Canadian Pacific Airlines , Comet IA, CF-CUN, accident at Karachi, Pakistan, 03 March 1953,

Article by Ronald Keith author of "Bush Pilot with a Briefcase"

About the author

This article is taken from Ronald Keith's book "Bush Pilot with a Briefcase" published by Doubleday, Canada 1972. The book is a biography of Grant McConachie who ran Canadian Pacific Airlines from the 1940's until his death from heart failure. The information contained is this article remains the property of Ronald Keith and may not be distributed without his written approval.

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CF-CUN cleared for takeoff

Comet C-U-N. You are cleared for take- off." The rasp of tower control in his earphones snapped Captain Charles Pentland out of his pre-dawn drowsiness and the fatigue of yesterday's flight from London. He knew he would need all his powers of skill and concentration for the critical task of taking off in darkness from a strange runway with this unfamiliar type of aircraft with a maximum load, including nearly two tons of kerosene in the wing tanks. On board with Pentland were four other crewmembers and six technicians from the DH factory. They were on a rather unusual delivery run.

In planning the first jet air service across the Pacific, McConachie had been forced into a compromise because of the Comet's limited range. He had conceded he would have to base the jet airliner in Australia and operate it up the line as far as Honolulu to connect there with the piston-powered DC-6B for the long shuttle to Vancouver. The Empress of Hawaii, the first of the two CPA Comets, would have to be ferried from England to Australia to start the service. But it was not intended to be a simple delivery flight. McConachie ballyhooed it as a record-setter---the Comet was to establish a new elapsed-time air record from England to Australia. Great publicity---but, as Pentland put it, "bloody rough on us cockpit help."

The captains he chose for this assignment were tops in their trade, both veterans of twelve years at the controls: Pentland with Imperial Airways and British Overseas Airways, Sawle as a bush pilot in the rugged Canadian north. Pentland was CPA's manager of overseas operations. Sawle was chief pilot, overseas.

At the de Havilland aerodrome, Hatfield, England, the CPA captains took a crash course in flying the Comet They were annoyed to find themselves regarded as old-fashioned "windmill jockeys," and novices in the mysteries of jet flight. Some of the new procedures, they discovered, clashed with flying instincts formed by many thousands of hours at the controls of conventional planes. However, after a short course of ground study and flight instruction, Pentland and Sawle were pronounced qualified for Comet command. Neither had experienced a night take-off in the jet, nor had they flown it heavily loaded. They made preparations to depart from London airport for the flight to Australia.

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The brakes are released

Thus, Captain Charles Pentland found himself reaching for the throttles in the gloom of the Comet flight deck on a runway of Karachi Airport a few minutes after three in the morning of March 3. As he pushed the throttles forward to take-off position he set the brakes against the surging thrust of the four Ghosts submerged in the Comet's wing roots. Conserve runway by starting the roll at full bore. Without the air-bite of the big props, these gassers were sluggish on initial acceleration, especially when fuelled to the gills like this. In seconds the luminous gauges were clocking take-off rpm. The Comet shuddered with restrained power. Pentland released the brakes. The Empress of Hawaii lurched forward to roll down the runway into the pitch blackness that enveloped Karachi Airport.

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What happened ?

What happened then inside the cockpit of the CPA Comet? The evidence included a tyre scuff mark on the runway surface 1,250 yards from the starting point, and tire tracks in the hard sand of the overrun strip between the far end of the runway and the perimeter fence. This was enough to piece together the story.

As the heavily-loaded jet picked up speed Pentland concentrated his attention on steering a course between the runway lights. Sawle called off the airspeed readings. At 85 knots Pentland exerted firm back pressure on the control column to reduce ground friction by raising the nose wheel off the runway. At this point he made his first error. He should have levelled the plane until the forward wheel was almost skimming the surface. Instead he continued to roll nose-high.

The design of the Comet 1A wing and the shape of the jet's air intakes were such that in this nose-high position the wing drag increased and the jet thrust diminished. Instead of accelerating to the 122-knot take-off speed, the Comet rumbled on at less than 100 knots, using up precious runway but gaining no more speed. Pentland had ignored the procedure he had been taught during his Comet check-out at de Havilland. At 1,250 yards along the runway the situation was desperate. Pentland tried to hoist the Comet into the air by pulling the nose up sharply. The Comet continued to hug the ground. Then the captain must have recognised his error. He pushed forward on the controls. The plane levelled. The nose wheel came down leaving a tyre scuff mark on the runway. The Comet picked up flying speed. But there was no more runway. Tire tracks on the sand beyond showed the imprint of the nose wheel as well as the main undercarriage. Then the tracks skipped. The Comet was ready to fly. Three seconds more and it would have been up and away. But time had run out for the Empress of Hawaii and for the eleven people on board.

