather than dragging out an existence as training units. A second alternative would be to change the rôle of the squadrons to either fighter/bomber or army transport.

A third, and perhaps more appropriate, way would be to turn the squadrons into regular units, retaining their present names and associations, the auxiliary personnel being completely integrated with other members of the squadrons—not relegated to "auxiliary flights." Under this arrangement it would be necessary to add only such regular personnel as were found essential; and if, as your contributor avers, "swept-wing" standard could be attained, then a very small regular element would be required —everyone being on his toes to reduce it to nil.

London, S.W.19. AUX.

The Slab Tail

IN connection with your recent leader and subsequent correspondence, it may be of interest that we were flying a slab tail on the Gillette Falcon in 1944. This aircraft was used for flight research on the very thin bi-convex wing and empennage sections of the supersonic M.52 project which was abandoned due to a change in official policy when the aircraft was approaching completion.

G. H. MILES,
Shoreham, Sussex. Director, F. G. Miles, Ltd.

FORTHCOMING EVENTS

Feb. 18. Institute of Welding: London branches' annual dinner.
Feb. 18. Institute of Navigation: "Automatic Dead Reckoning Instruments," by H. C. Pritchard.
Feb. 18. A.T.A. Association: Reunion dinner.
Feb. 19. British Interplanetary Society (provisional Yorkshire branch): Film show.
Feb. 22. R.Ae.C.: Film Show.
Feb. 23. Royal United Service Institution: "Rocket Propulsion and its Implications to Human Society," by A. V. Cleaver, F.R.Ae.S.
Feb. 24. Aerodrome Owners' Association: Annual general meeting and dinner.
Feb. 26. Northern Heights Model Flying Club: Annual dinner and dance.
Mar. 1. R.Ae.S. Section lecture: "The Scientific Approach and Research in Aircraft Production," by Prof. J. V. Connolly, B.Eng., F.R.Ae.S.
Mar. 3. British Institution of Radio Engineers (North-western section): "Computing Circuits in Flight Simulators," by A. E. Cutler, B.Sc., Ph.D
Mar. 5. British Interplanetary Society: "Radio Exploration of Space," by R. C. Jennison, B.Sc.
Mar. 5. British Interplanetary Society (Midlands branch): "The Path to Space Travel," by K. W. Gatland.
Mar. 5. The Cranfield Society: Annual dinner and annual general meeting.

R.Ae.S. Branch Fixtures (to March 3rd)

Feb. 21, *Halton*, Branch night, "Aircraft Operations in the Arctic," by Maj. Webb; *Henlow*, "Aircraft Production," by Prof. J. V. Connolly. Feb. 22, *Belfast*, "Trends of Engine Development," by Dr. S. G. Hooker; *Bristol*, "Work of an Aircraft Establishment," by Handel Davies. Feb. 23, *Preston*, Lecture; *Southampton*, Branch prize papers; *Weybridge*, R. K. Pierson Memorial Lecture, by W. E. W. Petter.

Mar. 1, *Boscombe Down*, "Developments in Gliding," by A. H. Yates. *Mar. 2, Brough*, "Pilots' Limitations in Aircraft Design," by W/C. H. P. Ruffell Smith; *Luton*, "Aerial Photography". Mar. 3, *Isle of Wight*, "Aircraft Engineering in the Arctic," by Maj. James H. Webb, U.S.A.F.

THE INDUSTRY

Blackburn (Dumbarton) Appointment

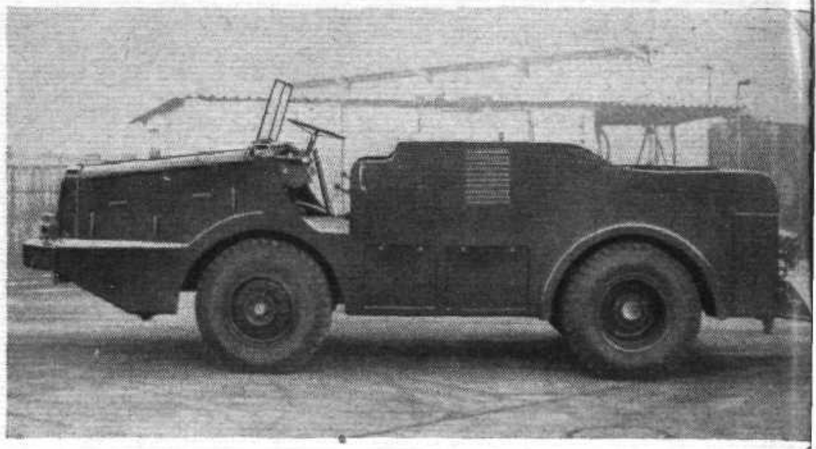
FROM Blackburn and General Aircraft, Ltd., comes the announcement of the appointment to the board of their associated company, Blackburn (Dumbarton), Ltd., where Mr. Thomas Bancroft, M.I.P.E., A.F.R.Ae.S., is to fill the vacancy caused by the retirement, through ill-health, of Mr. W. A. Hargreaves. "Tommy" Bancroft was a flight sergeant in the R.F.C. during the first world war and afterwards joined the Blackburn Company, devoting his energies to their associated North Sea Aerial and General Transport Company, of which he eventually became chief engineer. Then, for 15 years from 1925, he held a similar post in the Blackburn flying training schools at Hanworth and Brough. During the second world war he was works manager of the Blackburn factory at Sherburn, where Fairey Swordfish were being produced; in 1944 he returned to Brough to become general works manager and deputy to Mr. Hargreaves.

Mr. Bancroft

The Dumbarton factory in addition to its original large-scale production of prefabricated housing units, is also engaged on components (clamshell doors, engine nacelles and undercarriage bogies) for the Beverley, and on Britannia fuselage sections and other sub-contract work.

Rescue Saws Ordered

FOLLOWING the recent demonstration at London Airport of the Black and Decker aircraft rescue saw (described in *Flight* of December 31st, 1954), the makers have received an initial order from the M.T.C.A. for 15 of these machines. They will be used both for training purposes and for permanent installation in major British airports. Black and Decker, Ltd., has also received an order for one machine from Borneo Motors, Ltd., Singapore; it is understood the saw is to be installed in a rescue tender which that firm are supplying to Kallang Airport. Many other inquiries have been received from other parts of the world.



The Douglas "Tugmaster" Series I tractor (see below) as supplied to the Air Ministry for handling aircraft of up to 200,000 lb weight

Tractors and Tenders

ILLUSTRATED above is the Series I "Tugmaster" aircraft tractor produced by Douglas Equipment, Ltd., of Kingsditch Lane, Tewkesbury Road, Cheltenham, Glos. The company now offer a comprehensive range of aircraft tractors and chassis for airfield fire and crash tenders.

The "Tugmaster" series is available with petrol or diesel engines rated to give from 4,500 lb to 22,000 lb tractive effort for handling aircraft of up to 200,000 lb. Specifications include hydraulic assisted or manual steering; fluid drive and epicyclic gearbox or orthodox clutch and synchromesh gearbox; full power winch; and auxiliary electrical equipment for providing ground-test supplies for aircraft.

