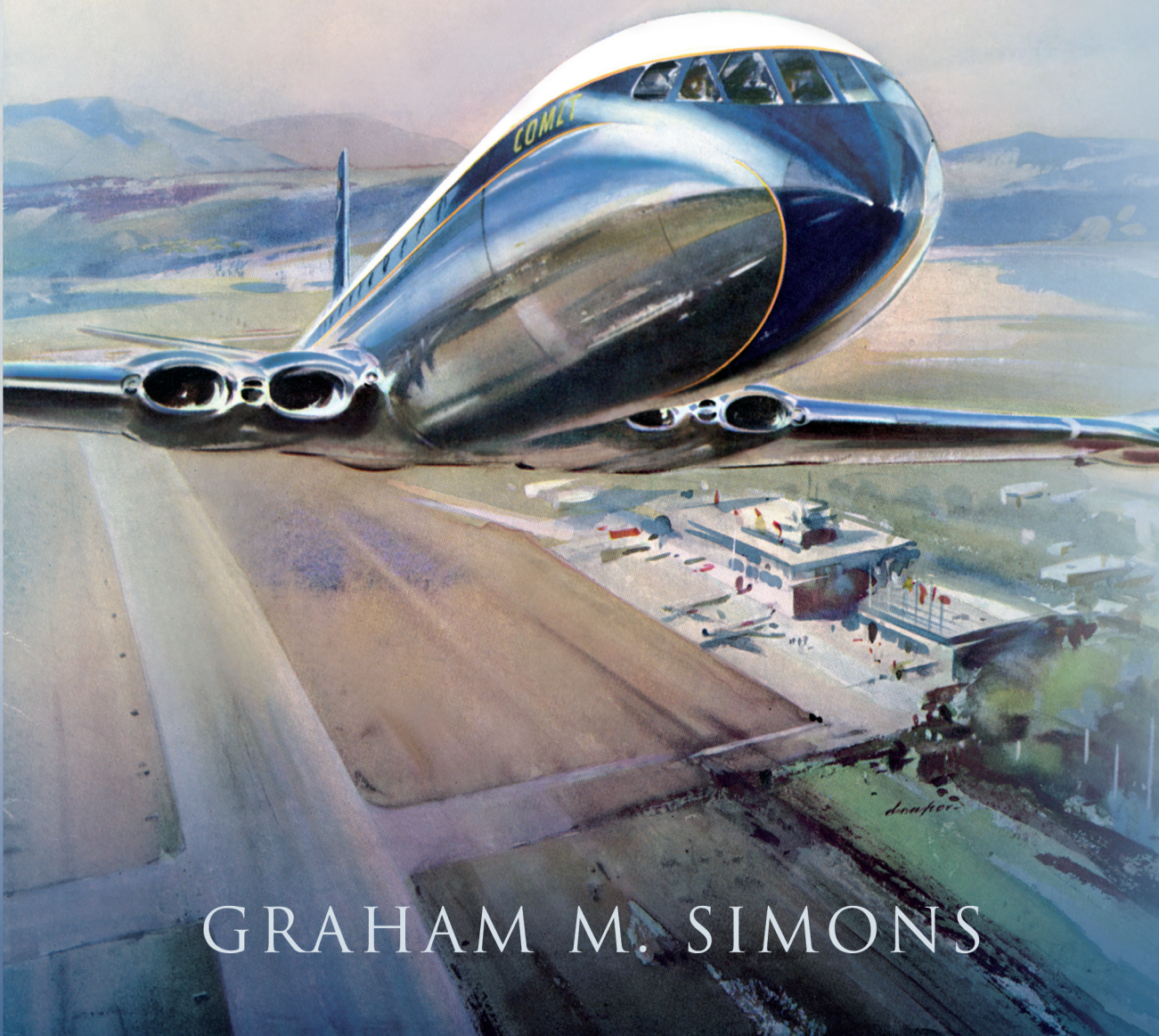


COMET!

THE WORLD'S FIRST JET AIRLINER



GRAHAM M. SIMONS

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AVIATION

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INTRODUCTION

Comet! Let it be fully and completely understood from the outset - the British De Havilland DH.106 Comet was the world's first jet airliner, it was not the Avro Canada C-102 Jetliner, it was not anything Russian, French or Italian - and it was certainly not the Boeing 707 or its numerous predecessors!

Not only was the Comet the first to take to the air, it was the first to enter full passenger service, and the first jet to carry passengers across the Atlantic.

In 1952, the United Kingdom was entering a new Elizabethan Age and the world was on the cusp of great changes. One highlight of that year was the introduction of the Comet into the world's passenger air services, reducing the journey times of smooth, high altitude, vibrationless flight by nearly a half. Flying in the Comet was, as De Havilland's publicity material reported '*...to arrive without the feeling of having travelled*'.

Nearly fifty years later, this remarkable aeroplane was commemorated by a new postage stamp. The UK Post Office chose the Comet to represent one of Britain's greatest achievements during that millennium. Also, whenever a driver is advised of the proximity of an airport, airfield or even low-flying aircraft, the design they see on the relevant road sign is the outline of a Comet I!

No praise is high enough for the team whose combined experience, knowledge, intuition, foresight, and, above all, courage, produced the world's first commercial jet airliner - only four years after the British aircraft industry had emerged from a crippling Second World War, and had abandoned several promising airliner projects in 1939.

Often forgotten today is the mood of the aeronautical world at the time. Sceptics were almost unanimous in asserting that jet propulsion may have been suitable for military aircraft, but excessive and expensive fuel consumption would rule out commercial applications. De Havilland's faith in their own project proved them wrong. Much credit must go to the launch customer, British Overseas Airways Corporation, the British

state-owned airline who matched De Havilland's faith with equally enthusiastic support. De Havilland and BOAC together introduced jet travel to a world that was sceptical in some quarters.

Sadly, the devastating crashes of 1954 set the project back by four years, and provided fuel to the doom-mongers. The crashes also allowed rival manufacturers to benefit from De Havilland's enterprise. The company had leaped boldly into the unknown realms of seven-mile-high-altitude flying, meeting operational phenomena which were completely unknown at the time.

Indeed, there are echoes from this past at the time of writing with the Boeing 787 Dreamliner battery fires. Boeing came to dominate the jet airliner industry with their flagship 707 in large part because of the De Havilland Comet accidents. The Comet embraced new technologies before they were fully understood. Now, in 2013, similar things are happening again. Although the makers of lithium ion batteries work within some of the most stringent quality control standards in industry today and they make cells by the million, there are still failures up in the region of hundreds or thousands every year.

Part of Boeing's battery fix is to not just to try to eliminate battery fires but also contain any that might break out. This means, in part, thermally insulating every lithium cobalt oxide cell within the battery's stainless steel container that in itself is designed to contain any fire. However, reports indicate that this could also cause a problem. It is known that as the cells are used, they heat up, and have to be able to dissipate this heat, but if they get above about 90 degrees Celsius or so, and the heat is contained, then the battery may begin to self-heat and undergo a thermal runaway. Boeing have put forward a statement that in the unlikely event of this happening, then the fire would be contained - however, it is my opinion from this, it could mean that anyone flying on a Dreamliner would be playing Russian Roulette that the aircraft they are travelling on will not suffer a cell failure - or on board fire.

In composing this story, I have tried to remember that we all write with the benefit and the handicap of hindsight. Hindsight can sometimes see the past clearly - with 20/20 vision. But the path of what happened is so brightly lit that it places everything else more deeply into shadow. Commenting on Pearl Harbor, Roberta Wohlstetter - one of America's most important historians of military intelligence - found it '*...much easier after the event to sort the relevant from the irrelevant signals. After the event, of course, a signal is always crystal clear; we can now see what disaster it was signalling since the disaster has occurred. But before the event it is obscure and pregnant with conflicting meanings.*'

The same is true of the Comet accidents; as time passes, more documents and evidence became available, and the bare facts of what happened became still clearer. Yet the picture of how those things happened becomes harder to re-imagine, as that past world, with its preoccupations and uncertainty, recedes and the remaining memories of it become coloured by what happened and what was written about it later. With that caution in mind, I had to ask whether the insights that seem so apparent now would really have been meaningful at the time, given the limits of what people then could reasonably have known or done. To that end I tried to rely on primary source documents, reporting on what was available at the time.

Counteracting that tragic episode were the Comet's numerous achievements that have been invariably overlooked by so many aviation historians, particularly those from across the pond: yes, there was high fuel consumption but this was more than compensated for by cheap price at the bowzers; the maintenance requirements were dramatically reduced because of the smooth running of the jet engines, a fact that considerably lengthened airframe lives. Yes, it was smaller than it possibly could have been, but the market at the time clearly indicated that there was a tremendous market for an aircraft of that size. When the Comet was introduced there was nothing to suggest that a 'bigger and faster' battle was just over the

horizon. The Comet demonstrated an efficient swept wing, a reliable jet engine, multiple wheel undercarriage, high-level pressurization, full power controls, and many other related engineering advances. These advances, coupled with the freely available findings of the court of enquiry into the accidents meant that entire aviation world was, or at least should have been, the grateful beneficiary of DH enterprise.

Two years later, Aeroflot's Tupolev Tu-104 began service in the Soviet Union, and two years later still, Pan American put the Boeing 707 into service, just three weeks after the rejuvenated Comet 4. In the jet airliner race, the Comet had been the pacesetter, faltering early, but recovering bravely, to cross the line in advance of all others as the winner in a trans-Atlantic photo-finish.

The Comet went on to achieve many things, including opening up the world to air travel to a whole new generation when it was put to great use by UK airline Dan-Air Services.

Even after Dan-Air retired the last one from commercial service in 1980, the story was far from over, for with the Comet derivative Nimrod the RAF operated the aircraft well into the 21st Century until the MRA.4 spluttered to a halt in a political and financial quagmire!

The de Havilland DH.106 Comet occupies a unique place in aeronautical history that can never be emulated. Without ignoring the development problems - or the terrible penalty of being first, I look in detail at the work that went on with the accident inquiry - this book tries to do justice to the memory of a tremendous technical achievement. Above all, I would like to think that not only does it put on record, but also pays tribute to the design, manufacturing and test teams, whose sleek, beautiful aircraft can be described as the result of collective genius.