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The explosion

A wheel on the starboard undercarriage struck the culvert of a perimeter drainage ditch. The airliner swerved, staggered, then plunged into a dry canal used for the run-off of monsoon rainwater. At a speed of more than 138 mph, the Comet shattered against the forty-foot embankment on the far side of the canal. The explosion lit up the entire airport and several miles of surrounding countryside.

Comet history The history of the first jet airliner
Comet variants From the 1st prototype to the Mk5
Comet crashes Summary of all crashes & incidents

Accident reports Several Comet accidents reports
Picture gallery Picture collection of various Comet's
Comet flight 2002 Celebrate 50 years of jet service
Technical data Summary of all the Comet data

Featured Geocities site
since 27-Feb-98. Comet production Comet data frame by frame
The Seattle Comet Restoration of the sole US Comet

[Main Comet page] Canopus XS235 The last active Comet

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http://surf.to/comet: Comet crashes and accident reports

All Comet crashes : Summary of all De Havilland Comet accidents.
All hull-losses : Summary of all De Havilland Comet incidents.
Descriptions : Detailed descriptions of all Comet accidents and incidents.
Available Comet accident reports : List of available De

Havilland Comet accident reports.

http://surf.to/comet: Official accident report of Comet I G-ALYP

Final moments of Comet Mk1 G-ALYP

The present sound is a very good simulation of the last communications of G-ALYP. File size is 256 Kb and download time is 1.5 minutes at 3.3K/s. Hear the final moments of G-ALYP. The **copyright** of this sound file is held by **Stanley Hitchcock**. The file is very realistic and should only be listened by a mature audience. *Thanks to Nils Alegren for transmitting this sound file*.

Following is the detail of the last communications:

* **G-ALYP** Ciampino this is George Yoke Peter passing flight level 260 for cruising altitude 360.
* **ATC** Hallo George Yoke Peter passing flight level 260.
* **G-ALHJ** George Yoke Peter from George How Jig understand you are passing 260 what's the cloud cover ?
* **G-ALYP** George How Jig from George Yoke Peter did you get my (cut)

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THE CIVIL AVIATION ACT, 1949

THE CIVIL AVIATION (INVESTIGATION OF ACCIDENTS) REGULATIONS 1951

Report of the Public Inquiry into the causes and circumstances of the accident which occurred on the 10th January, 1954, to the Comet aircraft G-ALYP

* AIRCRAFT: Comet G-ALYP
* ENGINES: Four de Havilland Ghost 50
* REGISTERED OWNERS AND OPERATORS: British Overseas Airways Corporation
* CREW:
* Captain A. Gibson - Killed
* First Officer W. J. Bury - Killed
* Engineer Officer F. C. Macdonald - Killed
* Radio Officer L. P. McMahon - Killed
* Steward F. L. Saunders - Killed
* Stewardess J. E. Clarke - Killed
* PASSENGERS: 29- All Killed
* PLACE OF ACCIDENT: Over the Mediterranean off Elba.

* DATE AND TIME: 10th January, 1954, at about 1000 G.M.T.
All times in this Report are G.M.T.

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PART I INTRODUCTORY

(a) Definitions

1. In this Report the following expressions bear the following meanings:

* " **A.R.B.**" means the Air Registration Board incorporated as a company limited by guarantee under the Companies Act, 1929, on the 26th February, 1937.
* " **A.S.B.**" means the Air Safety Board appointed by the Minister of Transport and Civil Aviation.
* " **de Havillands** " means the de Havilland Aircraft Company Limited.
* " **R.A.E.**" means the Royal Aircraft Establishment controlled by the Minister of Supply.
* " **B.O.A.C.**" means British Overseas Airways Corporation.

(b) The Air Registration Board

2. The primary object of A.R.B. is to carry out such administrative and advisory functions with regard to the design, construction and maintenance of aircraft and matters connected therewith as may from time to time be delegated to A.R.B. by the Minister of Transport and Civil Aviation. Under its Articles of Association A.R.B. is to consist of two members appointed by the Minister and sixteen other members. Of these sixteen four must represent operators of aircraft, four must represent constructors of aircraft, four must represent insurers engaged in aircraft insurance business and the remaining four are co-opted. It is provided that of the two members to be nominated by the Minister one is to be an independent person and the other a person who has had not less than five years' professional experience as a pilot of civil aircraft. It is further provided that the co-opted members are to be persons representative of some interest connected with civil aviation.