The heavy Series I "Tugmaster" is in production for the Air Ministry and the light Series III are in operation with Silver City Airways at Ferryfield.

An entirely new addition to the range is in course of construction—the Series IV, designed for work where the space available is limited. This vehicle will be available with either petrol or diesel engines and fluid drive, and will have an overall height and length of 3ft 4in and 9ft 6in respectively, and a turning radius of 8ft 6in.

Douglas fire and crash chassis are available with either petrol or diesel engines and with two-, four-, or six-wheel drive, and a maximum speed of 50 m.p.h. These chassis are fitted with a wide range of fire-fighting equipment, foam and water supplies, and a personnel capacity of five or six men.

IN BRIEF

The retirement is announced of Mr. N. G. Thomas, manager of the machine tool division at Fort Dunlop. He joined the company in 1919.

* * *

Mr. W. A. Hardy, A.C.I.S., has been appointed company secretary to Winston Electronics, Ltd., of Hampton Hill, Middlesex.

* * *

The British Welding Research Association is to hold its 5th summer school at Ashorne Hill, near Leamington Spa, from June 27th to July 2nd. Details are obtainable from the B.W.R.A. at 29 Park Crescent, London, W.1.

* * *

Mr. K. E. Harris, director of development to A. C. Cossor, Ltd., recently flew to America in order to discuss airborne navigation and traffic control equipment at the invitation of the Air Navigation Development Board and the Airline and Electronic Engineering Committee. He is accompanied by Mr. D. Levell.

* * *

Ferranti, Ltd., have been engaged for a considerable time on the development of resin-cast transformers, and these components have now received a Limited Type Approval Certificate from the Radio Components Standardization Committee. Known as the Pentland series, the new range of transformers and chokes are stated to be completely moisture-proof and to withstand a temperature range considerably in excess of the −40 deg C to 110 deg C specified by the Services.

* * *

Specialists for a number of years in the development of solderless connections, for aircraft wiring in particular, the firm of Erma, Ltd. (Exhibition Grounds, Wembley, Middlesex) have produced a new catalogue of cable lugs, solderless terminals, crimping tools and allied equipment. The booklet, in loose-leaf form that can be easily kept up to date, contains a great deal of general information on the subject of crimping, together with reference tables and conversion tables showing equivalent items of American equipment.

* * *

Northern Aluminium Co., Ltd., announce that Mr. B. N. H. Thornely, a director, has been made secretary of the company, in addition to his present duties; Mr. E. A. Trigg, formerly with Aluminum Co. of Canada, Ltd., has been appointed chief financial officer; and that Mr. J. Mason, formerly assistant treasurer, is now chief accountant.

* * *

Following the normal suspension of A.I.D. approval during a transfer of premises, the firm of Creators, Ltd., have been granted approval for their new factory, Plansel Works, Sheerwater, Woking, Surrey. Specialists in thermoplastics, the company produce components for both civil and military aircraft.

* * *

Weatherfoil Heatings Systems, Ltd., of Slough, Bucks, announce that the Coventry Radiator and Presswork Co., Ltd., have appointed them sole United Kingdom sales and servicing agents for Dravo industrial space heaters. Produced under licence from a well-known American company, Dravo heaters are fully automatic oil-fired units available in six ratings of from 400,000 to 1½m B.Th.U./hr. Weatherfoil Heating Systems, Ltd., are a member of the Powell Duffryn group of companies.

* * *

Blick Engineering, Ltd., of Bede Trading Estate, Jarrow, Co. Durham, announce change of their name to Blickvac Engineering, Ltd.; on January 3rd they acquired the high-vacuum engineering business producing equipment under the trade mark "Blickvac." In addition to high-vacuum impregnators, potting-resin impregnating and casting plant, electric ovens and other high-vacuum apparatus, the company will continue to manufacture Blick time-recording and associated equipment.

Latest additions to the fleet of U.A.T., leading French independent, are two Hercules - powered Nord Noratlas twin-boom transports, one of which is shown in its new airline colours. During recent North African trials a Noratlas demonstrated its ability to lift a 6-ton payload 750 miles at over 200 m.p.h.

CIVIL AVIATION

COMETS: THE NEXT STEP

FOLLOWING publication of the Cohen report, summarized on pages 193-195 of this issue, an official statement on future plans for the Comet was expected towards the end of this week. At the time of going to press it was not certain whether the statement would be made by the Minister of Transport and Civil Aviation, to whom the report was addressed, or by the Minister of Supply. In effect, the Court's findings cleared the way for the introduction of re-designed Comets on the routes of B.O.A.C. and other airlines.

First, however, a Government decision must be made on the extent of ground and flight testing which such Comets must complete before being offered for certification. Both technical and financial considerations are involved. While B.O.A.C. have at no time suggested cancelling any orders for Comets, the airline would obviously prefer not to meet the cost of an intensive series of proving flights, for example, out of its own budget. This particular problem might be solved by the adoption of Comets for Transport Command, a step which has been regarded as likely for several weeks. At present on order for B.O.A.C. are five Comet 3s and 12 Comet 2s, of which some Series 2s have already been completed. Should these Comet 2s be allocated to Transport Command, the Corporation might decide to order an increased number of Comet 3s rather than accept further delays in deliveries of Series 2s; in some quarters it is considered likely that B.O.A.C. will by-pass the Mk 2 altogether and wait for the Series 3 before re-introducing Comet services.

The official statement was expected to give an indication of the time which may elapse before the new Comets are ready for airline service. In an announcement made shortly before the Cohen report was published, de Havillands had already outlined their plans for modifying the Comet 2 in the light of the accident investigations. A second de Havilland statement, issued after the Court's findings were made public, expressed the firm's appreciation of the clarity and fairness of the report, and said careful consideration was being given to plans for their future Comet production.

U.S. NAVAID POLICY CHANGE

THERE were definite indications, last week, that the American attitude in regard to a standardized short-range navigation aid has radically changed. It will be remembered that a few years ago an American recommendation for a route coverage system using V.O.R. and D.M.E., though meeting with considerable opposition, was generally accepted. The position subsequently, however, was that V.O.R. coverage in Europe was slow in developing and D.M.E., both in Europe and America, left something to be desired. It was, of course, realized that for the purposes of position fixing V.O.R. suffered considerably without the support of D.M.E.

The U.S.A.F., being a large-scale user of radio navigation installations all over the world, has a large say in American government policy in these matters and recently the U.S.A.F. and C.A.A. had basic differences about the continued use as an American standard system of V.O.R./D.M.E. The U.S.A.F. then entered the field with a system called TACAN which, though still classified, is presumed to be an area coverage system with an accuracy considerably better than V.O.R. Differences between the U.S.A.F. and C.A.A. (represented by the Air Navigation Development Board) led to a complete reorganization of A.N.D.B. leadership. It is now presumed that C.A.A. policy will have to fall in with U.S.A.F. requirements, i.e., an area coverage system as opposed to a distance/azimuth system.