Graham M Simons
Peterborough
September 2013

Chapter One

GENESIS BY COMMITTEE

On 23 December 1942 - in that grand old British tradition - a committee was formed under the chairmanship of aviation pioneer John Theodore Cuthbert Moore-Brabazon, 1st Baron Brabazon of Tara, GBE, MC, PC. to investigate the future needs of the British Empire's civilian airliner market. The study was an attempt at defining in broad overview; the impact of projected advances in aviation technology and to forecast the global needs of the post war British Empire (in South Asia, Africa, the Near and Far East) and Commonwealth (Australia, Canada, New Zealand) in the area of air transport, for passengers, mail, and cargo.

The study both recognized and accepted that the British Empire and Commonwealth as both a political and economic entity would have a vital need for aviation systems (principally aircraft) to facilitate its continued existence and self reliance in the post-war world. For military and commercial reasons, the empire simply could not continue to exist if did not understand the needs, and develop the industrial infrastructure to provide, the aviation systems and sub-systems necessary to supply and maintain a global air transport service.

Moore-Brabazon was born in London to Lieutenant-Colonel John Arthur Henry Moore-Brabazon (1828–1908) and his wife, Emma Sophia (d. 1937). He was educated at Harrow School before reading engineering at Trinity College, Cambridge, but did not graduate. He spent his university holidays working for Charles Rolls as an unpaid mechanic, and became an apprentice at Darracq in Paris after leaving Cambridge. In 1907 he won the Circuit des Ardennes in a Minerva.

With the outbreak of War, Moore-Brabazon return to flying, joining the Royal Flying Corps. He served on the Western Front, where he played a key role in the development of aerial

photography and reconnaissance. In March 1915 he was promoted to captain and appointed as an equipment officer. On 1 April 1918, when the Royal Flying Corps merged with the Royal Naval Air Service to form the Royal Air Force, Moore-Brabazon was appointed as a staff officer (first class) and made a temporary lieutenant-colonel. Moore-Brabazon finished the war with the rank of Lieutenant-Colonel, had been awarded the Military Cross, and had become a commander of the Légion d'Honneur.

Moore-Brabazon later became a Conservative Member of Parliament for Chatham (1918-1929) and Wallasey (1931-1942) and served as a junior minister during the 1920s. In Winston Churchill's wartime government, he was appointed Minister of Transport in October 1940 and joined the Privy Council, becoming Minister of Aircraft Production in May 1941, succeeding Lord Beaverbrook. As the Minister of Transport he proposed the use of Airgraphs to reduce the weight and bulk of mails travelling between troops fighting in the Middle East and their families in the UK.

He was forced to resign in 1942 for expressing the hope that Germany and the Soviet Union, then fighting the Battle of Stalingrad, would destroy each other. Since the Soviet Union was fighting on the same side as the UK, the hope that it would be destroyed, although common in the Conservative Party, was regarded as being unacceptable to the war effort. Moore-Brabazon was elevated to the House of Lords as Baron Brabazon of Tara, of Sandwich in the County of Kent, in April 1942.

During 1942, the Prime Minister, Winston Churchill, sought his advice regarding the setting up of an advisory committee to formulate plans for post-war civil aviation in Britain. Initially known as the Civil Aviation Committee on

John Theodore Cuthbert Moore-Brabazon, (8 February 1884 – 17 May 1964) 1st Baron Brabazon of Tara, GBE, MC, PC.
(author's collection)



Post-War Transport, the first meeting was held on 23 December 1942; its members from the Air Ministry and Ministry of Aircraft Production were. under the chairmanship of The Rt Hon. The Lord Brabazon, Sir Henry Self (Ministry of Aircraft Production), Sir Francis Shelmerdine, William P Hildred and J.H. Riddoch from the Air Ministry, Norbert E. Rowe and Kelvin T. Spencer (Ministry of Aircraft Production)

The Committee's official terms of reference were:

- 1a To prepare outline specifications of the several aircraft types that would be needed for post-war air transport.
- 1b To suggest which firms should be invited, as soon as urgent war work permitted, to prepare tender designs.
- 2 To consider, in consultation with the aircraft firms concerned, which existing military aircraft could usefully be converted to air transport purposes for use whilst new civil types were being produced, and to plan for such conversions.
- 3 To prepare a plan for the immediate utilisation, in the interests of post-war air transport, of spare design and production capacity whilst the aircraft industry made its transition from war to peace.

They studied a number of designs and technical considerations, meeting several times over the next two years to further clarify the needs of different market segments.

Following the Committee's tenth meeting on 9 February 1943 a series of outline recommendations were made to the Secretary of State for Air and the Minister of Aircraft Production:

- A. The adaptation of four existing types:
 1. Avro York
 2. A civil version of the Vickers Warwick.

The Avro 685 York used Lancaster wings, tailplanes and Rolls Royce Merlin engines. (*author's collection*)



3. Development of the Sunderland III - the Short Hythe.
4. Development of the Sunderland III - the Short Sandringham.
- B. The design of five new types:
 1. A large, long-range landplane for the North Atlantic route
 2. A DC-3 replacement for European services
 3. A four-engine medium-range landplane for the Empire routes
 4. A jet propelled mailplane for the North Atlantic
 5. A twin-engined fourteen-passenger feeder liner
- C. Work on these five new types of aircraft should commence as soon as circumstances permitted. Their specifications were to be drafted jointly by potential users and aircraft manufacturers whose selection would be agreed between the Air Ministry and the Ministry of Aircraft Production (MAP). However, top priority was to be given to Type I - the large, long-range landplane.

The Committee considered production numbers, as it was realised that the aircraft industry would obviously reduce considerably in size on return to peace. They included what would later turn out to be some very optimistic proposals, quoting over 1300 Yorks to be built over a three-year period! Other types were to be produced in hundreds. There was no mention as to who would operate such large numbers or how they were to be paid for.

After studying the recommendations, the Cabinet authorised the setting up of a second Brabazon Committee to undertake more detailed work; '*...to consider the types recommended in relation to traffic needs and to prepare a list of requirements for each*

type to provide a basis for design and development.'

This committee's first meeting was held on 25 May 1943 with the following membership: Alan C Campbell-Orde, assistant to Chairman BOAC; Capt. Geoffrey de Havilland, De Havilland Aircraft Co Ltd; Sir William P. Hildred, Director-General Civil Aviation; Group Capt. William Helmore, Technical Advisor, Ministry of Aircraft Production; Maj. J. Ronald McCrindle, Deputy Director-General BOAC; Maj. Ronald H. Thornton, Air Registration Board; Air Commodore Alfred R. Wardle, Air Ministry and John H. Riddoch, Director of Home Civil Aviation, Ministry of Civil Aviation.

These members provided a wider range of people which, in theory, meant a greater grasp of the practical problems of matching the proposed types to traffic and economic needs, considering both airframes and powerplants. They also studied such ancillary matters as pressurisation, navigation aids and runway lengths. Their government contact was Sir Stafford Cripps, the new Minister of Aircraft Production.

Winston Churchill took a personal interest in that he had already experienced first hand the hardship of long-distance travel in existing wartime aircraft flying in both the unpressurised B-24 Liberator and the Avro York. He was concerned that a comfortable, pressurised long-range airliner should be available.

In May 1943 MAP indicated to Bristol Aeroplane Co. that they would be ordering four prototypes of the definitive Type I requirement. This had not gone out to tender, as the MAP did not want design work and time duplicated between different constructors. Limited information concerning the Brabazon Type I had been made public back in March. By June it was agreed that preliminary design work on the other designs could begin '*...with no detriment to the war effort*'. The MAP asked Airspeed, aided by de Havilland, to proceed with the Type II, Avro with the Type III and de Havilland with the Type V.

The committee noted that the British aircraft industry remained fully committed to military

production and could not devote much time to these new airliner requirements. However, it was felt that more notice should be taken of their recommendations, otherwise any delays might render the new airliners obsolete before entering service.

Following the Brabazon Committee's first report in August 1943, Winston Churchill appointed Lord Beaverbrook to form the Committee on Air Transport which was tasked with co-ordinating post-war civil air transport policies. Its first task was to oversee the production of the new aircraft. Peter Masfield was appointed as his secretary. Beaverbrook worked closely with the Brabazon Committee, where it was confirmed that the first requirement – and certainly the most difficult task - was for the five thousand mile range Type I transatlantic airliner. A conference in October 1943 saw representatives of Empire countries and airlines approve a derivative of the Avro Lincoln bomber, thus leading to the Tudor. Specifications for all the Brabazon designs were issued to the British aircraft industry, their initial responses being submitted to the Committee by 1944.

The Brabazon Committee's second report in November 1943 saw the Type III and Type V both split into two. The original Empire airliner now becoming the IIIA, with a new medium-to-long-range Empire airliner becoming the IIIB. The original Type V now became VA with a Type VB added as an eight-seat feeder-liner.

Following this Report, the Director General of Civil Aviation confirmed in January 1944 that the Government had decided that '*...work on design of a limited number of aircraft for civil use should proceed in so far as this can be done without interfering with war production. Certain work should be done on adaptation of existing types for use as transport aircraft during interim period before new types are ready*'.

The aircraft so designated became known as 'interim' designs eventually being developed as:

- (i) A pressurised transport based on the Lincoln for non-stop North Atlantic service. This became the Tudor I. Despite its size, the

Decidedly one of the 'interim' designs was Avro 691 Lancastrian G-AGLF. The aircraft - configured as a 15-seater - entered service with BOAC on 1 December 1944, passing to Skyways Ltd and named 'Sky Diplomat' on 8 April 1946 and crashed at landing ground H3 in the Syrian Desert on 11 March 1947. (author's collection)



Another interim design was the Handley Page Halifax, converted from the Halifax bomber. Here is G-AHDU 'Falkirk' of BOAC, that was fitted out by Short & Harland Ltd of Belfast with an under-fuselage freight pannier. The aircraft was able to carry ten passengers in rudimentary comfort in the fuselage.



Tudor would only be required to carry twelve passengers plus mail.

- (ii) The Avro York was planned to be used on the major Empire trunk routes.
 - (iii) A civil Handley Page Halifax III - designated Hermes - to be used on shorter Empire routes.
 - (iv) A civil Sunderland (Sandringham)
- Mentioned in the announcement – albeit briefly - were two of the main proposals - the Brabazon I fifty-passenger airliner from the Bristol Aeroplane Company and a De Havilland feeder airliner that was eventually to appear as the Dove. Also mentioned was the large Short Shetland II flying boat that would operate Empire routes as well as summer services across the North Atlantic.

