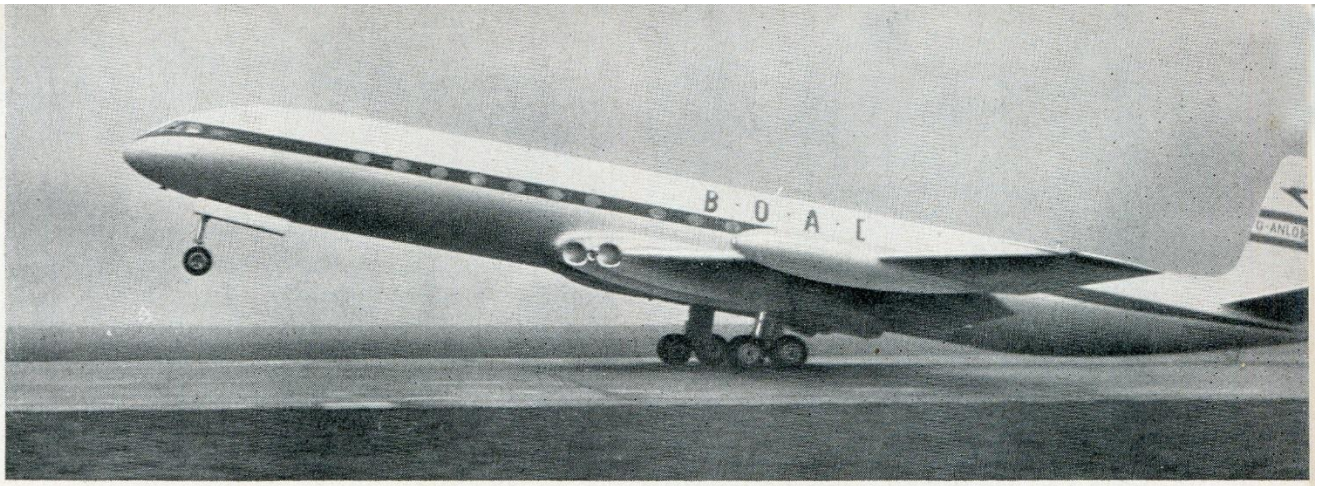


To demonstrate the effectiveness of the Comet 3's cambered wing leading-edge profile, John Cunningham—who, with de Havilland's chief designer, Mr. R. E. Bishop, was the author of this paper—carried out "tail scraping" take-off tests, one of which is shown in this enlightening photograph. There was no difficulty in becoming airborne, and in only a fractionally greater distance than is needed for a normal take-off.

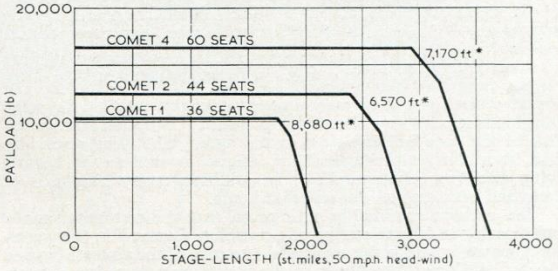
The Comet 4—Its Design and Operation

A Synopsis of the Paper Presented in Canada by the Designer and Chief Test Pilot

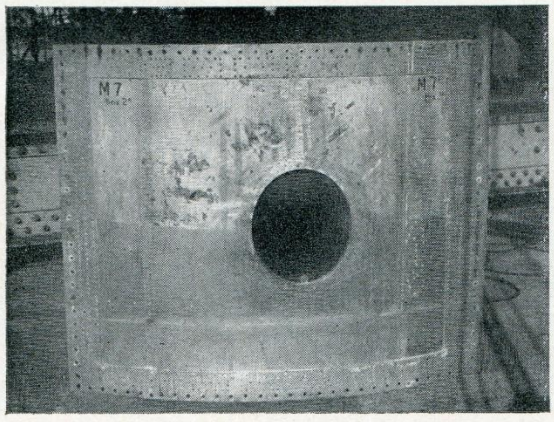
ABSTRACTED in these pages is a paper presented on May 4 before the Canadian Aeronautical Institute. Prepared by the Comet's designer, Mr. R. E. Bishop, C.B.E., F.R.Ae.S., and the chief test pilot, Mr. John Cunningham, D.S.O., O.B.E., D.F.C., it was read by the latter. Phrased in general terms, and disclosing comparatively little that is new, the paper is nevertheless a reminder that the de Havilland Company possesses an understanding of the jet airliner, and in particular of its structure, that must be second to none.