TACAN, whatever its merits or demerits (and these cannot be known until it is declassified), is not yet fully developed. Recent reports indicate that it is accepted in principle, but that "a CW omnirange facility in a higher frequency band" is to be kept in reserve, should TACAN fail. Meanwhile the Area Navigation Development Board has decided that the service from existing civil D.M.E. facilities cannot be guaranteed beyond June 30th this year, but that V.O.R. should continue as a Common System aid at least until 1965. In view of the American influence on the I.C.A.O. adoption of V.O.R./D.M.E., it seems likely that TACAN will in its turn be strongly backed as another international common system.

The chopping and changing of international standards is most unsatisfactory and operators will not take kindly to any expense involved. Europe might do worse than to adopt its own standards while others sort out the world. In fact Decca, already widely used for shipping and aviation and virtually essential for helicopter services, amounts to such a standard so far as short- and medium-range area coverage is concerned.

NEW L.A.P. RADAR

NEW airfield radar, described by its makers, the Marconi Wireless Telegraph Co., Ltd., as the only completely crystal-controlled equipment of its type in the world, is soon to be installed at London Airport, where it will serve the southern air traffic control centre. The firm states that an early development model, in operational use there for some time past, has proved invaluable in providing continuous service during periods of bad weather. Being capable of detecting aircraft at ranges of from ¼ mile to 100 miles, it can perform several functions simultaneously; up to eight P.P.I. displays can be used with one aerial head.

Known as the Type S.232, the equipment is a multi-purpose radar for use at both civil and military airports. Marconi say that the price (in the region of £25,000) has been achieved partly by the relatively simple nature of the system employed and partly by the standardization of units. Its ability to work at full efficiency through all conditions of rain and cloud is obtained largely by operating in the 500-610 Mc/s (50 cm) band.

Another important feature of the S.232 is its employment of a new system for removing permanent echoes; known as the M.T.I. (moving target indicator), this part of the equipment differentiates between moving objects and fixed ones, cancelling the latter from the viewing screen and thus leaving a clear field for the observation of aircraft.

SABENA HELICOPTER NEWS

ON April 17th the Sabena helicopter network will be extended by the opening of a new route linking Brussels with Eindhoven, Duisburg and Essen. There will be three return services daily on each weekday; one flight will terminate at Duisburg, and the others will continue to Essen. Points already served are Antwerp, Bonn, Cologne, Liége, Lille, Maastricht and Rotterdam.

Since the inauguration of services in August 1953, Sabena's initial fleet of four helicopters have carried over 27,000 passengers. As a first step towards extending helicopter services to several more West European cities, the airline has bought two more S-55s for immediate delivery. It is reported that Sabena are also considering the purchase of a number of Sikorsky S-58s for delivery next year. The S-58 is a larger development of the S-55, powered by a single 1,640 h.p. Wright R-1820; military versions are in production for the U.S. armed forces. In civil form it would be capable of carrying 20 passengers.

The network was the subject of a recent London film show, sponsored by Sabena and the United Aircraft Export Corporation, of which the highlight was a preview of *The Helicopter*.

The first of three ex-T.E.A.L. Solents bought by Aquila Airways arrived at Southampton on February 5th after a 12,000-mile delivery flight from New Zealand. Formerly ZH-AMN, and now registered G-ANYI, it was routed via Genoa (where it is pictured above) to obtain experience of this Italian Riviera flying-boat base. Aquila's weekly service to Genoa will begin on June 4th.

CIVIL AVIATION . . .

Goes to Town, a 16 mm Kodachrome film by Robert Maillard of Sabena. Though made primarily to illustrate the workings of the helicopter service, the film is an excellent travelogue in its own right, the S-55 providing some unusual and exhilarating bird's-eye views of European cities. Also included are some fine aerial views of the S-55 and of the incredibly colourful Dutch tulip fields at springtime. Last year, incidentally, Sabena operated a series of highly successful helicopter pleasure flights taking in both the tulip country and the battlefield of Waterloo.

GUILD TROPHIES AND MEDAL AWARD

"RESPONSIBLE persons or bodies" are invited by the Guild of Air Pilots and Air Navigators of the British Empire to submit nominations for award of the Guild trophies and medal for the year ended December 31st, 1954. The awards are as follows:—

The Johnston Memorial Trophy is to be awarded for the most outstanding feat or performance in aerial navigation for flights involving the development of the technology of navigation by a person or persons engaged in a civilian or Service capacity. Navigation of a routine or spectacular character is not the essence of the award.

The Cumberbatch Trophy will be presented to organizations, or groups within organizations, whose actions over a period have contributed towards complete freedom from accidents, or any description coupled with regularity of operation, or it may be awarded to any person or group of persons or bodies corporate who, in the opinion of the Guild, have contributed towards air safety under the terms stated above, or any other terms that the Court of the Guild may decide.

The Brackley Memorial Trophy will be awarded for the most outstanding achievement concerning improvements in the operation of flying-boats. This achievement may be theoretical or practical in connection with the organization, flying or navigation of flying-boat flights or services but not in connection with the design or construction of flying-boats.

The Derry and Richards Memorial Medal is available for bestowal annually on a pilot not on active service in Her Majesty's regular forces but professionally engaged in flying for testing or development on British aircraft, whose flying over a period of time, including the previous year, has been of outstanding value to the advancement of the science of aviation. The medal becomes the personal property of the recipient.

Candidates for the trophies (or the captain and/or navigating officer in the case of aircrews) must be British subjects, though not necessarily members or associates of the Guild. In the case of crews, the captain or navigating officer will have physical possession of the trophy during the period of retention. The names of the recipients will be recorded on the trophies.

Nominations, with supporting details, should reach the Guild of Air Pilots and Air Navigators office at 19 Park Lane, London, W.1, not later than March 31st, 1955.

FAIRLOP TO BE SOLD

HAVING finally been forced to drop their plan for a civil airport at Fairlop, Essex, the City of London Corporation hope to recover the cost of the scheme by selling the 920-acre site to the Ilford Borough Council. The land was acquired by the City in 1938 for £316,000 and subsequent expenditure brought the cost to £344,818. It is to be sold to Ilford for £351,100.

Plans for building the airport at Fairlop were prevented by the outbreak of war in 1939; the site was used by the R.A.F. during the war; and in 1952, after a long period of uncertainty, the M.C.A. announced that the site would not be used for scheduled services. The abandonment of the Fairlop scheme has been an extreme personal disappointment to Captain Alfred Instone, one of the pioneers of British air transport and chairman of the City Airport Committee for the past five years.

ULSTER FERRY APPROVED

APPROVAL has been given to Silver City Airways' plans for a vehicle ferry service between Castle Kennedy, Stranraer, and Newtownards, Belfast and flights will begin on April 7th. Bristol 170s will complete the 35-mile North Channel crossing in 18 minutes.