3. By section 7 of the Civil Aviation Act, 1949, which reproduces section 2 of the Air Navigation Act, 1936, it is provided that the Minister may by order provide for delegating to a body appearing to him to be constituted as is A.R.B. under its Memorandum and Articles, such of the administrative functions of the Minister with respect to the matters mentioned in the subsection as may be specified in the order and for entrusting to that body such advisory functions in connection with any of such matters as may be specified.

4. In pursuance of this section the Minister by the Civil Aviation (Air Registration Board) Order of 1951 (which replaces Orders made under the 1936 Act) delegated a number of his administrative functions to A.R.B. and entrusted to it certain advisory functions. Under section 1 of the Order the Minister delegated to A.R.B. the following functions (inter alia):_

* **(a)** the formulation and publication of technical requirements as regards the design, construction and maintenance of aircraft and engines, components, accessories, instruments, equipment and apparatus of aircraft;
* **(b)** the investigation of aircraft (including their engines, components, accessories, instruments, equipment and apparatus (excluding radio apparatus) and the manner of the installation of the same) for the purposes of the issue and renewal of

certificates of airworthiness or of validations of such certificates and for the purposes of the variation of particulars and conditions specified in such certificates of any flight manual or performance schedule issued therewith;

* **(c)** the making of recommendations to the Minister as to the issue of certificates of airworthiness and of validations of such certificates and as to the variation of particulars and conditions specified in such certificates or any flight manual or performance schedule issued therewith;
* **(d)** the renewal of certificates of airworthiness and of validations of such certificates and to such extent as may be determined by the Minister in writing the variation of particulars and conditions specified in such certificates or any flight manual or performance schedule issued therewith;
* **(e)** the making of any investigation required in connection with an application for a special permission for an aircraft to fly without a certificate of airworthiness being in force in respect thereof and the making of recommendations to the Minister as to the giving of such a special permission;
* **(f)** the approval of engines for aircraft;
* **(g)** the making of inspections of organisations of persons or firms desiring to furnish reports or certificates as to compliance by aircraft and engines, components, accessories, instruments, equipment and apparatus of aircraft with airworthiness requirements, the approval of any such firm or persons as qualified to furnish such reports of certificates, and the acceptance of such reports or certificates;

5. The chairman of A.R.B. is the Rt. Hon. Lord Brabazon of Tara. The members of the Council are identical with the members of the Board. The Council are advised by a technical staff of about 125 of whom about 84 are employed on inspectional duties. The Chief Executive Officer is Mr. R. E. Hardingham and the Chief Technical Officer of the Board is Mr. W Tye.

6. To enable A.R.B. to discharge its functions it prepares and from time to time publishes detailed requirements which inform manufacturers of the minimum conditions with which, prima facie, they have to conform if they are to obtain a Certificate of Airworthiness. To assist A.R.B. in the preparation of these requirements they have appointed an " Airworthiness Requirements Co-ordinating Committee" which includes representatives of the Ministry of Supply, R.A.E., manufacturers of aircraft, operators of aircraft and A.R.B. itself.

7. Requirements are not, however. treated by A. R. B. as being as immutable as the laws of the Medes and Persians. On the one hand, during the development of a new type, requirements more exacting than those prescribed in the published regulations are often imposed or adopted by the manufacturer concerned. On the other hand, on occasions certain deviations from the prescribed conditions are accepted by A.R.B. provided that they are satisfied that the safety of the aircraft is not thereby jeopardised.

(c) The Air Safety Board

8. A.S.B. is a purely advisory body and has no statutory authority behind it. It was appointed in November. 1946, with the following terms of reference: " To keep under continuous review the needs of safety in British civil aviation and to recommend measures calculated to promote safety in respect of both (a) the operation of British civil aircraft throughout the world, and (b) the efficiency of the system of ground facilities provided for civil aircraft of all nations operating over the United Kingdom." Its members are appointed by the Minister and at the material date consisted of Air Chief Marshal Sir Frederick Bowhill, Lord Brabazon, Sir Leonard Bairstow Air Commodore Banks and Mr. (now Sir) Arnold Hall.

(d) The Royal Aircraft Establishment

9. R.A.E. is controlled by the Minister of Supply. The main establishment is at Farnborough but there are branch establishments in other parts of the country. In this Report I am mainly concerned with the work done at Farnborough. The Director of R.A.E. is Sir Arnold Hall. The Head of the Structures Department is Dr. P. B. Walker. The only other member of the staff who need be mentioned by name is Mr. E L. Ripley who was responsible for the work in connection with the reconstruction and investigation of the wreckage recovered after the accident. I should, however, add that R.A.E. has its own flight testing facilities which were fully used in the investigations which took place after the accident.