THE authors began by comparing the Comet 4's capabilities with those of its predecessors and presented a diagram [see Col. 2] showing basic payload-range characteristics of each type. It demonstrated that the aircraft can carry its capacity payload over most of the world's trunk routes non-stop—i.e., up to stage-lengths of 2,600 n.m. The take-off and landing performance of the Comet 4 was perhaps its most impressive feature, and one which had impressed airline pilots and airport officials during the Comet 3's world tour five months ago. "Generally speaking," the lecturer observed, "the Comet 4 will be able to operate into and out of almost all important aerodromes as they exist now without extension or runway strengthening." Governments would not willingly pay for improvements if jet transport were available that could use existing airports.

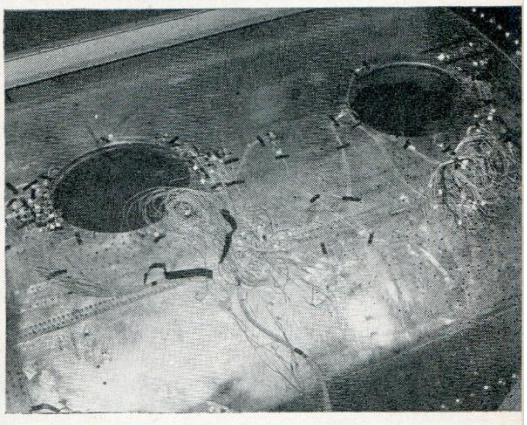
The authors put forward the case for the medium-sized airliner. The very large jet transport, they reasoned, was justified only on high traffic-density routes. Only a few sectors of the world were more than 2,400 n.m. long, and with the exception of the North Atlantic and the trans-polar route most of the traffic was generated at intermediate points, only a part of it being end-to-end. The medium-size aircraft was easier to handle at airports, and if an aircraft became too large personal service was lacking: four-abreast seating was a "must" for first-class travel. The large jet transports, the authors said, could not reduce their six-abreast tourist seating to four-abreast first-class seating without an economic penalty through waste of capacity. Although direct operating costs of the large aircraft were slightly better than those of the medium-sized transport, it was on the revenue side of the cost equation that the latter scored: it was easier to obtain high load factors. The large jet was, of course, more economical in its tourist form, because of the higher proportion of tourist to first-class seats that could be installed—but the