The airline states that most motorists will find the new ferry little dearer than sea transport and that owners of some small and medium-sized cars will find it cheaper. Cars will be carried for single charges of £7 to £17 10s according to overall length and motor cycle rates will vary from £1 10s for a 250 c.c. solo machine to £3 for a combination; the rate for pedal cycles is only 2s 6d. Passengers will pay £2 10s single and £5 return.

BREVITIES

FROM tomorrow, February 19th, the weekly Swissair all-freight service between Zurich and New York will make a traffic stop at Manchester. The service is operated by a DC-4 with a payload of four tons.

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Twice-weekly services between Brussels and Klagenfurt, Central Austria, will be operated by Sabena from May 15th. Two types of aircraft will be used—DC-6Bs on Saturdays and Convairs on Tuesdays.

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The third Super Constellation for Air-India International arrived at London Airport from Burbank recently. It flew on to Schiphol for modifications in K.L.M.'s hangars preparatory to joining the Air-India fleet at Bombay.

* * *

Seaboard and Western Airlines have been awarded a U.S.A.F. contract to operate an unstated number of services to Formosa with their new Super Constellation freighters. The company claims that it was the first commercial carrier to dispatch aircraft in support of the U.S.A.F. in both the Berlin and Pacific air-lifts.

* * *

B.O.A.C. announce new service names complementing the title "Monarch," which has been applied to first-class transatlantic flights for the past four years. All first-class flights other than the "Monarch"—i.e., those serving Africa, the Middle and Far East and Australia—will be known as "Majestic" services; all tourist services, including those on the North Atlantic, will be styled "Coronet."

The six passengers and crew of four were killed when an Indian Airlines DC-3 VT-CVB crashed on take-off from Nagpur on February 1st. Nagpur was the scene of a similar accident on December 12th, 1953, when 14 people were lost in an Indian Airlines DC-3.

* * *

Schiphol Airport, Amsterdam, handled 612,000 passengers during 1954, some 7 per cent more than in the previous year; the amount of freight handled (nearly 24,000 tons) increased by 20 per cent. Noted for its excellent public amenities, Schiphol attracted a record number of sightseers—906,000, compared with 896,000 in 1953. The airport's budget showed receipts amounting to £500,000, against expenses of £650,000.

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Trek Airways, Ltd., of Johannesburg, have applied to the South African authorities for permission to operate regular flights between Johannesburg and Luxembourg. If approval is given, the company will be the first private airline to operate scheduled international services from South Africa. Objections to Trek's application have been registered by both South African Airways and Africair, Ltd.

* * *

Total revenue of Scandinavian Airlines System during the year ended September 30th, 1954, amounted to £19,020,000, against expenses totalling £18,540,000. The surplus of £480,000 has been allocated to "extraordinary depreciation of aircraft"; ordinary depreciation for the year amounted to £1,940,000. The airline carried 709,000 passengers in 1954, 39,000 more than in 1952-53.

THE STUDY OF AIR LAW

THE lack of attention previously paid to the study of aviation law by British lawyers was emphasized by Mr. Christopher Shawcross, Q.C., in a lecture at the London School of Economics on February 8th. Speaking on *The Importance and Interest of the Study of Air Law,* Mr. Shawcross was inaugurating the new Lectureship in Air Law at the school.

Introducing the speaker, Mr. John Profumo, M.P., Parliamentary Secretary to the M.T.C.A. (representing the Minister), gave credit for the initial suggestion for an air law lectureship to Mr. Shawcross. Other countries, he said, had already established university chairs in the subject, and Britain must not lag behind if she was to lead in the development of civil air transport.

Mr. Shawcross began by reviewing the history of aviation and of air law. Even before the Wright brothers' flights, he said, lawyers had considered problems of air law: governments had lagged behind, however (possibly due to a preoccupation with military aviation), and nothing was done in this field until the Paris agreement of 1919. Although limited in extent, this did facilitate the progress of air transport in Europe and gave safety to the public.

It was not until 1944, however, that the real foundations for an international air law system were laid down, in the Chicago Convention. Although the convention had been made possible largely by the preparatory work of lawyers, little of this work had been done by British lawyers.

The speaker went on to trace the growth of the study of air law: Holland possessed a school of air law in the early 1920s, and the U.S.A., also, was far ahead of this country. Although Britain had a great tradition of maritime and mercantile law, there had been a reluctance among British lawyers to recognize the unique legal problems involved in civil aviation. There was a great deal of time to make up in this field. It had even been difficult to convince many eminent men that the separate title "air law" was justified, although about 80 per cent of the law relating to British civil aviation had an international basis—only the remaining 20 per cent attracting the well-known national laws.

If ever an activity required laws to make it a practical possibility, Mr. Shawcross continued, it was aerial navigation. Another significance of air law to Britain lay in the importance of air transport to the Commonwealth. Even on domestic flights, aircraft were being operated according to an international law. In this country's statute book, over 500 pages contained orders and regulations dealing with civil aviation, and there were even more in the international statute-book.

Another reason for the importance of air law lay in the establishment and functioning of the International Civil Aviation Organization, and in its system of aviation laws. All its laws depended on their validity being accepted by nations, and the success of international civil aviation in this provided a great example to other departments of human operation.

It followed that the study of air law, in addition to the subject itself, was important in this country. There had not been sufficient study of air law in the past in Britain or in any other Commonwealth country with the exception of Canada; civil aviation, as mentioned, was vitally important to the U.K.; and the fact remained that English was the official language used in civil aviation.

Mr. Shawcross turned next to the reasons why the study of aviation law was interesting. Although air transport was not an unusual feature of present-day life, technical development was continuing at a rapid rate. Other forms of transport, by comparison, remained relatively static and dull. The implications of the increasing speeds of aircraft, longer runways versus vertical take-off, and rocket propulsion for passenger-carrying aircraft were a few examples of fields of legal study in the future.

The question of sovereignty in air space was another intriguing problem. This would raise particularly complicated queries, for instance, in the case of space stations orbiting the earth.

The speaker next submitted that associated subjects such as weather control and mid-ocean aerodromes would also come within the scope of the legal problems of civil aviation.

After giving two examples of cases involving the more unusual aspects of air law, Mr. Shawcross emphasized that, while philosophers, governments and others had seen only a method of destruction in aviation, the inventors and manufacturers had always taken the opposite view. Contrary to lay thought, two world wars had retarded, not accelerated, the development of air transport. The three decades or so in which air law had developed had been overshadowed with preparation for war, otherwise progress in the subject might have reached much further.

The speaker concluded by hoping that the new lectureship at L.S.E. (filled by Mr. F. P. Neill, B.A., B.C.L.) would develop into a flourishing school of air law.