More developments

In March 1944 the Secretary of State for Air disclosed the development of an updated list of 'Brabazon' airliners, which included two new requirements:

- (i) A large transatlantic airliner.
- (ii) A North Atlantic 100,000 lb airliner, refuelling at Gander.
- (iii) Four engines, medium range, trunk routes
- (iv) Twin engines, medium range and European routes
- (v) A high speed transport, with jet engines
- (vi) A fourteen-seat feederliner for route and internal UK services.
- (vii) A eight-seat, twin engine machine for feeder routes & air taxi work.

Having already given development of the

transatlantic airliner to Bristol, the Committee selected other British aircraft manufacturers for the remaining 'Brabazon' aircraft: Airspeed; Avro; De Havilland; Miles and Vickers-Armstrongs. Miles had never produced airliners, although they had progressive ideas.

In the spring of 1944 Lord Beaverbrook was visited by his American counterpart. They discussed future aircraft and airline services, with the British offered US airliners at the end of the war. Beaverbrook felt there was no need to accept as the Brabazon aircraft would be available. Following the hectic events of D-Day in Europe. Beaverbrook and other officials visited the US in July 1944 to see first hand some of the US aircraft manufacturers, flying by Liberator transport direct from Northolt to Washington. They were following in the footsteps of some of the British aircraft designers – for instance, Avro's Roy Chadwick had visited the USA in 1943, visiting amongst others, Lockheed, Northrop and Boeing.

The Beaverbrook group were able to see that, as well as large numbers of fighters and bombers, there were many transport aircraft rolling off the production lines. Whilst in the US, it was agreed to hold a Conference in Montreal with fifty-two nations invited to consider post-war transport requirements and this led to the formation of International Civil Aviation Organisation (ICAO). Post-war this organised, amongst other matters, airline routes and tare structures. On his return home, Beaverbrook advised Churchill and the Cabinet of the progress seen in the US, with the need for Great Britain to do



The Roy Chadwick-designed Avro 688 Tudor I seen without markings on rollout at Woodford.
(Peter Clegg Collection)



During the war early versions of the Lockheed L-1049 Constellation were put to military use. Immediately peace broke out they were used by both Howard Hughes' Trans World Airlines and Juan Trippe's Pan American Airways. Such was the level of competition on the trans-Atlantic routes, that BOAC was forced to operate a small number in order to remain competitive.

something quickly: 'converted bombers will not do, new and efficient aircraft are needed as soon as possible'. Beaverbrook now felt that it might be necessary to accept the earlier offer of US airliners, as the interim Brabazon airliners might not be up to the job.

Somewhat pointedly it was made clear that Liberator transports, with BOAC crews, were regularly crossing the Atlantic with twelve passengers and Trans-Canada Lancastrians were carrying ten plus mail. So what improvements were offered by the proposed twelve-seater Tudor I? Luckily, Lord Beaverbrook did not have to answer these questions as he stood down in November 1944 on the appointment of a new post of Minister of Aviation.

As the second Brabazon Committee started to move towards its conclusions, it was aided by the Air Ministry which created the Ministry of Civil Aviation (MCA) in November 1944. This was able to concentrate its efforts on the airlines and their aircraft. The Committee held a total of sixty-two meetings, the final one in November 1945 when it produced its fifth report. During its meetings the Committee had been dealing with BOAC, which was considered to be the main customer for the new aircraft. It was not until August 1946 that the two additional state airline corporations – British European Airways (BEA) and British South American Airways (BSAA) – came into being and so became 'new' customers for the aircraft.

In 1946 Lord Brabazon joined the Air Registration Board, becoming its chairman in 1947. Beaverbrook's secretary, Peter Masefield, went on to become chief executive of BEA in October 1949.

The report identified four, later changed to five main types that would be required after the war.

The Type I was a very large transatlantic airliner serving the high-volume routes like London-New York, seating its passengers in luxury. This was the Bristol Brabazon I, created under Air Ministry



Specification 2/44. It built on submissions Bristols had made during the war for a '100 ton bomber'. The Type IA was the unfinished Brabazon II that was slightly redesigned and would have been powered by turbine-propellers - more commonly called 'turbo-props'. Air Ministry Specification 2/46 was created for it.

The Type II process was somewhat more complex. Several companies submitted designs to the original specification, but Vickers suggested a move to turbo-prop power. There was some scepticism on the part of the committee, and in the end they decided to split the specification in two, allowing the turboprop design to go ahead while at the same time



The BOAC board expressed a strong preference to buy American aviation products - although the balance of payments at the time severely restricted them.

BOAC expressed a wish to get a number of Douglas DC-4s but were thwarted...

...instead they obtained a number of Canadair C-4s, which were Canadian built versions of the pressurised Douglas DC-4 and powered by Rolls-Royce Merlin 624 engines. In BOAC service they were known as Argonauts, with G-ALHX 'Astraea' seen here in flight.



ordering a 'backup' piston design as well. This led to a split into the IIA and IIB types, the Airspeed Ambassador (Specification 25/43) filling the IIA requirement, and the Vickers VC.2 Viceroy (Specification 8/46) and the Armstrong Whitworth AW.55 Apollo filling IIB (Specification 16/46).

The Type III called for a larger medium-range aircraft for various multi-hop routes serving the British Empire. This was planned as the Avro 693. Originally a turbine-propeller design, it was finalised as a turbojet fitted with four Rolls-Royce Avons, but was cancelled in 1947. Another Type III machine (Specification C2/47) that eventually became a limited success for Bristol was the Britannia.

The Type IV was the most advanced of them all, a jet-powered 100-seat design. It was added at the personal urging of one of the committee members, Geoffrey de Havilland, whose company was involved in development of Britain's first jet fighters. The Type IV could, if the whole concept of a jet airliner could be made to work, be able to replace the Type III outright, and many of the duties of the other planes in shorter routes. Type IV was a jet propelled trans-Atlantic mail plane cruising at over 400 mph, capable of carrying a ton of payload and having a pressure cabin for the crew and passengers.

The Type V was later introduced to fill the original feeder-liner specifications after the Type II

had evolved into larger designs. The VA was a feeder-liner transport in the shape of the Miles Marathon under Specification 18/44 and the VB was the De Havilland Dove light transport under Specification 26/43.

In January 1946 a Government White Paper was published under the title 'British Air Service'. It recorded that twenty-seven Lancastrians - converted Lancaster bombers - had been delivered, with twelve on order intended for BOAC and BSAA. Twelve Halifax C.VIIIIs were to be acquired for BOAC's 'Tiger' route to India and also to West Africa. Twenty-four Shorts Sunderland IIIs were in service, with a further twelve to be converted by the autumn of 1946. At the time, BOAC was still operating thirteen pre-war C-Class flying boats and the one remaining G-Class. BOAC had twenty-five Yorks, with twelve on order, for its 'Springbok' services to South Africa and 'Tiger' services to India. Twenty Avro Tudor Is were due for delivery in October 1946, although they might not be available for North Atlantic services until 1947. Seventy-nine Tudor IIs would be delivered between May 1946 and May 1947. 108 Vikings were on order for European services, with the order expected to be completed during 1946. A number of Solents were on order for BOAC, along with other flying boats.

The White Paper also covered the Brabazon

BOAC also operated a number of Boeing 377 Stratocruisers such as G-AKGH 'Caledonia' as seen here on trans-Atlantic services. (BOAC)



Types saying: '*...it is still necessary to draw a veil of secrecy over these aircraft which should come into service from 1948.*

Some of them are revolutionary in design'. In July 1947 the Ministry of Civil Aviation confirmed that it was not intending to publish the Brabazon Committee recommendations as they were confidential and would not be in the national advantage!

In the immediate post-war years the British aviation industry still supported the Avro Tudor and Handley Page Hermes, despite the obvious advantage of the Lockheed Constellation. One reason was to support the home manufacturers but probably more importantly, Britain did not possess the requisite dollars with which to purchase the American aircraft.

Genesis

De Havillands had always built unorthodox aeroplanes, right from the day when young Geoffrey, later Sir Geoffrey de Havilland, taught himself to fly in a stick-and-string machine he had constructed with the help of his wife between 1909 and 1911. In the First World War there came a series of startling new designs from Geoffrey de Havilland's drawing-board, among them the DH.4, rated easily the best day-bomber used by either side. Modified to carry two passengers, this somewhat austere conveyance

operated the first post-war scheduled air services on international routes. And from that point onwards, British civil aviation and De Havilland's grew up together, through a succession of famous designs that each bore the stamp of fearless originality, from the rotund DH.34s that flew with BOAC's earliest ancestors, the Daimler and Instone Airways, to the stately three-engined DH.66 Hercules with which Imperial Airways pioneered the Eastern trunk routes.

Then in 1934 a sleek, twin-engined racer flashed half-way round the world to win a resounding victory in the international air race from England to Australia. It was the DH.88 and was called the Comet. From its clean lines evolved the magic aerodynamic formula that gave us the Albatross of 1938 - and from that came what was surely one of the most beautiful aircraft ever built - the Mosquito.

By all accounts Hatfield's first jet airliner drawing was dated 1941. In May that year the Aerodynamics Department made their first study of jet propulsion applied to civil purposes, using a modified DH.95 Flamingo with two Halford H.1s as Frank Halford's Whittle-inspired jet engine was designated, or De Havilland Goblins as they later became known.

Earlier that same year Hatfield had been studying a twin-jet Mosquito, talking about it with Dr Moulton of De Havilland Engines and Dr Griffiths of Rolls-Royce.

The early successes achieved by Frank Whittle formed the basis of De



One 'home grown' piston-powered airliner BOAC operated was the Handley Page Hermes.(BOAC)

Havilland research and development, but the company's special interest in the problems of aircraft efficiency as a whole led the design team to strike out on an independent line in selecting the layout of the Goblin.

The first Goblin ran on the test bed on 13 April 1942. Flight trials began on 5 March 1943, with a Gloster Meteor in which two Goblines were mounted. Vampire fighter flight-trials began on 20 September 1943. This aircraft exceeded 500 mph in the Spring of 1944 and was the first aircraft in Britain or America to do so by a handsome margin and over a deep altitude range.