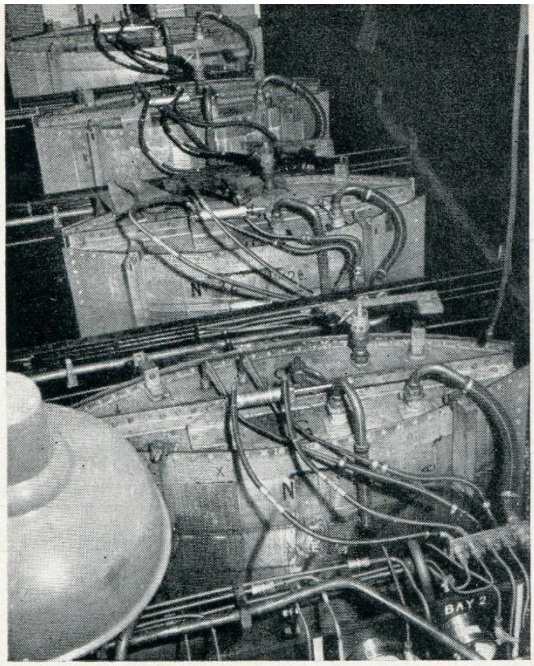


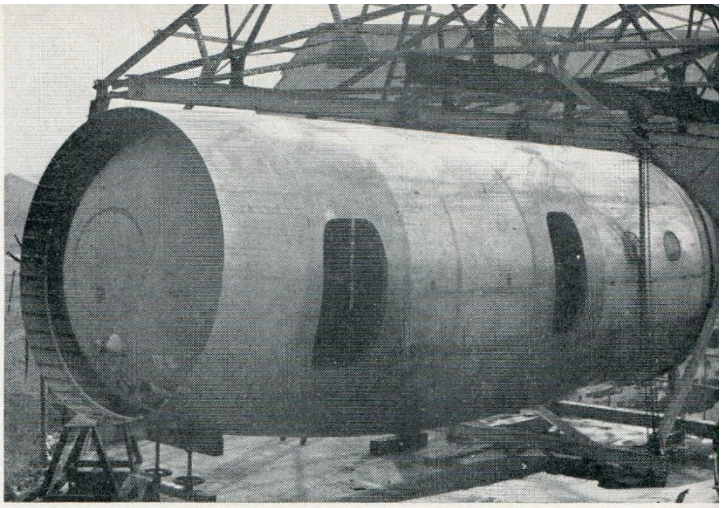
*These curves, which are based on the same system of fuel allowances (including 200-mile diversion), compare the payload-range performance of the Comet series. Figures marked * are the aerodrome lengths required for take-off at maximum all-up-weight at sea level, 30 deg C.*



Specimens of typical Comet 4 window cut-outs subjected to fatigue-tests of great severity. Some ran to the equivalent of half-a-million flying hours (150 years) before serious cracks began to form.







(Left) Comet 4 structure specimens—of the kind shown on the previous page—seen undergoing their water-pressure fatigue tests. (Above) A 28ft portion of fuselage, containing representative doors, hatches, windows, etc., about to go under water for fatigue-testing

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operator had to be certain that he could depend upon filling them, and the authors believed that there would be few world routes which would have the traffic density afforded, say, on the New York to Miami route.

With regard to structural design the philosophy was as follows. Thicker-gauge materials were used for the pressure cabin, with windows and cut-outs designed to a stress level so low that cracks would be most unlikely to occur during the aircraft's life. Should for any reason such cracks occur, then their rate of propagation would be so slow that they would be seen before becoming dangerous. The aim was to demonstrate on test-specimens that cracks would not occur before a minimum of 60,000 reversals, and would not propagate seriously before another 60,000. Assuming each reversal to represent a three-hour flight, the apparent life was 180,000 hours, giving a safe life of 30,000 hours after application of a scatter factor of six. The Comet 4's structural test programme included firstly the underwater testing of six representative types of cut-out. In addition to Comet 4 specimens, 30 panels of the Comet 1 type also were tested. Secondly, a 28ft section of the fuselage containing representative cut-outs had up to April 1 completed 85,000 reversals—255,000 "flying hours" [without factor]—without failure. A further 27ft centre-section was at present underwater, and was having wing gust loads applied as well as cabin pressure. A section representative of the nose had also been in the tank. The wing spars also had been closely investigated for fatigue, as well as the bottom wing skin (see photographs). In addition many hundreds of tests had been carried out on seam joints.

The authors confidently anticipated that the test programme, culminating in fatigue-testing of a complete Comet 4 in the water-tank, would establish the structural integrity of the aircraft beyond doubt. A Comet 2 had been in the water-tank since last autumn [described in *Flight* for December 30].

The lecturers put forward the case for the Comet's buried engine installation. Much had been said about the advantages of pods and it was of interest to consider the factors in favour of the wing installation:

(1) The height of the intakes from the ground reduced the risk of debris being sucked into the engines. (Fine-mesh guards could reduce take-off power by 20 per cent.)