(e) The de Havilland Aircraft Company Limited

10. de Havillands were the manufacturers of the Cornet aircraft and the engines were made by a subsidiary company. the de Havilland Engine Company Limited. Mr. R. E. Bishop is the Chief Designer of de Havillands and his Chief Assistant is Mr. C. Wilkins. Mr. R. H. T. Harper is the Chief Structural Engineer and Mr. H. Povey is the Director in charge of Production. de Havillands have an Inspection Department entirely separate from their Production Department and the independence of the Inspection Department is secured by the provision that it reports direct to the Managing Director and is not in any way under the control of the Production Department. de Havillands have been approved under paragraph 1(g) of the Civil Aviation (Air Registration Board) Order of 1951 as qualified to furnish reports and certificates as to compliance with airworthiness requirements.

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PART II
HISTORY OF THE COMET PROJECT

11. Mr. Bishop stated that at the end of the war de Havillands were faced with the problem of recommencing the manufacture of civil aircraft. During the war they had been building only military aircraft. They decided that it would be inadvisable merely to build another version of the conventional aircraft; they had had some years' experience with jet fighters and concluded that with the help of their engine company they should be able to produce a useful civil aircraft which would be a step ahead of the current type. With this end in view they commenced design by the end of September, 1946. Some idea, however, of the amount of work involved is indicated by the fact that it was not until the 27th July 1949, that the first prototype Comet made its first flight. de Havillands were, however, fortunate that B.O.A.C. and the Minister of Supply were willing to enter into a contract for the purchase of Comet aircraft without waiting for the prototype to be available. This enabled de Havillands at once to do preliminary work in the Production Department. The contract was entered into on the 21st January, 1947 and under it B.O.A.C. started their proving, flights in April, 1951.

12. At some date in 1951 it was arranged that the first two prototypes should be delivered to the Ministry of Supply but that the remaining aircraft to be supplied under the contract should be delivered to B.O.A.C. and that the approval of the Ministry of Supply to them should no longer be required.

13. A.R.B. issued a number of special category certificates of airworthiness to enable the requisite tests, both in this country and overseas, to be carried out, but it was not until early in 1952 that a full Certificate of Airworthiness was issued. This enabled the passenger service to be started and it was actually commenced on the 2nd May, 1952. The personnel for the service had received intensive training. B.O.A.C. had established a school for the training of pilots and crews and made full use of a special school which had been established by de Havillands for the training not only of pilots and crews, but also of station engineers. By the 8th April, 1954, when the Comet fleet of B.O.A.C. was grounded after the disaster near Naples, Comet aircraft had flown almost 25,000 hours, representing, on the basis of 400 miles per hour, a mileage of 10,000,000 miles.

14. Dealing more specifically with the technical aspect of the development of the project between September, 1946, and the 2nd May l952, de Havillands' outlook and practice underwent virtually no chance. In order to provide an economically satisfactory payload and range at the high cruising speed which the turbo-jet engines offered, it was essential that the cruising height should be upwards of 35,000 ft. double that of the then current airliners and that the weight of the structure and equipment should be as low as possible.

15. Throughout the design they relied upon well established methods, essentially the same as those in general use by aircraft designers. But they were going, outside the range of previous experience and they decided to make thorough tests of every part of the cabin structure. They had not only to prove to their own satisfaction that their design was basically sound, but also to investigate the effect, on the large variety of materials involved, of the extreme conditions which would be met. They gave special attention to the structural integrity of the pressure cabin. The difference -- This difference is sometimes referred to hereafter as ' P ' -- between the internal and external pressure (8.25 lb./sq. in) was about 50 per cent. greater than that in general use and there was in addition a larger difference between the internal and external temperatures.

16. Their policy of testing in the laboratory was not a novel one, nor indeed were they alone in their belief in it. They recognised, however, that testing alone is not sufficient. Every test is to some extent a compromise, since the conditions to be met in service can seldom be represented completely in the laboratory and in many cases are not accurately known. The result must therefore, be reviewed in the light of calculations based on fundamental knowledge, and on general experience and practice.

17. For the design of the basic structure of the cabin they adopted a multiple of the Working pressure difference, P. in excess of current requirements in any country. The British Civil Airworthiness Requirements (B.C.A.R.) called for a " proof " pressure of 1.33 P (under which the cabin must show no signs of permanent deformation), together with a "design" pressure of 2 P (at which the material may reach its ultimate strength). These requirements were the same as those of the International Civil Aviation Organisation (I.C.A.O.) and also those of this country for military transport aircraft. de Havillands used a design pressure of 2.5 P and tested the cabin to 2 P. Two test sections of the cabin were built. The front part, 26 ft. in length, extended from the nose nearly to the front spar of the wing, and included typical windows, hatches and door. The centre part, 24 ft. in length, extended from a few feet in front of the front spar to a few feet aft of the rear spar, covering the large cut-out containing the wine structure .