NEW INTERNATIONAL AEROBATICS TROPHY

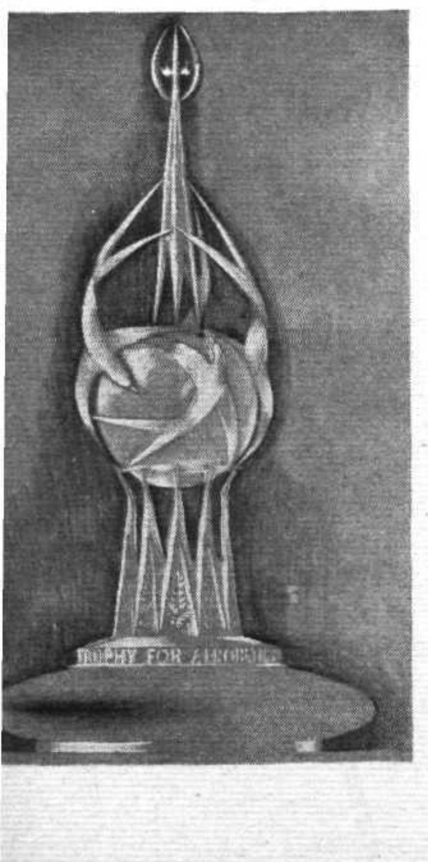
A NEW trophy and substantial cash prizes are to be awarded in the Royal Aero Club international aerobatic competition, to take place at Baginton aerodrome, Coventry, on August 19th and 20th. The trophy and prize-money have been presented by the Lockheed Hydraulic Brake Company, Ltd., of Leamington Spa. The trophy winner will receive £500, and second, third and fourth prizes will be £300, £200 and £100 respectively. Another £100 will be given for the best performance in an aircraft weighing less than 1,000 kg (2,205 lb) empty, flown by a British pilot but not in the first four places.

The contest is open to any type of aeroplane, of any nationality, entered by a private individual or an organization. Eliminating trials and the final contest will take place on August 19th and 20th respectively at Coventry Civic Aerodrome, the second day's flying forming part of the programme for the final National Air Race meeting, which also includes the King's Cup Race.

Each competitor in the aerobatic competition will be allowed five minutes' flying time, and his performance must include one slow roll, one loop and one half-roll off the top of a loop. Points will be awarded as follows: Scope (range of aerobatic manœuvres), 20; pilotage, 20; accuracy in execution of manœuvres, 25; artistry and positioning, 25; originality, 10.

Points may be deducted for exceeding the time limit and for bad airmanship, which includes flying over the crowd or below the minimum permitted height of 100 metres. The contest is to be held under the regulations of the F.A.I. and the competition rules of the Royal Aero Club, and the judging will be performed by a panel appointed by the R.Ae.C.

If the weather is bad on the 20th, the results of the eliminating trials will be taken as the actual contest results. The entry fee is £10, and detailed requirements and entry forms will be available from the Royal Aero Club from March 14th.



The trophy, of solid silver, 24in high, is of contemporary design.

A DUNSTABLE EVENING

LONDON Gliding Club's annual dinner was held this year at the Old Sugar Loaf Hotel, Dunstable, on February 5th, and was followed by a dance in the club-house. At the dinner, the health of the guests was proposed by Dr. A. Ivanof, who glanced into a possible future in which light aeroplanes were very rare birds indeed. After recalling the earlier—and cheaper—days of gliding, he went on to speak kindly of the guests who, in various ways helped the club to fly. Mr. A. Moore, of the Sporting Owner-drivers' Club (part-time operators at Dunstable Downs) replied for the guests.

After Mr. Dan Smith, chairman and C.F.I., had read a telegram from the club's president, Capt. Lamplugh, the health of the ladies was proposed by Mr. Dudley Hiscox. Not only were the ladies decorative, he pointed out; in gliding they worked, too. In a witty response, Mrs. F. Gentry made some sartorial comparisons between the sexes and, after expressing her appreciation of the club's good companionship, went on to propose the health of the club. Mr. John Jeffries replied.

Mr. Smith then presented bouquets to Mrs. Turvey and Mrs. Walker, in recognition of their work for the club over many years, and paid a tribute to the efforts of all members of the club's staff, both old and new.

Later that evening, just outside the club-house, a specially built engineless flying-machine took to the air, employing neither winch-launch nor aero-tow. The vehicle involved was a man-size hot-air balloon, constructed of high-grade, lightweight paper and showing excellent inherent stability on its fiery ascent. The Montgolfier brothers, it was unanimously agreed, had quite an idea.

AMERICAN FIGHTER AUTOPILOT

Lear Announce the L.10 Installation for Supersonic Aircraft

IT is well known that for some years many American fighters have been equipped with autopilots for use either during long transit and operational flights or in connection with automatic fire-control systems. All F-84Gs, for example, have the Lear F-5 for long-distance flights, while such aircraft as the F-86D Sabre and F-94C Starfire carry out the final phase of the collision-course attack entirely under autopilot control. The rockets which constitute the offensive armament of the two last-named aircraft are launched by the fire-control system.

The fighter-type aircraft so equipped have hitherto presented their autopilots with comparatively simple aerodynamic problems. In supersonic aircraft, however, a number of additional factors arise, such as the supersonic fighter's great sensitivity, in terms of fore-and-aft stability, to speed changes. It may even become necessary, in order to obtain sufficient accuracy of flight manœuvre, to fly the aircraft at second hand, so to speak, through an autopilot rather than under direct human guidance. One method of achieving this is by making the control for the autopilot an integral part of the stick. The pilot then selects an autopilot-controlled manœuvre through the stick rather than by manipulating the knobs on the standard controller.

The Lear L-10 is a new autopilot, just out of the test stage, which has been designed specifically to meet conditions such as those outlined above. One of its most valuable features, incidentally, is the fact that it is almost directly developed from its predecessor, the F-5; the proven reliability of many of the F-5's components, and the existing production facilities, are certain to be of great assistance in getting the new equipment into service. The L-10 has so far been tested in an F-84E and is shortly to be installed in an F-86D Sabre and an F-84F Thunderstreak for evaluation by the U.S.A.F. The standard F-84F autopilot is at present the Lear MB-2, which the company turned out on a production basis only three weeks after the initial contract was placed. The MB-2 has been referred to as an "L-7½" (the development mid-point between F-5 and L-10) and it is to be further tested in a B-57 Canberra and a reconnaissance version of the F-84F.

As the accompanying diagram shows, the L-10 includes several new features, such as an automatic Mach number control or "Mach hold," an automatic g-limiter, all-attitude manœuvrability, automatic heading selection, and control through either a conventional panel or by articulated stick-top. Continuous automatic trimming for all surfaces is provided, together with a sideslip eliminator. The latter involves a new principle of autopilot operation which is described below.

The central component or "brain" of the L-10 is the main amplifier which, as in the F-5, is assembled on the "building-block" principle with plug-in amplifier units. One of its features is that it provides more gain than before (about ten times as much as the F-5), resulting in increased accuracy of control-surface positioning. Several other design-points lead to faster control-response, and speed of reaction in such a system is a valuable adjunct in the control of supersonic aircraft. Continuous stability-augmentation by the extensible-link servos in the L-10, and automatic damping of lateral and longitudinal control modes, even when the autopilot is disengaged, result in a stability in speed and attitude which is most useful to the pilot. Moreover, he cannot feel the damping action on the controls and no separate electronic damping systems are required.