(2) Control runs, and cabin and de-icing systems ducting from the compressors, were simpler. The mounting structure, in which the engines were hung between ribs, was reduced to its simplest possible form.

(3) Maintenance access was excellent and afforded maintenance engineers the protection of the wing and cowling doors in the worst weathers.

(4) Unlike the pod, the spacing of ancillary equipment was less closely packed.

(5) The close proximity of the engines allowed the greatest possible advantage to be taken of the available fire extinguisher fluid.

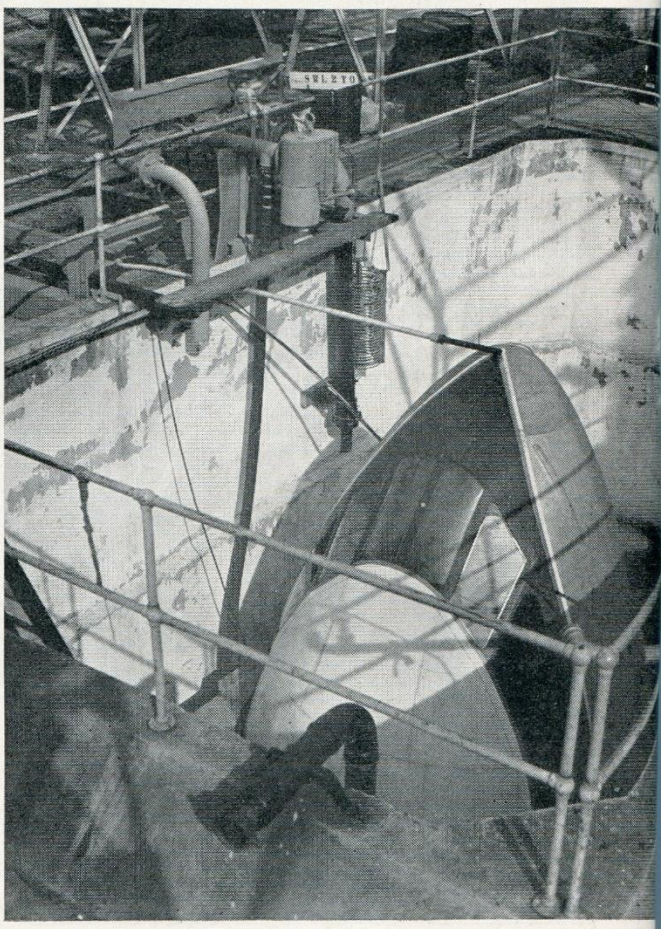
(6) In a wheels-up landing, whereas pods must bear the full impact with the ground, the wing installation provided a high degree of protection for the engines.

(7) A pod striking the ground could be the cause of fuel tank rupture; in the case of the Comet no fuel was carried above or behind the engines, and the serious fire hazard of the fuel being sucked into the intakes was reduced to a minimum.

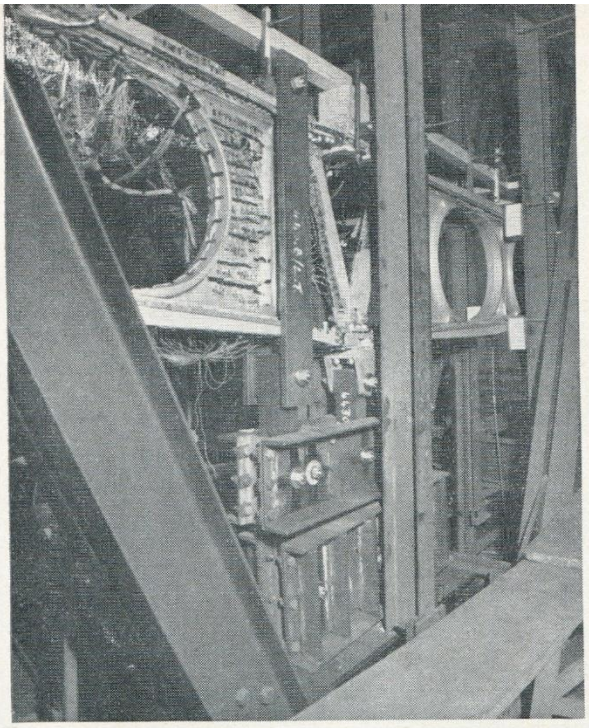
(8) Effective means of containing turbine blade-failure were incorporated in the Avon engine installation. In the case of disc failure, release energy could have equally severe consequences were it within a wing or a pod. The possibility was in any case remote.