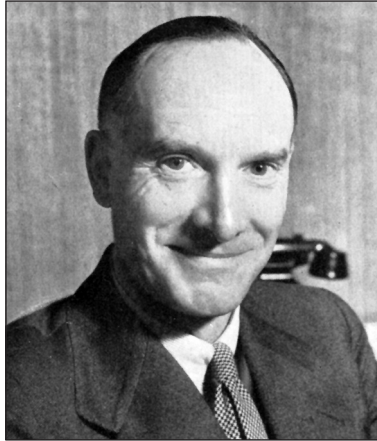
Goblin engines were air-freighted to America and powered the Lockheed XP.80A Shooting Star prototype; it exceeded 500 mph shortly afterwards.

As we have already seen, in the same year, an august body of experts known as the Brabazon Committee issued a series of far-reaching proposals. A committee is one of those much maligned and typically British institutions that only occasionally serve a very useful purpose; luckily, this one did!

With an eye on all the huge strides manufacturers in the USA had been making with transport aircraft such as the Lockheed Constellation and the Douglas DC-4 and DC-6, its members tried to forecast what sort of machines Britain might need when the war was over. Among their various proposals - to which, incidentally, both the Viscount and the Britannia owe their origin - was one for a high-speed mail carrier, powered by jet engines, and capable of flying the Atlantic with six passengers and half a ton of mail.

The de Havilland Goblin centrifugal jet engine developed some 3,000 lbs. static thrust. It was the first of the De Havilland range of gas turbines, and was the first jet engine to pass the British official type-approval tests.

Bishop, along with Hatfield Head of Aerodynamics Richard Clarkson and his assistant David Newman began feasibility studies and design work in April 1941, at a time when no other established aero engine manufacturer had yet entered the gas-turbine field. The aircraft and engine divisions of



Captain Sir Geoffrey de Havilland, OM, CBE, AFC, RDI, FRAeS, (b. 27 July 1882 - d. 21 May 1965)

the De Havilland Enterprise embarked upon the venture together, for it was realised that the much higher speeds of flight made possible by jet propulsion would bring aircraft and engine problems into closer association than ever before.

The later De Havilland Ghost was very similar in concept, but developed 5,000 lbs. static thrust. During the period January to June 1943, a short range civil design based on four Goblines was being considered. Later that year, a more detailed twenty passenger project was proposed having a Vampire layout with three Goblines in the rear of the nacelle.

The design range was approximately 700 miles. From November 1943 to April 1944 the design again changed to a canard layout with three DH Ghosts in the tail.

Development and experience with the de Havilland Vampire suggested that long range flights might be possible and BOAC, who appreciated the benefits to passenger travel of vibrationless flight over long ranges, saw the possibilities of range development with increasing runway lengths and therefore heavier fuel loads.

After one of Geoffrey de Havilland Jnr's demonstration flights in a Vampire, Charles C. Walker was supposedly heard to say to Alan Campbell-Orde of BOAC: 'You know, you could have all that in a transport aircraft...' meaning a cruising speed of 530 mph, at the time the cruising speed of the fastest transport aircraft then in service was less than half that.

The jet-propelled airliner project - designated DH. 106 in October 1944, was proposed to the Brabazon Committee as a scaled-up DH.100 Vampire De Havilland Halford H.2 engines, later named Ghost. Bishop is supposed to have called it a '...stupid aeroplane' with a London - New York payload of 18 passengers and 1,800 lb of mail.

However, this project was becoming so specialised that an alternative proposal was made for a more conventional airliner. Studies were made with various



Ronald Eric Bishop, CBE, FRAeS, Design Director, De Havilland Aircraft Co. Ltd (1903 - 11 June 1989)

fuselage designs in March 1945, seating twenty-four to thirty-six passengers.

In October 1945 - after Bishop and Clarkson visited Germany to see their swept wing research - a tailless design was proposed having a 40° sweep wing, weighing 75,000 lbs. and powered by four DH Ghosts. This idea was dropped in March 1946 as it was considered basically uneconomical, due to the limited effectiveness of the flight controls in this layout. However, much experience on this design was later obtained with the tailless DH.108, three of which were built. Although its efficiency was amply demonstrated, the controllability factor proved to be marginal at very high speed and, in addition, it was found that the landing weight for a given landing speed would be uneconomical. Data provided from the DH.108 showed the sweepback to be uneconomical due to the lower maximum lift coefficient and higher structural weight. It was therefore decided that, with the knowledge then available, the tail-less layout was not suitable for a passenger aircraft.

By May 1946, a more conventional design with 40° wing sweep was proposed showing an Atlantic payload of 5,000 lbs.

To De Havilland's, who had been largely responsible for persuading the Brabazon Committee— rather against the judgement of the majority of its members—to include a jet airliner in its recommendations, this looked like a somewhat specialized and extravagant requirement. However, they decided to see what they could do about meeting it and a project team set to work under the leadership of Ronald Bishop, the brilliant Chief Designer who had joined de Havilland in 1921 as an apprentice of eighteen and was now a director of the company.

Bishop realized that it was going to take far longer than they could afford to get the bugs out of the tailless layout. The United Kingdom was in desperate need of an aircraft with which to win back

the share of international air traffic lost to carriers using US designed and manufactured aircraft. The first post-war hope, the Avro Tudor, was turning out to be an expensive, unmitigated disaster, and her present motley fleet of adapted military aircraft was proving quite incapable of taking business away from its competitors, with the inevitable result that BOAC was losing money fast. Even the new Handley Page Hermes, when it was ready for service, would be barely a match for the fast, economical Constellations and DC-6s, and as an interim measure the Government sanctioned the expenditure of precious dollars on a few American aircraft with which BOAC could defend its prestige routes.

Bishop realised that if the sweepback was eliminated payload could be almost doubled. As a compromise, a more orthodox 20° sweepback wing aircraft was settled upon, incidentally saving about a ton weight of wing structure – it also greatly improved take-off and landing lift.

The words 'straight wing' appeared in an Aerodynamics Department report dated July 1946. The next month Bishop drew the final layout. The tail now had elevators, and the cabin was 120 inches wide compared with the original 100 inches.

So the final Comet shape was established. The final configuration, agreed upon in the closing months of 1946, represented a logical step forward rather than a too-hasty step into the unknown. BOAC and BSAA said they would order fourteen if performance and weights could be guaranteed - and they were. By November 1946, a complete weight and performance statement was available with performance guarantees, all of which were met by the time the Comet entered service in 1952.

Different perspectives

Wilfred Nixon, the Managing Director of the De Havilland Aircraft Company Ltd, gives a different perspective to the background.

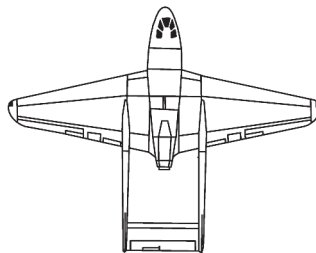
“It was our experience with a jet fighter, having our own jet engine, and in



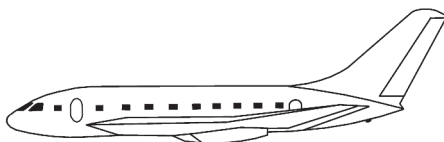
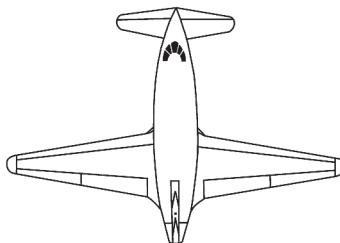
The De Havilland team - left to right: Frank T Hearle, Wilfred E Nixon, Sir Geoffrey de Havilland, Charles C Walker, Francis E N St Barbe, Alan W Butler. (DH Hatfield).



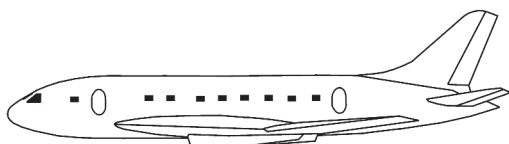
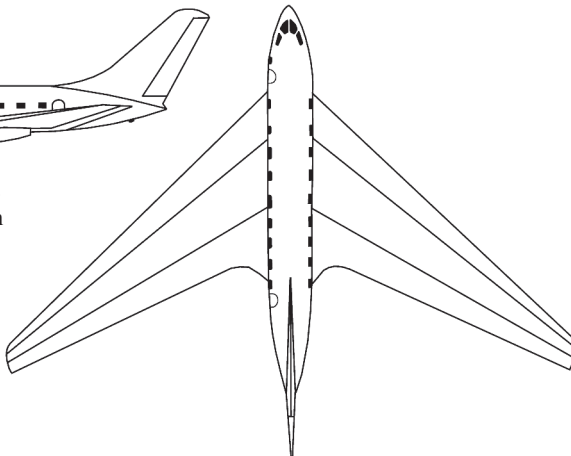
Clearly based on the DH.100 Vampire, this mail-carrier had the air intake for the engine above the wing, feeding the air to the DH Ghost via an S-duct.



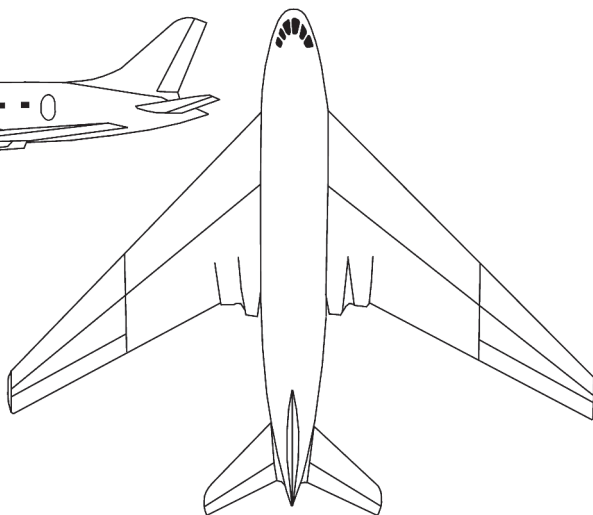
This canard design had three DH Ghost engines buried in the rear fuselage in a triangular pattern.



Building on the work done with the DH.108 tailless research aircraft that was used to gain data on the behaviour of swept wings, this enlarged aircraft appears to have a pair of engines buried in the wing.