Another feature of the L-10 is the fact that it can operate from a variety of types of remote vertical gyro and close-tolerance gyro direction-indicators or from three-gyro stable platforms—a significant step towards the integration of systems which make use of remote attitude-gyros. This is a real problem in many American aircraft, particularly in intercepters, where there may be as many as five separate vertical gyros serving such systems as panel instruments, flight directors, fire-control computors, autopilot and radar aerial stabilizer. If any one of these vertical gyros should fail, a vital link in a chain of systems would become inoperative. The L-10 is designed to be able to take its attitude and directional signals from the panel instruments supplying the relevant information. Moreover, Lear has developed a series of stable platforms designed to act as master references for all types of fire-control and bombing systems, as well as for instrument-panel indications. The stable platform, which has no manœuvre limitations (it is fully free in all axes), could be conveniently duplicated to provide a stand-by; it has even been mooted as a suitable master reference for such exacting applications as V.T.O. instrumentation systems. The master-gyro concept has, of course, wide implications in the field of aircraft instrumentation and automatic control in general.

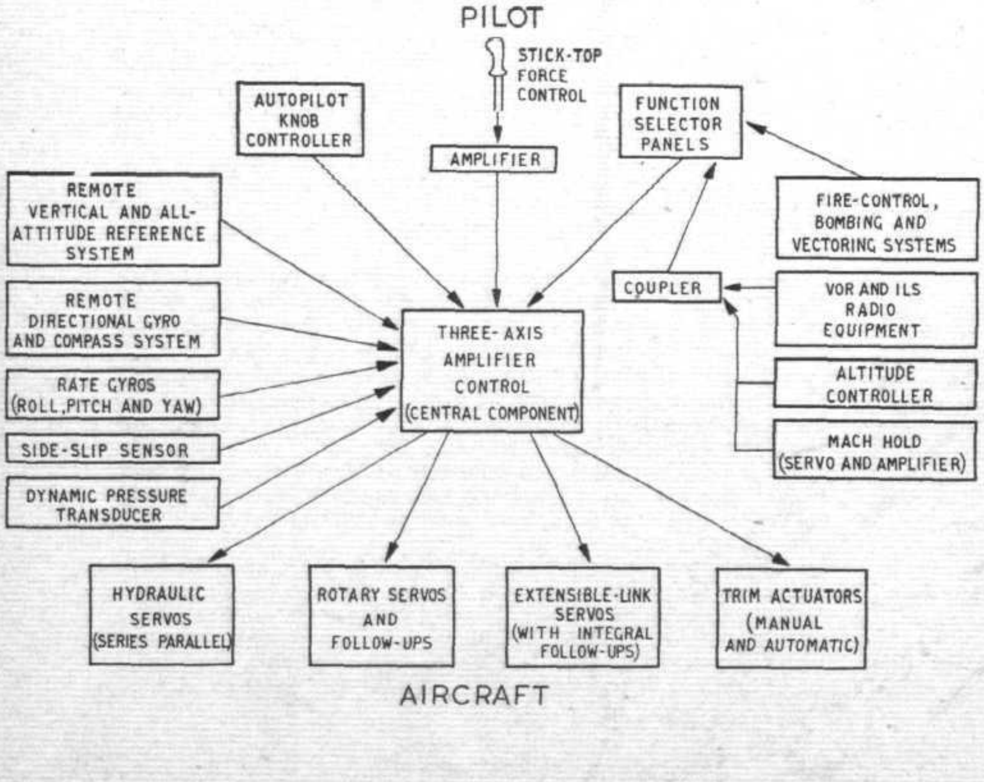
One way in which the L-10 differs from a great number of the present autopilots is in its method of achieving directional control. The L-10's rudder control is relegated largely to the rôle of turn co-ordination and side-slip correction—the latter especially in case of asymmetric power or external load conditions. For course control the L-10 feeds azimuth error, detected by the compass, to the roll servos rather than to the yaw servos (under certain conditions a proportion of the course signal is fed to the rudder as well). The principal course control is, however, achieved by banking the aircraft. This conforms both to the flight characteristics of jet aircraft in general and to those of very-high-speed machines. Full co-ordination of the turn is assured by a rate gyro orientated in yaw and by a side-slip detector, both controlling rudder positioning. This type of control is particularly important when the autopilot is being directed by automatic guidance systems either for interception or bombing.

Consistent response for both attitude and track control is accomplished by automatic variation of the system gains with varying flight conditions. It is also possible to adjust gain-variation to suit the characteristics of various types of aircraft.

The L-10 is designed to accommodate a new line of electronically-controlled Lear hydraulic servos consisting of two different types—firstly, actuators set to apply output in parallel with manual effort, and secondly, actuators whose output is introduced differentially into the control system to give stability augmentation.

An aircraft can be flown with this autopilot through almost any type of manœuvre and for this purpose there are, as already briefly mentioned, two alternative methods of directing the autopilot. One is by the conventional type of control panel, and the other is through a force-control lever which is substituted for the handgrip of a conventional control column. If, using this latter type of controller, the pilot wishes to turn, he applies the normal pressure on the stick and the aircraft will begin to roll. When he has

Schematic layout of the L-10's components, showing the distribution of its controlling, executive, reference and guidance sections. Either the knob controller or stick top director, or both, can be installed, and the navigation, fire-control or bombing systems would be incorporated as required for particular applications.



AMERICAN FIGHTER AUTOPILOT . . .

reached the desired bank angle he can release the stick and the autopilot will maintain that angle. To return to level flight, he simply applies centering pressure to the stick, releasing it when the wings are once more level. Alternatively, he can push a "levelling button," whereupon the aircraft will roll out and automatically lock on to the course indicated when he pressed the button.

The L-10 can also achieve the following types of flight control: It can be coupled to localizer and glide-path signals for automatic approaches; an altitude lock may be engaged to hold the aircraft close to its existing barometric altitude; the "Mach hold" can be selected by pushing a button, upon which it will correct the aircraft's pitch attitude to maintain the airspeed at the existing Mach number value; the L-10 will accomplish automatic omni-range navigation along any beacon radial selected by the pilot; finally, it can follow guidance signals supplied either by ground or airborne armament systems, and for this purpose the rapid response and close-tolerance control positioning inherent in the L-10 are particularly useful.

A variety of ground equipment has in recent years been designed and tested by the U.S.A.F. and the Marine Air Corps whereby an aircraft can be remotely controlled through its autopilot to bomb, rocket or machine-gun a previously ground-surveyed target from a type of mobile radar control post.

Among the safety features of the L-10 is provision for preventing manœuvres which exceed the safe structural strength limits of the aircraft. Manual over-ride is included and, in the event of malfunctioning, both automatic and manual disengagement are possible.