18. Their reasons for adopting these substantially higher figures were two. They believed, and this belief was shared by A.R.B. and other expert opinion, that a cabin which would survive undamaged a test to double its working pressure, 2 P. should not fail in service under the action of fatigues -- There is attached hereto as Appendix IV a note on the subject of fatigue in metals and its bearing on the design of engineering structures which has been prepared for my assistance by my Assessors. -- due to the pressurisation to working pressure, P, on each flight, and to other fluctuating loads to which it is subjected in operations.

Secondly, they considered that it would ensure a larger margin of safety against the possible failure of windows, doors, and hatches. These are contingencies which had been shown by experience to be a serious risk, for even if nothing worse happens, the resulting loss of pressure may be rapid.

19. So much importance did they attach to this latter consideration that they made many tests of window panes to very high pressures in addition, they applied pressures of between P and 2P some 30 times to the test section of the front part of the cabin together with a series of 2,000 pressurisations to rather over P. These tests were not intended as a test of the fatigue resisting properties of the structure, but rather as providing an assurance that the cabin would be satisfactory as a pressure vessel. But they undoubtedly contributed to de Havillands' confidence in the soundness of the cabin.

20. Simultaneously With the design and testing of the pressure cabin, all other parts of the structure were receiving treatment based on the same outlook -- design to at least the current requirements, coupled with exhaustive tests. The wing is of special interest, since it is here that requirements specifically directed to resistance to fatigue first became important. During the period 1949 o 1951 there had been growing among all aircraft designers and users a realisation that the life of the essential structure of an aircraft is not unlimited. The effects of atmospheric turbulence had produced unexpected and relatively early failure of the wings of certain transport aircraft. Gusts are most severe near the ground and in the tropics. Methods had been devised, and have since been improved and extended, for determining their frequency and intensity. In the light of this knowledge, repeated loading tests -- In which the appropriate load is applied and removed many times, simulating the effects of gusts, or any other cause of variation of load -- of the wings of transport aircraft became accepted as necessary. Tests of the Comet's wing were made in close co-operation with R.A.E.

21. Until about the middle of 1952 the likelihood that the fatigue resistance properties of a pressure cabin demanded further precautions, either in design or by test, than were provided by the current static strength requirements had not been realised. The matter first came to de Havillands' notice through Sir. Harper's association with the problem on Service (R.A.F.) transport aircraft, as a member of the Joint Airworthiness Committee (J.A.C.) of the Ministry of Supply. Draft Requirements (Paper 579, Oct., 1952) called for a static test to 2 P, a proof test to 1.33 P, together with repeated loading tests of 1.25 P applied 10,000 times.

22. At about the same time A.R.B. were reviewing the civil position. In due course they issued proposals in Paper No. 230 (19th June 1953) which called for the same static test to 2 P and proof test to 1.33 P but raised the number of applications of 1.25 P to 15,000. At the same time the paper suggested that certain structural parts such as riveted joints, door and window frames etc., might have to be designed to 3 P (on the ultimate strength of the material), in order to meet these requirements. It also stated that the figure of 15,000 was intended to cover the number of applications of P during the life of an aircraft, and that the test pressure of 1.25 P was intended to cover the phenomenon of "scatter" -- see Appendix IV -- in the fatigue strength of different cabins built to the same design.

23. The result of these developments was that in July, 1953 de Havillands reconsidered the position of the Comet's cabin. Up to that time no Comet had exceeded 2,500 hours flying say 800 pressurised flights. In order to satisfy themselves of its safety, and also to discover its probable safe working life, they carried out repeated loading tests of the test section of the fore part of the cabin, applying the working pressure P about 16,000 times. By September, 1953, this specimen had withstood 18.000 applications of P in addition to some 30 earlier applications of pressures between P and 2P.

24. These tests were ended by a failure of the skin in fatigue at the corner of a window, originating at a small defect in the skin. But the number of pressurisations sustained was so large that, in conjunction with the numerous other tests, it was regarded as establishing the safety of the Comet's cabin with an ample margin.

25. Meanwhile, on the 2nd May, 1953, **Comet G-ALYV had crashed** in a tropical storm of exceptional severity near Calcutta. An inquiry was directed by the Central Government of India and was held under Rule 75 of the Indian Aircraft Rules 1937. The Court reported on the 26th May, 1953, that the accident was caused by structural failure of the airframe during flight through a thundersquall. In the opinion of the Court the structural failure was due to overstressing which resulted front either :

* (i) Severe gusts encountered in the thundersquall, or
* (ii) Overcontrolling or loss of control by the pilot when flying through the thunderstorm.