Looking more like the final Comet I design, this machine had a conventional tail with four engines buried in the wing, close to the fuselage.



EARLY DE HAVILLAND
DESIGN STUDIES

GENESIS BY COMMITTEE

particular the inherent simplicity and robustness of our type of jet engine, and the high degree of reliability which we quickly attained with it, which gave us confidence that a larger aircraft with four such engines, in fact a passenger liner, could be evolved as a sound proposition. On the economic side, whilst the fuel bill must be considerably heavier than the fuel bill for a comparable piston-engined liner the jet liner would fly so much faster that it would be able to accomplish a great deal more transportation in the year, and this would bring down the cost per passenger-mile to be keenly competitive with that of the piston-engined type. And, of course, the accomplishment of much more work in the year—about half as much again, would mean increased turnover and earning capacity. Thus the advantages of a much faster and much smoother journey appeared obtainable at a competitive cost. Moreover, the simplicity of the jet engine appealed enormously, for the extraction of more and more power out of the piston engine has made it so complex that airline operators are finding its maintenance a most serious problem.

The propeller-driving turbine had attractions, particularly for exceptionally long range, but for ordinary mainline operation the fast jet aeroplane was more attractive; the pure jet engine had reached a more advanced development than the shaft-driving turbine, and it was much simpler. It was an unusual case where a large step forward was easier to take than a smaller one.

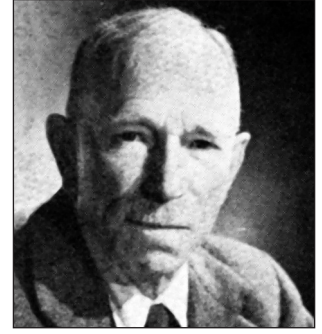
Because we were ahead of the Americans in turbine development we saw in the jet airliner an opportunity to re-establish British leadership on the airways of the world, which had been denied us from the middle thirties when British airline operations had not been encouraged to anything like the degree enjoyed by American airlines. The leeway had been increased by the war period in which, by agreement, America concentrated on heavy bombers and transport aircraft while British effort was devoted to fighters and other combat types.

The Comet airliner with our Ghost jet engines, as we conceived it in 1946, represented the greatest step forward in design which we felt justified in taking, assuming that we should go straight into production from the drawing board. Had we built and tested a prototype first the aircraft would have been out of date before it could be delivered to the airlines, and we should miss the market altogether; to build a prototype airliner is, in our opinion, wrong in principle.

The financing of the Comet project was a matter of great importance to its success. Doubtless we

De Havilland Men!

Charles C Walker
CBE, AMICE, Hon
FRAeS. Director and
Chief Engineer.
(b. 25 Aug 1877).



Richard M Clarkson
OBE, BSc, ACGI,
FRAeS. Assistant
Chief Engineer,
Aircraft.
(b. 14 July 1904).



Major Frank B Halford
CBE, FRAeS, MSAE.
Chairman and
Technical Director,
Engines.
(b. 7 March 1894).

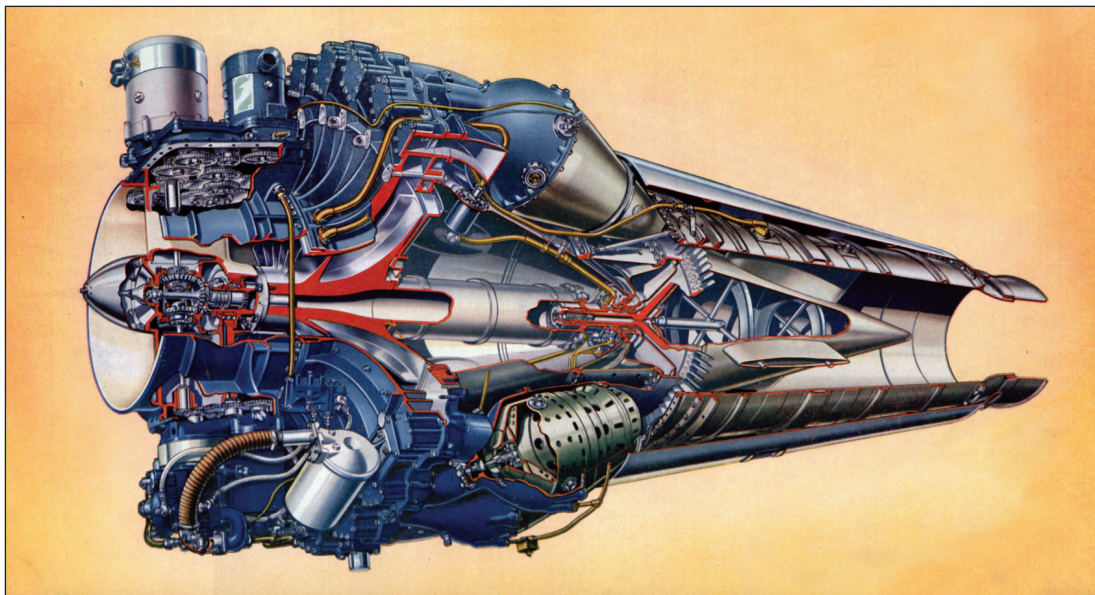


Wilfred E Nixon
Managing Director.
(b. 1892).



Eric S Moulton
PhD, BSc, (Eng)
MIMechE, FRAeS
Chief Engineer,
Engines.
(b. 15 June 1903).





An August 1947 release of the De Havilland cutaway artwork for the 5,000 lb static thrust De Havilland Ghost engine that embodied the principal of single impeller for maximum installed efficiency. (DH Hatfield).

could have obtained Government finance, but it would mean loss of control in some degree and we know that a good airliner can evolve only from the direct partnership of the two naturally responsible entities, the builder and the user, this partnership taking the form of a straight contract with guarantees of technical performance, delivery date and price. With that system there can be no misunderstanding of liabilities, no passing of blame. Knowing where they stand, both builder and user can go forward with enthusiasm and with a joint interest in making a success of the project.

With these principles very firmly in mind we put forward a proposal to British Overseas Airways and to the Ministries concerned. We explained that we could not proceed without an order for a reasonable number of Comets - not sufficient by any means to break even because that would call for some dozens of aircraft - but a sufficient quantity to make the prospect of selling the remainder a worthwhile commercial risk. BOAC, interested in the possibilities of at last offering the most up-to-date airline service in the world, were confident enough to give us the order we needed, an order for 14 aircraft, with the price and delivery date fixed and the performance guaranteed by us. The Ministry of Supply ordered two more aircraft at the same time and at the same commercial price, these to be at Government disposal for development and experimental work.

On the basis of these orders we were able to go ahead with the design, and three years later we had

the first aircraft flying. We have surpassed the guaranteed performance figures and hope to better the delivery dates. Now we face the difficult task of securing world-wide business from the established airlines, bearing in mind that for 15 years or so they have been using American equipment and forming happy and satisfactory associations with our American competitors. The Americans will, of course, do all they can to save their market and we know that we must press forward with the development of the Comet to still better capabilities. As I said before, it represented the greatest technical advance that we felt justified in making at a single step; in its initial form it can carry an economical payload on all but the very long Empire stages at a speed approaching 500 miles an hour, compared with the present-day speed of something under 300 miles an hour.

Ronald Bishop: 'The Comet has resulted from a joint effort by builder and operator. At the end of the war we were faced with the problem of catching up the American lead in transport aircraft. We felt that to embark upon the design of an aeroplane similar to the Lockheed Constellation or the Douglas DC-6, or even a little in advance of those designs, would be fruitless, since our aircraft would inevitably be five years late. We felt also that the American airliners would be able to take advantage of engine developments up to the stage of the propeller turbine, and that we would always be trailing along behind them and striving to catch up.'

Chapter Two

DEVELOPMENT OF THE CONCEPT

The Comet design specification represents a substantial advance in airliner performance without calling for radical changes in operational procedure. The Comet is an aircraft of moderate wing loading - far less in fact than some of the latest propeller driven airliners of its time. Thus in all ordinary handling respects the Comet is orthodox'.

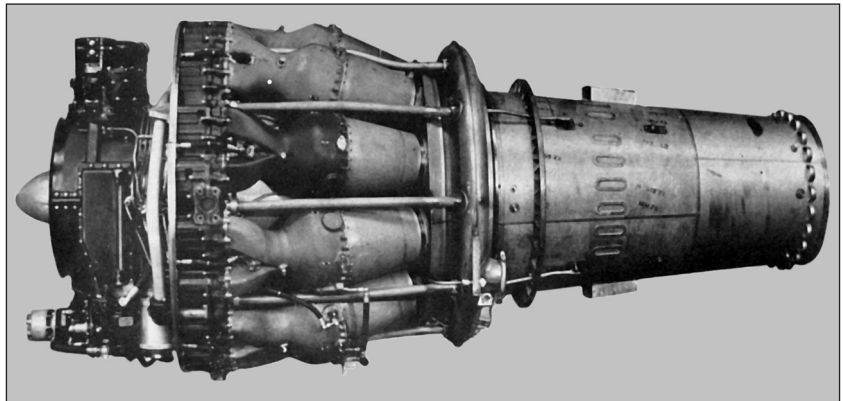
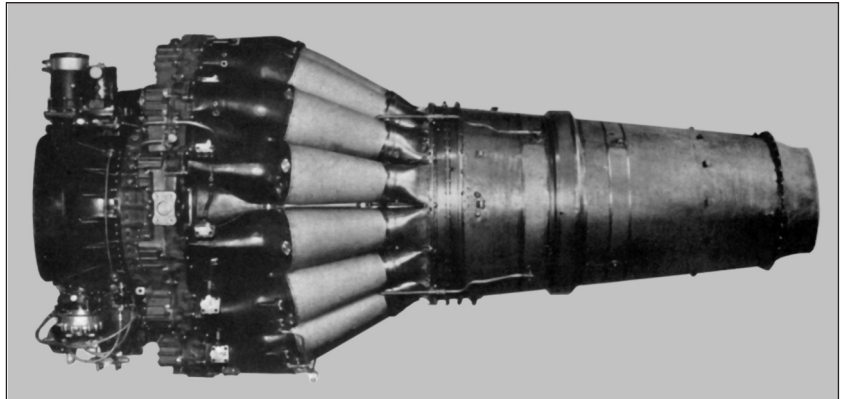
So said the opening paragraph of De Havilland's General Statement for the Comet 1. As dramatic as it reads now, even then it was a case of typical British understatement. De Havilland's were taking highly advanced, rapidly evolving engine technology and merging that with an airframe that was designed around advanced lessons learned in World War Two. Ronald Bishop, De Havilland's Chief Designer provided a greater insight: *'We had considerable experience of the Goblin jet engine in Vampire fighters since September, 1943, and we had the larger engine, the Ghost, entering the test-bed stage.*

We felt that it should be possible to produce a useful civil aeroplane based upon the Ghost engine. At that time, 1945 and 1946, the axial form of gas turbine showed great promise of achieving better fuel consumption, but we considered that the axial was not sufficiently developed for adoption in a civil project. Nobody had yet succeeded in de-icing an axial engine, neither had the problem of tapping the blower for pressure cabin air and de-icing air been tackled by anyone. Looking back, six or seven years later, it appears that the decision to fit a centrifugal engine in the first version of the Comet was a wise one. Had we adopted an axial engine from the first we should not yet have got the Comet into commercial operation.