Finally, a number of features, such as compactness, combination of components within fewer assemblies, and the use of "versatile" components to avoid duplication, have resulted in the overall weight of the L-10 being lower than that of its predecessor, the F-5.

THE TV FILM: POST-WAR AIR POWER

ENTITLED *The Unquiet Peace*, Episode 14 (and last but one) of the B.B.C. Television film *War in the Air*, comprised a condensed review of world affairs since the end of the war in 1945. Many events not directly connected with air power were included, presumably to give continuity and atmosphere, with the result that matters of aeronautical interest were not covered so fully as some of us would have liked. For example, the setting up of I.C.A.O. was mentioned but, apart from a brief glimpse of a weather ship, little was explained of its aims, hopes and achievements.

A sequence depicting post-war British airliners included the curious statement that the Brabazon was the "prototype of future shapes", and the Comet shown was so presented as to give the impression that it materialized at the same time as the Viking and Brabazon. A point of interest made in this sequence was the scheduled time of 63 hours for the immediate post-war London-Sydney journey by Lancastrian—quicker than today's services.

Next, in 1948, came the Berlin Airlift. With all road, rail and canal transport communications with the capital closed by the Russians, the combined American and British operation started in July. For the next 15 months, in the words of the narrator, "The men who had bombed Berlin flew to save it." American pilots made over 370,000 flights and British over 170,000. Up to 12,000 tons of food were lifted into the city in one day; and during the period of the operation 100,000,000 miles were flown, and over 200,000 passengers and 2,000,000 tons of freight carried. These impressive figures were accompanied by scenes depicting activity at the Berlin terminals during the airlift, in which the shot of a Sunderland landing on one of the lakes in a suburb served as a reminder of the flying-boat's adaptability.

"Air power had won the first battle of the cold war," but the lessons of the lift—the value of big aircraft and the incredible organization required to land one aeroplane every four minutes—were not the subject of comment.

In a brief excursion to Malaya the statement that it was here that the "helicopter came into its own" will have probably conveyed a quite wrong impression of the number of these machines in use in that country. It is, as is well known, pitifully small. On the other hand, when the film came to the Korean War, the part played by helicopters was hardly mentioned at all. Yet it was in this campaign that the helicopter proved its utility beyond doubt and, in the words of an American commander, "began to replace the jeep".

The work of the aircraft carriers was prominently covered and emphasis given to their value when all air bases on the mainland had been over-run. Dog fights between Sabres and Mig-15s were mentioned—the baptism of fire of jet aircraft—and this sequence included some interesting shots of Mig-15s in flight and in action. (Including, surely, a shot of a "La-17" taking-off, suspiciously similar to one which not so long ago was released as having been obtained "from a captured Russian newsreel"?)

The film concluded with the part played by air power, particularly that of Britain, in sustaining NATO countries.

M. F. A.

FARNBOROUGH PRIZE-GIVING

A SUCCESSFUL year was reported by Mr. R. D. Peggs, M.A., principal of the R.A.E. Technical College, at its annual prize-distribution at Farnborough on February 4th. The presentation of prizes and certificates was made on this occasion by Sir James Helmore, K.C.B., K.C.M.G., M.A., Permanent Secretary to the Ministry of Supply, and the Director of the R.A.E., Sir Arnold Hall, F.R.S., M.A., was in the chair.

Among the students' results quoted by Mr. Peggs, in his report for the 1953-54 session, were the award of one of the first King George VI memorial fellowships, two M.o.S. post-graduate scholarships, two technical State scholarships and, for the fourth year in succession, all the medals and prizes awarded for the final City and Guilds examinations in Aeronautical Engineering Practice.

The Grinsted Prize for the best student of the year, and the Perring Prize for student apprentices, were first presented by Sir James to Mr. D. P. Hunt. The other major awards included the Farren Prize for craft apprentices, P. D. Taylor; the Hilda Lyon Prize for scientific assistants, W. R. Crawford; and the Principal's Prize for outstanding leadership, A. J. Robinson. The certificates included two B.Sc.(Eng.) degrees, 46 Higher National Certificates in mechanical engineering, 19 H.N.C.s in electrical engineering, 16 H.N.C.s in production engineering, and 83 final City and Guilds certificates.

In an amusing speech, Sir James Helmore divulged what the M.o.S. thought of the College (all of it favourable) and paid a tribute to the various people and organizations to whom the College owed a great deal. To those students who were leaving he said that, no matter what aspect of aircraft they specialized in, the fact that they were concerned with the air was the key to a community of very friendly people. He wished them every success in their careers.

Sir William S. Farren, C.B., M.B.E., F.R.S., M.A., chairman of the College Advisory Board, said in his address that the College's most important problem was not the shortage of space or of staff, but to ensure that individual students followed their own natural abilities.

"For four years I have sat on the floor of this hall," began Mr. D. J. Faddy, President of the Students' Union, in his vote of thanks. In less ambiguous style, he went on to record the various recent activities of the 601 "souls" who formed the Union's present membership. Among the distinguished persons who had forsaken the safety of homes and offices to attend the prize-giving ("to entertain us with practised eloquence and the assurance that they do not know what to say"), Sir William Farren was regarded not as a guest, but as a very welcome installation.

A pair of book-ends, made by one of the students, was presented to Sir James Helmore at the close of the ceremony.

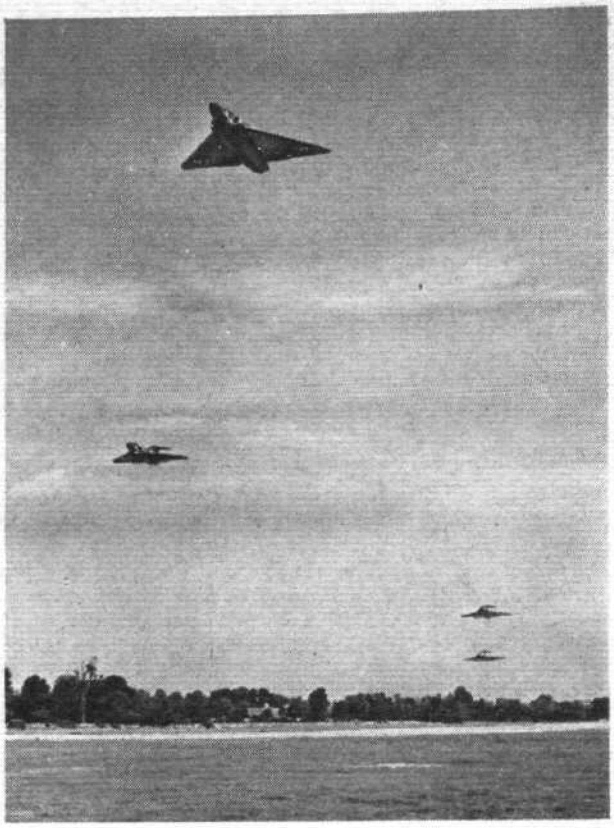
YPENBURG 1955

ONCE again the Royal Netherlands Aero Club is to stage an international air display at Ypenburg, near the Hague. It is to take place on May 30th, this year's event celebrating the golden jubilee of the F.A.I. Invitations to take part have been sent to military and civil aviation authorities in Belgium, Canada, France, Great Britain, Germany, Italy, Jugoslavia, Sweden, Switzerland, Turkey and the U.S.A., but nine applications to participate had been received before the invitations were sent. Among them was one from the 1st Air Division, R.C.A.F., Metz (Sabre individual and team aerobatics), Louis Clément, France (aerobatics in his Lignel 44), and Albert Falderbaum, Germany (aerobatics in a Lo-100 glider). There is, as yet, no news of British Service or private participation.