Fatigue failure of the cabin was not then suspected as a cause and in my opinion the evidence adduced in the course of the present Inquiry affords no sufficient reason for doubting the conclusion of the Indian Court.

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PART III
THE ACCIDENT

26. Comet G-ALYP (sometimes hereinafter called Yoke Peter) left Ciampino Airport, Rome, at 09:31 hours on the 10th January, 1954, on a flight to London. After taking off the aircraft was in touch with Ciampino control tower by radio telephone and from time to time reported its position. These reports indicated that the flight was proceeding according to the B.O.A.C. flight plan and the last of them, which was received at 09:50 hours, said that the aircraft was over the Orbetello Beacon. The Captain of another B.0.A.C. aircraft, Argonaut G-ALHJ. gave evidence of communications which passed between him and Yoke Peter. The last such message received by the Argonaut began "George How Jig frown George Yoke Peter did you get my" and then broke off. The Captain of the Argonaut gave it as his opinion that the message was not merely interrupted by another aircraft but that transmission ceased after the word "my" and he estimated that the message was received by him at approximately 09:51 hours. Shortly after 10:00 hours the Ciampino Traffic Control Clerk heard a sound which he suggested might have been an unmodulated transmission from Yoke Peter.

27. The evidence of four witnesses from Elba as to things seen and heard by them on the 10th January suggests that Yoke Peter must have crashed into the sea at about 10:00 hours and it therefore appears that something happened to the aircraft with catastrophic suddenness which may have accounted for the interruption of the transmission of the last message to the Argonaut. It is also clear from the evidence of the Elba witnesses that part of Yoke Peter fell into the sea in flames.

28. The chart, which is Figure 1 of this Report, was prepared from all the information available and produced by a Navigating Officer from B.O.A.C. The estimated flight track of the aircraft and the position in which bodies and wreckage were found can be seen on the chart and the witness gave it as his opinion that at 09:51 hours the aircraft was probably approaching a height of 27 000 feet.

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PART IV
THE AIRCRAFT

29. Yoke Peter was designed and constructed by de Havillands and was of the type properly described as DH106 series 1, commonly known as the Comet 1. It was designed for high speed long distance, passenger and freight transport at high altitude and was propelled by four de Havilland Ghost 50 turbo-jet engines mounted within the wings, each engine developing a static thrust of 5,000 lb. The crew and passenger compartments were pressurised, so that when flying at 40,000 ft. a cabin pressure equivalent to atmospheric pressure at an altitude of 8,000 ft. was maintained. The cabin pressure was regulated to a maximum pressure difference between cabin and outside atmosphere of 8.25 lb/sq. in. and a safety valve was set to open at a pressure difference of 8.5 lb/sq. in. The dual flying control were power operated by hydraulic servo control units. The fuel for the engines was kerosene carried in a centre section tank made up of four inter-connected bag tanks and in four integral wing tanks. The authorised maximum all-up weight was 107,000 lb. Yoke Peter first flew on the 9th January, 1951, and was granted a Certificate of Registration No. R.3162/1 on the 18th September, 1951, in the name of B.O.A.C. as owner. A Certificate of Airworthiness No. A.3162, valid until the 12th March, 1953, was granted on the 22nd March, 1952. The aircraft was delivered to B.0.A.C. on the 13th March, 1952, and from that date was operated by B.O.A.C. On the 2nd May, 1952, having by then flown a total of 339 flying hours in experimental, test and training flights on behalf of de Havillands and B.O.A.C. it entered scheduled passenger service and was the first jet-propelled passenger aircraft carrying aircraft in the world to do so.

30. On the 11th March, 1953. the Certificate of Airworthiness was renewed for one year and was therefore, valid at the time of the accident. On the 11th November 1953, after the aircraft had flown 3,207 hours and following a repair to the passenger entrance door the fuselage was subjected to a proving test to 11 lb/sq. in. The airframe and engine log books show that the airframe and engines had been regularly inspected and maintained in accordance with the Approved Maintenance Schedules and that the number of flying hours of each engine since its last complete overhaul was well within the approved life.

31. In accordance with the Approved Maintenance Schedules a Check I inspection was completed on the 6th January, 1954, at London Airport and a Certificate of Maintenance, signed by properly licensed airframe and engine maintenance engineers and valid for 75 flying hours, was issued on the 7th January 1954. At the time of the accident the aircraft had flown only 40 hours since the issue of the Certificate of Maintenance and its total flying life was 3,681 hours. An Aircraft Radio Station Certificate of Serviceability was issued in respect of Yoke Peter on the 7th January, 1954, with the remark "no items unserviceable."

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PART V
THE CREW

32. Captain Alan Gibson, D.F.C., who was in command of Yoke Peter at the time of the accident was aged 31 years and 3 months. He held Airline Transport Pilot's Licence No. 22713, valid until the 24th February 1954, which entitled him to fly in command of Comet aircraft and he had a valid Instrument Rating.