The specification for a civil jet aeroplane on which we first focused our thoughts was for flying the Atlantic with 1,000 lb of mail and six passengers. We were told that there would be a use for a high-speed

The starting point for the Comet was the De Havilland Goblin jet engine. The design featured ensured the shortest, simplest, engine obtainable within a given cowed diameter. A compact engine with a minimum divergence of gas flow was clearly necessary when handling a hundred tons of air per hour, compressing, heating and expanding it, and ejecting it at a nozzle velocity of over a thousand miles an hour.

Above: The first Ghost engine - a military type - with fourteen combustion chambers, compared with the ten-chamber Comet I engine on the right. On the latter are visible the manifolds for cabin pressurising and aircraft de-icing. (DH Hatfield)



transatlantic mail carrier of this capacity. We envisaged it as a sort of enlarged Vampire with three Goblin engines grouped in the rear fuselage, and with twin booms carrying the empennage. Our own inclinations, however, were towards an airliner in the true sense, and we felt that it should be designed around four Ghosts. This would not give us in its original form a transatlantic passenger vehicle, but we thought that it would be a valuable aeroplane for the Empire routes and a step in the right direction. At first we saw it as a vehicle of moderate size, with a fuselage of about the size of that of the D.C.3, with its diameter of 8 ft. 6 in. and accommodation for 24 passengers, but the more we studied the problem the more confident we became that a full-size airliner for about 40 passengers was justifiable.

Concurrently with these considerations, one of the main technical decisions which occupied us was whether or not to employ a wing of marked sweep-back, and to eliminate the tailplane and elevator. The same problem was engaging us in connection with fighter development, and we decided to study it in a practical way by building a tailless swept-wing adaptation of the Vampire. This was the DH.108 and we had it flying by May, 1946. The work which we did with it during the next two or three years has proved invaluable to our fighter projects and to the Comet. And by September, 1946, we were decided that a tailless airliner, based on our knowledge at that time, would be less practical and economical than a more conventional design. The tailless formula would take more time to resolve than we could allow ourselves. We had recognised from the first the importance of being able to go into production straight off the drawing-board. And this meant that we had to reach sufficiently far ahead in design to take good advantage of the new form of power unit, but not so far as to involve ourselves in highly

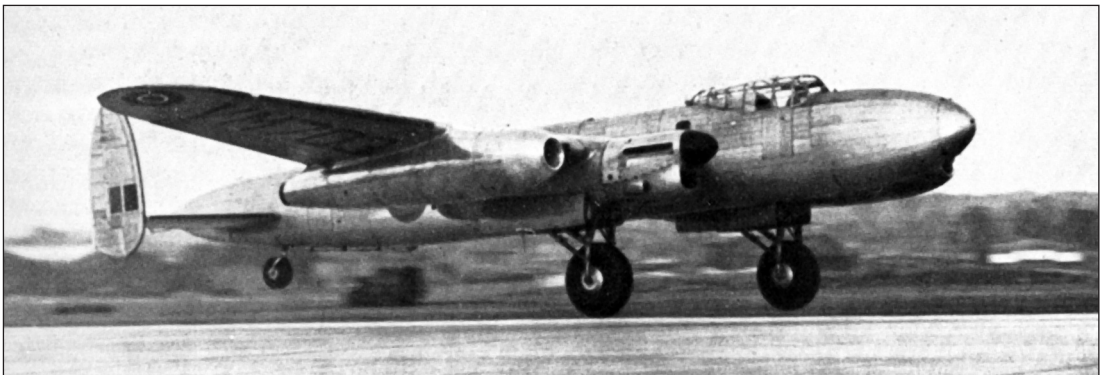
experimental features. In every way the design must represent a logical step forward. We were keen to retain a moderate wing-loading. Thus we came by stages to the Comet design as we know it to-day. In 1946 we saw this as a valuable aeroplane for the Empire routes and as a design having sufficient 'stretch' in it to take advantage of the more powerful and more economical axial engines, when, as we expected, they would be developed to civil standards.

The decision to go into production without waiting for a prototype was made possible by the foresight and initiative of BOAC in ordering a production batch. They were willing to place orders, provided that we would give contractual guarantees under penalty, relating to performance and delivery date, and agree the price in advance. This decision, which was a very courageous one at that time, has, I think, been justified.

Of course, the orders which we were able to obtain on this basis, amounting to 14 aircraft for the airlines and two development aircraft for the British Government, all at a fixed price based upon the costs which were current in 1946, did not amount to a break-even quantity, but we had not expected that. What we secured was a starting order for 16 Comets and we considered that offered us a justifiable commercial risk in proceeding with the project.

Serious design work was started in September, 1946, and the first aeroplane, built by our experimental department, made its maiden flight on July 27, 1949. The second machine, which was built by our production department, took the air a year later to the day. British Overseas Airways started their proving flights in April, 1951, and their passenger service 13 months later on May 2, 1952. The period of two and three-quarter years from the start of design to the first flight, and a further two and three-quarter to the commencement of passenger

Two turning and two burning! The De Havilland Ghost turbojet engines took to the air for the first time when the outer Rolls Royce Merlins on Avro Lancastrian VM903 were replaced. The first airborne testing of the Ghosts occurred in July 1947 as the Lancastrian is seen taking to the air from Hatfield. (*DH Hatfield*)





Once airborne the Lancaster flew on the outboard Ghosts alone. The tests were made by John Cunningham and Chris Beaumont, with a second Ghost Lancastrian VM729 added to speed the testing up. (DH Hatfield)

service, was less than we had expected. Certainly, had we waited for a prototype to fly before starting production, we should have added at least two years to the overall time of getting into service.

Design and Experiment

Detail design work had barely begun when, early in the New Year, there came the stimulating news that no less than sixteen of the new aircraft - costing, at that time, about £450,000 apiece - had been ordered on the strength of the preliminary plans. This did not amount to a 'break-even' quantity, but it was sufficient to reduce considerably the tremendous commercial risks in starting to build.

Two machines were for the Ministry of Supply - the rest were a bold move by BOAC and British South American Airways, both of whom had been pushing the project right from the outset, to ensure that full production could start straight away, without having to wait perhaps two years or more for the results of tests on the prototype.

Whilst this served to emphasize the urgency of the whole programme, it also called for considerable courage on the part of De Havilland's, who had not only to guarantee exact delivery dates and performance figures before they had even begun building, but had to fix the price while design work was still in progress.

It also meant that they had to risk a mass of last-minute modifications to all the production aircraft on the assembly lines, if any serious faults should show up on the prototype. With such a revolutionary design, this was quite possible, for even the most conventional aircraft have their share of teething troubles. De Havilland's resolved to use every possible means of avoiding this costly contingency, and even as the first jiggling and tooling began, they put in hand an urgent programme of research aimed

at eliminating as many faults as possible at the laboratory stage, and also to discover ways and means of lightening the construction. This was particularly vital, because, of the total weight of the aircraft, exactly half consisted of fuel and only one eighth was payload. One pound of extra structure meant one pound less payload, and every pound of payload was worth £50 a year to BOAC.

Ronald Bishop again: *'Tare weight may be mentioned as the first of the design problems. Since the payload would be little more than 10 per cent of the all-up weight at take-off, great efforts were made to keep the structure weight and equipment weight down to the minimum. We went for the smallest fuselage diameter which would accommodate two passengers on each side of the aisle with reasonable comfort. A great deal of investigation and testing was done to achieve the most efficient wing structure. We had been employing Redux cement extensively; it was used in the Dove light transport first built in 1945, and we had been working on the process for three or four years before that. We decided to use it in the Comet wing and fuselage, including double-curvature applications, and a method of construction was evolved for the wing, making use of extruded top-hat sections Reduxed to the skin, which enabled us to employ high allowable compressive stresses in the skin and stringer combination. This construction appeared to be very suitable for a wing having integral fuel tanks, due to the lack of rivets.*

Since the jet aircraft is very sensitive to drag we made every effort to reduce this to a minimum. The Comet has a relatively thin wing, the thickness-chord ratio being 11 per cent. All aerials are buried within the contour of the aircraft and the windscreen also forms part of the fuselage profile. There was a certain amount of doubt about the view from such a windscreen and we decided on a practical test at an

early stage in the design. This we accomplished by making a special nose and mounting it on the front of a Horsa glider which we then towed behind a Halifax. The view for the pilot, both in clear air and in rain, proved to be quite adequate, and it has in fact never been criticised.

The Horsa, which happened conveniently to be the same diameter as the new Comet, with a Halifax bomber acting as tug, toured the skies of Britain looking for some suitably severe rainstorms. At the controls of the hybrid glider was Group Captain John Cunningham, OBE, DSO and two bars, DFC and bar, who had now become Chief Test Pilot. It took several weeks of searching before he was satisfied that he could see out clearly under any conditions. Several

years later a French jet airliner, the Caravelle, was to adopt an identical nose section, the first few actually being purchased from de Havilland's - an interesting tribute to the original design.