This will be the fifth Ypenburg display, and the organizers hope to take full advantage of recent extensions of the airfield. Details are obtainable from Royal Netherlands Aero Club, 3, Anna Paulownaplein, The Hague.

SERVICE AVIATION

Royal Air Force and Fleet Air Arm News



Javelins over the Gloster Aircraft Company's airfield at Moreton Valence. These all-weather day and night interceptors are expected to be in squadron service this year or early in 1956.

Flag Officer Appointment

IN succession to Vice-Admiral Sir John A. S. Eccles, K.C.B., K.C.V.O., C.B.E., Vice-Admiral Caspar John, C.B., is to be Flag Officer Air (Home), with effect from June next.

Vice-Admiral John has an exceptionally wide experience of aeronautical matters. Before the war he was a private owner, taking part in a number of air races, and was also a distinguished pilot in the Fleet Air Arm.

In 1941 he was appointed Chief Naval Representative for Naval Aircraft Development and Production at the Ministry of Aircraft Production. In 1943 he left for Washington to become the Head of the British Naval Air Service Representation in the United States.

In October 1944, Vice-Admiral John took command of H.M.S. *Pretoria Castle,* which had been converted for use as an aircraft carrier, and in the following year he commanded the light fleet carrier *Ocean.*

Spending another spell of duty ashore, in 1948 he was appointed to command R.N. Air Station, Lossiemouth, Scotland, and later served in the Admiralty as Deputy Chief of Naval Air Equipment and later as Director of Air Organisation and Training.

On promotion to Rear-Admiral, in January 1951, he was appointed to the command of the Third Aircraft Carrier Squadron. A year later he became Chief of Naval Air Equipment and Chief Naval Representative at the Ministry of Supply and, following a reorganization, Vice-Admiral John became Deputy Controller of Aircraft Production at the Ministry of Supply, an appointment he still holds.

Squadron Standard Presentation

AT a ceremony in Singapore on February 10th Air Marshal F. J. Fressanges, C-in-C. F.E.A.F., presented No. 45 Squadron with its Squadron Standard. The Rt. Hon. Malcolm MacDonald, Commissioner-General for South-East Asia, and Sir John Nicoll, Governor of Singapore, were both present. This is the first presentation of a Standard to a squadron of the Far East Air Force.

No. 45, commanded by S/L. V. K. Jacobs, is now equipped with D.H. Hornets and stationed at Tengah. It was first formed in 1916 and arrived in France during the latter part of the Battle of the Somme. It was equipped with two-seater Sopwiths with the then-new Scarff-Dibovsky interrupter gear on the forward-firing gun and a Scarff ring mounting for the rear Lewis gun. Capt. Louis Strange was the commanding officer for a time.

A number of the past members of the squadron have reached high rank, including Marshal of the Royal Air Force Sir Arthur Harris, Air Chief Marshals Sir Basil Embry and the Hon. Sir Ralph Cochrane, and Air Marshals Sir Alan Lees and Sir Robert Saundby.

No. 47 Squadron Standard

ON March 25th, at Abingdon, Marshal of the Royal Air Force Sir John Slessor will present a Standard to No. 47 Squadron of Transport Command. The unit is at present equipped with Handley Page Hastings aircraft and commanded by S/L. D. P. Boulnois.

Canberras Visit Cyprus

TODAY, February 18th, twenty Canberras drawn from Nos. 21 and 27 Squadrons at Scampton are due to leave for Cyprus, where they will be based for a month, taking part in NATO exercises in conjunction with units of the M.E.A.F.

This is the first time an R.A.F. jet bomber force has been sent to take part in Mediterranean exercises and the visit is also arranged with the purpose of demonstrating the speed with which overseas commands can be re-inforced. The Canberras, which are expected to make the journey with one stop (at Idris, Libya), will be supported by six Hastings of Transport Command.

Apart from flying in exercises, the Canberras will carry out practice bombing in Iraq; two aircraft, also, will fly to Aden and a further two to Kenya.

The detachment will operate under the command of W/C. J. D. Warne, D.S.O., D.F.C., Wing Commander Flying at Scampton. The C.O. of No. 21 Squadron is S/L. N. B. Freeman, A.F.C., and No. 27 is commanded by S/L. P. W. Helmore, D.F.C., A.F.C. A return to Scampton on March 21st and 22nd is expected.

Air Marshal Sir George H. Mills, A.O.C-in-C. Bomber Command, accepts from Mr. A. G. Townley, the Australian Air Minister, a trophy recently presented by members of No. 460 Squadron, R.A.A.F. (now disbanded) for annual competition between the V-bomber squadrons.

Swedish Visitor

AT the invitation of the Air Ministry, Lt-General Axel Ljungdahl is visiting Great Britain; he arrives next Monday and is to stay until March 1st.

The Royal Swedish Air Force has a number of Hawker Hunters on order, and Gen. Ljungdahl intends to visit one of the Hawker Aircraft factories and some of the Fighter Command units equipped with the Hunter.

Sir George Mills' Tour

ON Sunday last Air Marshal Sir George H. Mills, K.C.B., D.F.C., A.O.C-in-C. Bomber Command, left for America at the invitation of the U.S.A.F. He is also visiting Canada.

While in America Sir George is expected to give lectures to the U.S.A.F. Air University and at the Command and Staff College at Maxwell Field, Alabama, and to the R.C.A.F. Staff College and the Canadian National Defence College. He is accompanied by his P.S.O. S/L. R. S. Boast, D.F.C.

"Bulwark" in Service

THE first landing on H.M.S. *Bulwark* (Capt. J. M. Villiers, O.B.E., R.N.) was made on February 7th, when Lt-Cdr. J. W. Nance, U.S.N., put an Avenger down on the deck. Lt-Cdr. Nance is on an exchange posting with the Royal Navy and is serving with No. 703 Squadron at Ford. The remainder of the unit flew on the next day.

No. 703 is a unit which conducts trials of various front-line aircraft. Flight-deck equipment will be tested first and, later, aircraft testing and personnel training will begin.

Bulwark, one of the three *Hermes*-class carriers which joined the Fleet last year, is scheduled to take over the duties of trials and training carrier next month.