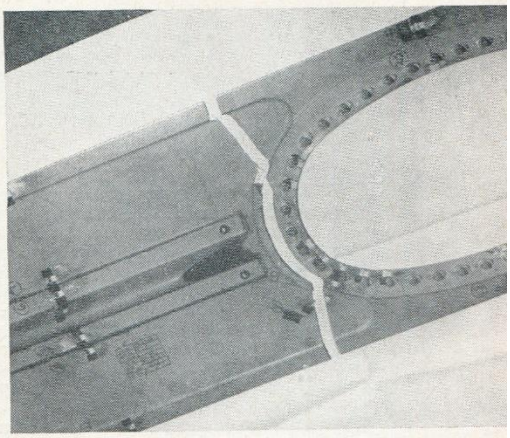
(9) The close grouping of the Comet's engines simplified the fuel feed system, there being no complicated system of cock operation.

(10) Closeness of the engines to the aircraft centre-line virtually eliminated asymmetric thrust in the event of outboard engine



Tank fatigue-testing of a Comet nose-canopy (taken from Comet 1 G-ALYX) to assess the life of the windscreen structure.





(Left). Close-up of a main-wing spar in its fatigue-testing gantry. The one-piece cut-outs — comprehensively strain-gauged—in the spar web for the engines may be noted to differ from those of the Comet 1, which had bolted ring-pieces. The centre-section structure, separately tested, is here simulated by a V-strut. (Right). A portion of the bottom wing-skin, incorporating an inspection-hole, shown after its fatigue test.

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failure. This was perhaps the most important advantage of the buried installation.

It had been considered better to concentrate on a pure powered system for the flying controls, and the reason for this was the consideration that any stand-by system should be as good as the primary system as regards effectiveness and pilot-effort. Such dangers as runaway control valves, a seized ram in the booster, or a mechanical failure of any kind in the control circuit and booster mechanism, were all common to the pure powered-control system and to the powered-control system with manual reversion. The authors believed very strongly that, *provided really adequate safeguards were taken against loss of hydraulic fluid, and that boosters and other valves were duplicated,* it was far better to have a simple powered system.

During the last six years considerable development had gone into the Comet's controls. To provide lower elevator gearing for all flying except in the circuit and during take-off and landing the Comet 4 would have a gear-change device in the elevator system, and "Q-feel" was being incorporated in the elevator.

Some of the detailed design improvements made to the Comet since the aircraft flew in its original form on July 27, 1949 were: (1) A change of wing section, eliminating the possibility of a ground stall during take-off. (2) Greatly increased flap area to provide an increase in drag during final approach. (3) The hydraulic equipment in the fuselage had been located in an entirely separate equipment bay remote from any electrical equipment. (4) Considerable development work and a great deal of testing had been devoted to improving the flameproof properties of all electrical equipment. (5) Fuel heaters and integrating flow-meters were provided in the fuel system. (6) A great deal of development had gone into improving engine ventilation and the fire-prevention and detection systems. The Comet 4 engine installation was scheduled to be tested in the Rolls-Royce fire tunnel at Hucknall. (7) Dunlop Maxaret anti-skid brakes were fitted and provision made for a tail parachute. Reverse thrust was under active development on the Comet 2 and would be fitted to the Comet 4 as soon as a satisfactory system had been developed. (8) Considerable development work was being done to reduce jet noise, although the Comet 4 with its more moderately powered engines was not in such great need of noise-reduction as were its more powerful competitors. (9) The flight deck had been largely re-designed to provide for five crew-stations. (10) Full provision was made for automatic blind approach and for cloud-warning search radar. (11) Alternative cabin arrangements had been devised to accommodate either all first-class passengers, mixed-class, or all tourist-class.