Among the first steps was the building of two very important models. One was a super-accurate scale pattern of the complete aircraft, which could be suspended in the wind tunnel and exposed to a hurricane blast of air, while technicians studied its behaviour 'in flight'. The other was a full-size facsimile, or 'mock-up', of the fuselage and inner wing section, built mostly of plywood and used for planning the layout, colour scheme, furnishing and lighting of the passenger and crew accommodation, the details of the engine installation with its cavernous air intakes and huge jet pipes, and the intricate geometry of the wires, ducts and hydraulic lines that snaked throughout the interior of the machine.

It might be thought that all this sort of thing

Below: this strange looking vehicle built from a three-ton truck chassis. A pair of transverse I-beams at the front held a pair of Mosquito main undercarriage units as outriggers and a Comet nosewheel leg with tanks of scrap metal on either side to simulate the loads on the nosewheels. The gentleman in the trilby is Sir Geoffrey himself.

Left: Charles T Wilkins, Assistant Chief Designer applies himself to navigational as well as technical problems with the device. (DH Hatfield)



could just as easily be done on the drawing-board, but as so often happens, there is a world of difference between paper and practice, and things that look fine on paper have a disconcerting habit of getting in the way of something else when they come to be fitted, or of being completely inaccessible to the unfortunate mechanic who has to work them. Similarly, there is only one way of making sure that the positioning of the various instruments and controls will be convenient for the pilot, and that is to let him spend some time sitting in the mock-up trying them for himself.

Ronald Bishop continues: *The problem of carrying fare-paying passengers at a height of 40,000 feet in comfort was one which caused us considerable worry. The temperature of the outside air at this altitude is frequently as low as minus 70 degrees Centigrade, so that the cabin heating and insulation became extremely important. One great advantage of the jet engine is that hot air under pressure can be readily tapped from the main engine compressor, thus doing away with the complication and weight of separate cabin blowers and combustion heaters such as are used at the present time on piston-engined transports. In fact, the temperature control on the Comet is effected by cooling the incoming air.*

We were faced with cabin differential pressures nearly double those in use on existing transports, and the consequences of a

pressure-cabin failure would be so serious that the fuselage must be designed rather like a submarine, so that it would never fail. A great deal of testing was done on large specimens of the fuselage with this object in view. In the early stages, after a failure using air pressure, we found that the only safe way of testing these large fuselage specimens was to submerge them in water and to employ water pressure instead of air pressure. Apart from the danger of the air-pressure method, a failure brought about such a disruption that it was not easy to determine where it originated; in a water-pressure test the failure was localised. We built the first water tank for this purpose in this country and we have found this method of testing to be entirely satisfactory.

We adopted a policy of testing every part of the pressure cabin to destruction, never relying entirely upon calculations, and we employed factors on the pressure part of the fuselage considerably higher than those demanded by the Airworthiness Requirements. Requiring a cabin differential pressure of eight and a quarter pounds per square inch, we



The windscreen rain clearance capabilities of the new design were tested 'in the real world' by putting a mock-up nose on the front of a Airspeed Horsa glider and flown from Hatfield during the bitter winter of 1946. (DH Hatfield)

designed to a safety factor of 2.5, i.e., twenty and a half pounds per square inch, subjected test pieces to a factor of 2 (sixteen and a half pounds per square inch.) and we test all fuselages to a factor of 1.33 (eleven pounds per square inch). We treated the windows as a special case and tested them to a safety factor of 10 (eighty-two pounds per square inch).

The pressure cabin came in for more than its fair share of torture, or so it seemed to some people at the time. But jet engines have an extravagant thirst for fuel at low altitudes, and the entire economic success of the Comet was going to depend on its ability to operate at very great heights. In one of their earliest destructive tests on a specimen of the fuselage, they had pumped it up with air pressure until it burst, and the resulting explosion had been so shattering it had virtually destroyed all the evidence they were seeking.

They solved this particular problem by building a large tank, submerging each fuselage specimen in water and then bursting it quite gently with water pressure. This enabled them to see where every break occurred.

The cabin windows were treated as a separate case, and a set of test windows were pressurised every day for three years under simulated airline

Tucked away in a screened-off area the Comet mock-up took shape out of timber, plywood and brown paper.

(DH Hatfield)

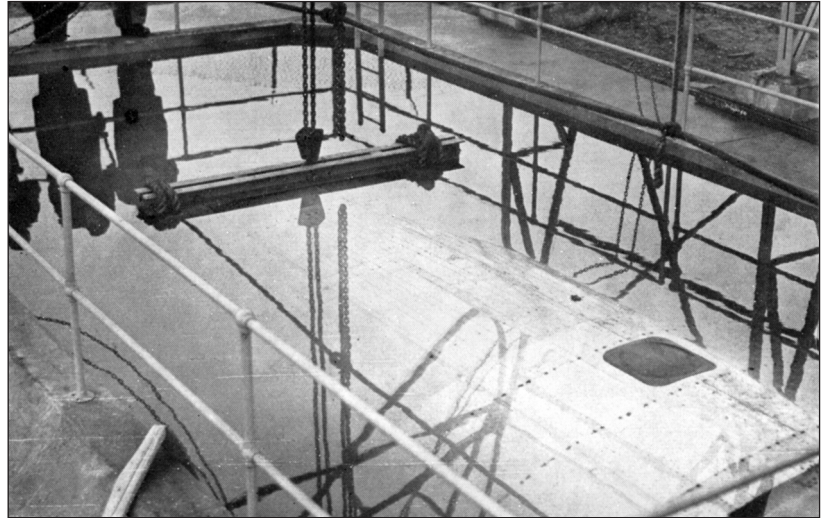
conditions which even included cleaning them with scratch remover in case this should affect their strength. Bishop goes on:

The supply of air for pressurising the fuselage is completely duplicated - in fact, any one engine will maintain the pressure-cabin supply. From the first we insisted upon inward-opening doors and hatches throughout. Considerable care was necessary to ensure that materials would not get brittle after several hours in temperatures down to minus 70°C. To explore this problem and to test equipment which must function in very low temperatures and air pressures we built a decompression chamber, capable of taking the full diameter of the Comet fuselage, in which we could simulate air conditions at altitudes up to 70,000 feet and with temperatures down to minus 70°C. We soon found that the standard materials used for such things as bag tanks, flexible hoses, etc., were useless, and a great deal of development work was undertaken before we were able to obtain materials which would remain reasonably flexible after soaking for five or six hours in air at such temperatures.

We decided to use power-operated flying controls, and although perhaps it could be argued

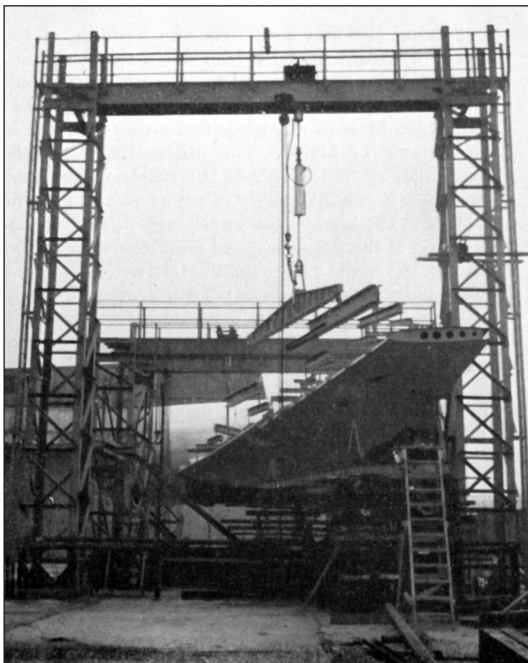


A test section of the Comet fuselage in the water tank at Hatfield. As the company said *'The use of water inside and outside the test specimen, instead of air, removes any danger of an explosive burst and localises the damage if a rupture does occur'*. (DH Hatfield)



that we might have made a success of aerodynamically balanced controls on an aircraft of this size, the advantages of power controls are so great that they seemed to us to be worth the effort. The uncertainties of aerodynamic balance appeared great, especially for an aeroplane with the speed range of the Comet, which operates at high altitude and cruises at a relatively high Mach number. It is significant that we were able to do 200 hours of flying with the Comet prototype in the first five months of trials, and I am convinced that had we had normal aerodynamically balanced controls we should have spent most of this time getting the controls right.

The great advantage of a power control system is that it can be got right on the ground on a test rig.

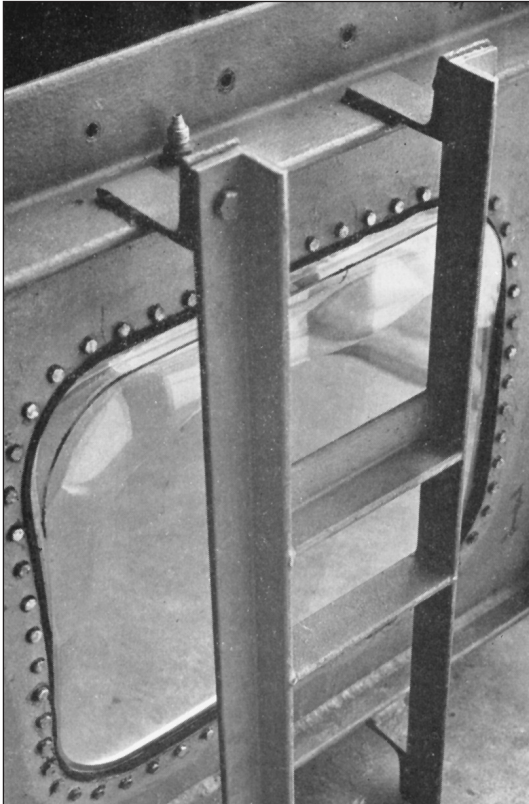


Powered controls have the additional advantage that they allow controls of larger chord to be used, and larger angular travel. Very considerable precautions have to be taken on a power-controlled aircraft. The hydraulic rams and valves are completely duplicated. The primary power control system serves no function other than the operation of the ailerons, elevator and rudder. The undercarriage and flaps are operated by secondary systems. There are three separate hydraulic-power-supply systems on the aircraft, available for flying controls.

John Cunningham and his fellow-pilots also played an important part in the early development of the power-operated control system. This was a system of powerful hydraulic rams which moved the control surfaces up and down for him at the touch of a finger - so effortlessly, in fact, that the cockpit control column and rudder bar had then to be restrained by springs in order to give the pilot an artificial sense of the 'feel' of the aircraft and prevent him from inadvertently overstressing it. The precise degree of response and 'feel' was something that could only be worked out in practice, and a complete set of powered controls was accordingly tried out in the air, first on a Hornet fighter and afterwards on the Swallow.