Captain Gibson also held Flight Navigator' s Licence No. 1442 which was valid until the 19th February, 1954. He entered the employment of B.O.A.C. under contract in 1946 having previously been employed by B.O.A.C. on secondment from the Royal Air Force. While in the Royal Air Force Captain Gibson had a total flying experience of 1,348 hours of which 1.175 were flown in command. He had flown a total of 4,062 hours by day and 1,165 hours by night with B.O.A.C. and most of these were flown as first pilot. He had flown Comets for 84 hours by day and 48 hours by night as second pilot and for 79 hours by day and 80 hours by night as first pilot. During the six months preceding the accident he had flown 79 hours by day and 80 hours by night as first pilot of Comets and 47 hours by day and 31 hours by night under supervision.

33. While with B.O.A.C. Captain Gibson was concerned in an accident involving the forced landing of a Hermes aircraft in 1951 and was complimented by the Operations Manager for his conduct on that occasion. He was successful in both his flying checks during the period when he was flying Comets and l am satisfied that he was fully equipped to carry out his normal duties as a pilot and as a captain and to deal with emergencies.

34. The second pilot of Yoke Peter was First Officer William John Bury whose ace was 33 years and 10 months. He held Airline Transport Pilot's Licence No. 27251 valid until the 8th April, 1954, and a valid Instrument Rating. In addition he held Flight Navigator's Licence No. 2583 valid until the 9th October,

1954. He had flown a total of 1,917 hours in the Royal Air Force of which 1,735 were as first pilot, all in piston engined aircraft. With B.O.A.C. he had flown 2,355 hours by day and 643 by night as second pilot and 11 hours by day and 1 hour by night as first pilot and altogether had flown 153 hours by day and 109 by night in Comets, all as second pilot. I am satisfied that First Officer Bury was fully equipped to carry out his normal duties and to support his captain in emergencies.

35. The Engineer Officer was Mr. Francis Charles Macdonald who was aged 27 years and 11 months. Since joining B.O.A.C. on the 21st January, 1952, he had 439 hours flying as Engineer Officer in Hermes aircraft and 281 hours in Comets of which 225 hours were flown during the six months preceding the accident Mr. Macdonald's Flight Engineer's Licence was No. 428 and had expired on the 11th December, 1953. During its validity this licence included Comet aircraft. Had he applied to renew his licence he would have been required to give Log Book evidence of six hours flying as engineer-in-charge including six flights during the 12 months preceding the date of application and would have been required to pass a medical examination.

36. On joining B.O.A.C. Comet Fleet Mr. Macdonald obtained an endorsement to his licence which made it valid in respect of Comet aircraft and he completed a form giving details of his licence. In completing this form he stated, wrongly, though no doubt in good faith, that his licence was valid until the 24th April, 1954. He himself made no application to renew the licence before its expiry nor was he given any reminder to do so by B.0.A.C. This matter is further referred to in paragraph 147 of this Report.

37. I am satisfied that Mr. Macdonald's flying experience was sufficient to support an application for renewal of his licence but I have no evidence as to his medical fitness. However, I have no reason to suppose that he was in fact unfit at the time of the accident.

38. The Radio Officer was Mr. Luke Patrick Mc Mahon who was aged 32 years and 2 months. He held a First Class Flight Radio Telegraphy Operator's Licence No. 1235 which was valid until the 16th October, 1954, and had done 2,946 flying hours with B.O.A.C. in various aircraft before the 3rd October, 1952, and 629 hours in Comets thereafter. During the six months preceding the accident he had flown 207 hours in Comets. I am satisfied that he was a capable officer.

39. The other members of the crew were Steward Frank Leonard Saunders and Stewardess Jean Evelyn Clarke, both of whose services had at all times been entirely satisfactory.

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PART VI
THE PASSENGERS AND CARGO

40. Yoke Peter carried a total of 29 passengers, all of whom were killed in the accident. The cargo carried did not include any items which could have been relevant to the cause of the accident. The comparison between the amount of cargo known to have been carried and that shown in the Load Distribution and Trim Sheet showed a discrepancy of 27 kilograms in hold 2A. Moreover, no load was shown on the Load Distribution and Trim Sheet for hold 3, whereas there was evidence that 15 kilograms of baggage were placed in that hold. I am satisfied, however by the evidence of Mr. B. J. Folliard that these errors in the Load Distribution and Trim Sheet would have left the loading and trim of the aircraft well within the prescribed safe limits.