Mr. Cunningham recounted the flying experience gained since July 1949, both by de Havilland and by B.O.A.C. It was possible from the Comet's 30,000 hours of airline service to answer some of the controversial questions being discussed today. Firstly, there was absolutely no doubt that passengers preferred jets. Turbulence was a rarity, and the smoothness of the pure jet had to be experienced to be believed (the instruments and radio gave very good service because of this). The Ghost engines, which reached a 750 hr overhaul life, were less liable to failure than piston engines. Noise had never been any real problem, and the aircraft was never towed to the runway before engines were started. Underwing pressure refuelling made rapid transit times possible; normal turnround time was 40 minutes, although times as low as 25 minutes had been achieved by B.O.A.C.

Throughout the Comet 3's recent world tour it fitted into the airports easily and the standard navaids and meteorological facilities were found to be very satisfactory, with one exception: there was a lack of D.M.E., vital to a jet airliner beginning its descent from cruising height at a predetermined distance from its destination, usually 180 n.m. away. The upper air wind forecasts were very accurate throughout the tour and variations in forecast speeds had to be pretty big to have much effect on the flight time.

On the mechanical side nothing out of the ordinary in the way of ground equipment was needed by the Comet except for the provision of kerosene or JP1. The aircraft battery system was capable of starting all engines when no ground unit was available. The Comet 3 had a high acceleration and a quick unstick, and power was reduced to cruising setting by the time the end of the runway was crossed; the high rate of climb at the reduced setting made the aircraft relatively quiet in the vicinity of an airfield. It was hoped for a great improvement with the fitting of the Rolls-Royce nozzle, which did not, incidentally, prevent the use of a thrust reverser. There would be some price to pay in efficiency and weight for the latter, and the authors had no doubt that the Comet 4 could be operated perfectly satisfactorily without such reversers. If it was said that it was not possible to rely on wheel brakes on icy runways, how was it that North Stars managed to operate continuously without braking propellers on icy runways? Nevertheless, an experimental reverse-thrust installation was just about to be flown on a Comet 2.

Perhaps the feature most remarked on by pilots converting from a piston-engined transport to the Comet was the lack of deceleration when closing the throttles on landing. This feature, present in most jet aircraft, had been largely overcome by the provision of big wing flaps. Conversion to the Comet was no longer than that required to convert to another piston engined type: so far as flying and handling were concerned the Comet presented no big problem, but what had to be impressed upon the jet transport pilot was that he had to stay up high to achieve range, any decision to divert had to be taken quickly and, in general, his mind had to work more quickly.

N.Z. AGRICULTURAL AVIATION SHOW

THE world's first "agricultural aviation" show is to be held, on November 9th and 10th, at Palmerston North, New Zealand. It is expected that this will be by far the biggest aerial display ever held in the Dominion, and a mass fly-past of 100 aircraft will probably constitute the largest single formation seen in the Southern Hemisphere since the war.

The Aviation Industry Association of New Zealand, in collaboration with interested commercial organizations and Government Departments, is organizing the exhibition.

Mr. E. R. Curtis, chairman of the committee, said recently that the show would be to a very large extent a display of the outcome of the New Zealand Meat Producers' Board's decision to loan £250,000 to assist the development of the aerial top-dressing industry. In 1950, said Mr. Curtis, 5,000 tons of fertilizer were spread by the agricultural aviation industry and 800 gallons of spray used. Respective figures for 1955 were 350,000 tons and 250,000 gallons.