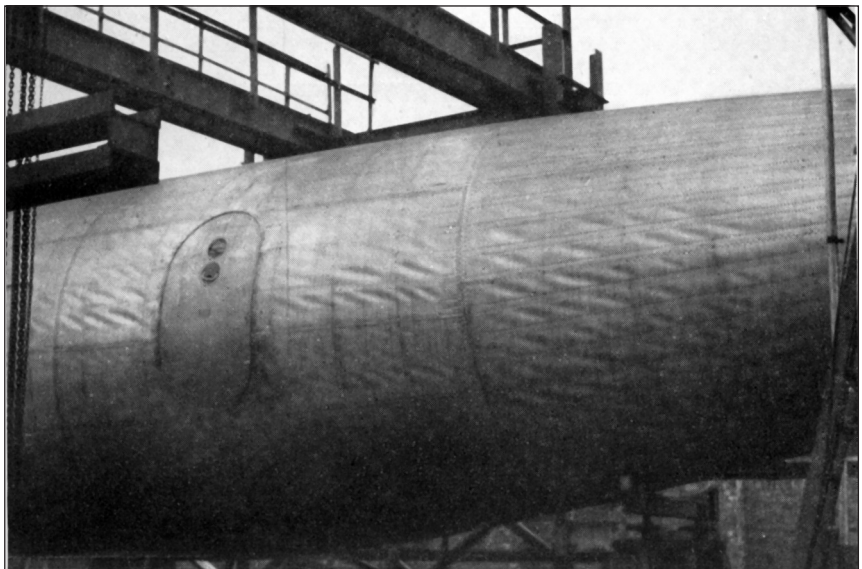
The next step was to prove the mechanical

Another test rig was the huge gantry that checked the strength of a Comet wing. The tests called for many thousands of reversals of load and besides providing an effective check of the structure strength they also served to establish the leak-proof quality of the integral wing fuel tanks, which were filled with kerosene during the tests. (DH Hatfield)



Above: A Comet I cabin window under pressure test - the steelwork was there to prevent the pieces from flying if the window burst. There is a popular misconception that these windows were 'square', with sharp corners, but as can be seen, they were rectangular with rounded corners. wrinkles on the fuselage skin disappeared. (DH Hatfield)

Right: Comet cabin under full pressure is twisted to check its strength. The torsion wrinkles in the skin are clearly visible. The photograph shows the fuselage under a torsional load many times more severe than would ever occur in flight. On this occasion the cabin was not pressurised. When cabin air-pressure was applied at a later stage in the test the stress wrinkles on the fuselage skin disappeared. (DH Hatfield)

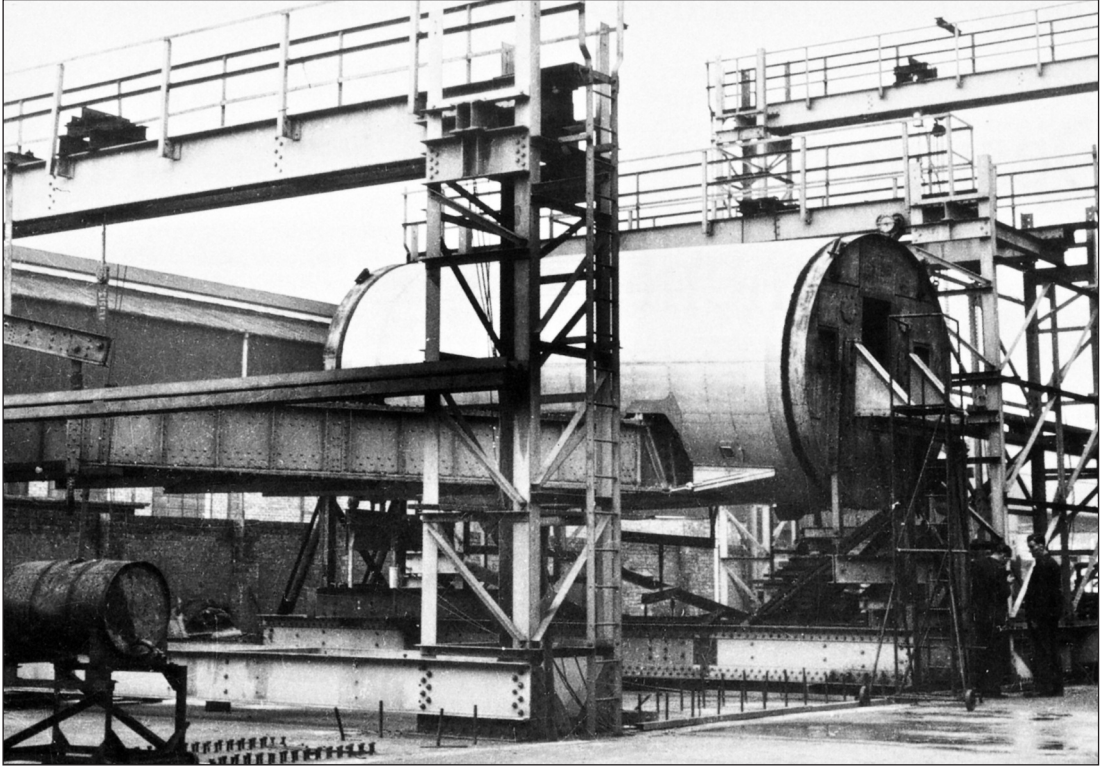


reliability of the system beyond all doubt. To be on the safe side, every vital part was triplicated throughout the system so that even if two failed, another could take over, and this reduced the risk to negligible proportions. Nevertheless, a full-size set of control equipment was put to work on a ground rig at the Hatfield works and only after it had run continuously, day in and day out, for over three years, were the engineers satisfied that nothing was likely to go wrong with it in the normal working life of the aircraft.

This was typical of the exhaustive ground tests undergone by practically every other part of the Comet - as it was now known. Because of the need to keep all structural weight to the barest minimum, a radically new method of construction had been adopted, using a thin skin of aluminium alloy - about the thickness of a postcard - attached to the skeleton framework of the aircraft not by the usual rivets, but with a special metal cement known as Redux.

Redux has become known as the generic name of a family of phenyl-formaldehyde/polyvinyl-formal adhesives developed by Aero Research Limited at Duxford, UK, in the 1940s and subsequently produced by Ciba-Geigy. The brand name is now used for a range of epoxy adhesives manufactured by Hexcel. The name is a contraction of REsearch at DUXford.

It was devised at Aero Research by Dr. Norman de Bruyne and George Newell in 1941 for use in the aircraft industry - at that time specifically De Havilland. The adhesive is used for the bonding of metal-to-metal and metal-to-wood structures, and the adhesive system comprises a liquid adhesive and a powder hardener.



Another test section of the Comet fuselage 'on the rack undergoing torture' at Hatfield. This picture appears to show the centre-section with parts of a wing structure installed, but one that does not have the apertures for the engines. (DH Hatfield)

In this and a hundred lesser ways, pounds were pared off here, ounces off there, but always the strength of the finished component was kept up to standard, proved in a seemingly endless series of gruelling tests in which wings, with their integral fuel tanks filled, and a fuselage under full pressurization, were strained and twisted by powerful hydraulic jacks, the loads being steadily increased until the structure finally failed.

Bishop explains about the fire and fuelling problems that had to be overcome: 'Since we had engines buried in the wing, we realised from the start of the design that very great attention must be paid to fire precautions. The hot parts of the engines are separated from the main structure by steel fireproof bulkheads, and the whole of the tailpipe is enclosed in a steel tube with cooling air passing down the annulus. Perhaps the greatest need in regard to fire risk with a jet engine is a reliable means of detecting the fire quickly should it occur, since once the pilot knows that there is a fire it can be put out instantly by cutting off the supply of fuel to the engine. I am convinced that one of the biggest steps forward in safety from fire in the air is made by the use of

paraffin instead of petrol. I hope that there will never be any talk of using in civil aircraft fuels other than paraffin, such as the new American J.P.4 jet fuel which is, in effect, a low-grade petrol.

Since the advantage of the speed of the jet aircraft can so easily be lost by long stops on the ground, it was essential to develop a good, reliable means of pressure refuelling. The Comet carries 7,000 Imperial gallons of paraffin, and it can be refuelled in 20 minutes. The pressure-refuelling system has been used from the first flight of the prototype in 1949 and has proved entirely satisfactory.

Because of the relatively thin wing and the large amount of fuel to be carried in the aircraft—which, incidentally, could not be carried in the fuselage—we decided to go for integral tanks for the major part of the fuel. By using Redux to cement stringers to the skin and by the use of bolts for assembly, we were able to avoid rivets in the integral-tank area. This system appears to have worked out well, and the integral tanks have given no trouble at all in service.

During the designing of the aeroplane we were concerned about noise in the cabin. After a flight in the Nene Viking we decided to shift two rows of

passengers from the back of the cabin to the front to get them away from the area of jet-pipe noise.

Early in the period of test flying we were worried by the whine of the impeller in the front part of the cabin. After a lot of sound-proofing experiments it was eventually found that this high-pitch noise was transmitted through the structure from the engine, and it was cured by mounting the engine on rubber. Although the Comet may not be a lot quieter than conventional civil aircraft it does appear that it has a less unpleasant sound, and a much more important thing is that there is an almost complete absence of vibration, which results in the passengers arriving at their destination feeling less fatigued than they would be after a flight of the same time in a piston-engined

aircraft. This, coupled with the fact that the flight itself takes much less time in the Comet, is without doubt going to add considerably to the passenger appeal of the Comet'.

Meanwhile it had been established that the Ghost engines were not affected by the intense cold. They had even proved capable of swallowing considerable quantities of ice, including, on several occasions, large chunks weighing several pounds each—with no more than a hesitant cough. This was due mainly to the rugged simplicity of their centrifugal type of compressor, and was one of the main reasons for De Havilland's decision to use this engine for the first Comets, instead of waiting for the more efficient axial turbojets which were coming along; these were more

The air conditioning and cabin pressurisation system took air from the engine impellers and then ducted it around the cabin. Due to the altitude the DH106 was to fly at, the system operated at much greater pressures.

(DH Hatfield)