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PART VII
PRE FLIGHT INCIDENTS

41. The last three flights made by Yoke Peter prior to that which ended in disaster were from Karachi to Bahrein, Bahrein to Beirut and Beirut to Rome. During refuelling at Karachi a defect developed in the port wing tanks the Engineer Officer of Yoke Peter adopted a procedure known as "off-load" refuelling which is authorised for use in such an emergency. It involves holding the refuelling switch in the "off-load" position -- The normal purpose of this position is to enable the tanks to be emptied -- and releasing it when refuelling is complete. In fact the Engineer Officer did not release the switch in time and about five gallons of fuel escaped from the airvent on the under surface of the mainplane. There was no repetition of this incident at Bahrein but at Beirut, after the Engineer Officer had explained to the ground engineer, who was assisting him with the refuelling what had happened at Karachi, a further incident occurred. When the Engineer Officer returned to the port wine after inspecting the starboard tanks he noticed fuel emerging from the port air vent. The refuelling switch was in the neutral position from which fact, and from the fact that fuel was obviously entering the tank, he deduced that somebody, intending to put the switch to the "off-load" position, from which it should automatically have returned to neutral when released must have failed to do so and that the switch, instead of returning to neutral had remained half open. He attempted to close the switch by moving it to the full "off-load" position and releasing it but this had no effect and the flow of fuel was eventually stopped by shutting down the bowser.

42. As a result of this incident the actuator was removed and as no replacement was available it was tested, found satisfactory and refitted. These incidents were reported by the Engineer Officer to Mr. Macdonald when the aircraft was handed over at Rome. The practice of "off-load" refuelling is further referred to in paragraph 111 of this Report.

43. Two other items were also unserviceable during the flights from Karachi to Rome. These were the No. 1 engine hydraulic flow warning light and the automatic temperature control selector. The former device is designed to draw the attention of the pilot to a possible failure of the engine-operated hydraulic pump. On this occasion, when the flow warning light appeared faulty, the operation of the pump was tested by other means and found satisfactory. The automatic temperature control selector is intended to control automatically the temperature of the crew and passenger compartments. When it was found to be faulty the temperature was controlled manually. I am satisfied that neither of these faults, both of which were drawn to the attention of Mr. Macdonald, can have endangered the aircraft in any way.

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PART VIII
WEATHER CONDITIONS AT THE TIME OF THE ACCIDENT

44. From take-off at Rome at 09:31 hours on the 10th January, 1954, to the time of the accident at approximately 27,000 ft. near Elba Comet G-ALYP experienced essentially good weather conditions. The climb was made through only thin and broken layers of cloud with no rain and with negligible icing conditions. At the time and position of the accident it is probable that some turbulence in clear air may have existed due to the proximity of a narrow high velocity wind current called a

" jet stream ". Such turbulence, if encountered, would be less than aircraft frequently experience in turbulent cloud conditions. It can, therefore, be assumed that the state of the weather was not a contributory cause of the accident.

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PART IX
ACTION TAKEN AFTER THE ACCIDENT AND PRIOR TO THE ACCIDENT TO COMET G-ALYY

(a) Local salvage and medical investigation

45. At 11:50 hours on the 10th January, 1954 the Harbour Authority at Portoferraio in the Isle of Elba was informed of the occurrence of the accident, being told that an aircraft had exploded in the air and crashed in flames into the sea south of Cape Calamita roughly in the direction of the island of Monte Cristo. With commendable promptness Lieutenant-Colonel Lombardi, the Officer Commanding the Harbour Authority of Portoferraio, despatched all available craft to the scene of the accident with a doctor and nurse on board and he himself put to sea after he had made all the necessary arrangements. In these salvage operations 15 bodies, various mail bags and some aircraft wreckage and personal effects were recovered. The ships had been assisted in their search by the collaboration of aircraft. On the two following days the search was continued. No more bodies were found but various pieces of wreckage and articles were recovered.

46. Under Lieutenant-Colonel Lombardi's directions the bodies were taken to the local cemetery at Porto Azzurro and devoutly placed in the chapel there. At the request of the examining magistrate at Portoferraio an examination of the bodies recovered was carried out by Professor Antonio Fornari who was acting under the direction of Dr. Folco Domenici, Director of the Institute of Forensic Medicine in the University of Pisa. Professor Fornari gave evidence before me and he put in a report which had been prepared by him and Dr. Domenici. The substance of their report is to be found in the conclusions at p. 60 of the translation of the report and may be summarised as follows :

(1) Death was caused by impact against parts of the aircraft.

(2) There was serious lesions resulting from explosive decompression and deceleration.

(3) The probable point of impact between the bodies and the structure of the aircraft was the forepart of the fuselage, perhaps in the vicinity of that part of the fuselage which lies above the engines.

(4) There were burns on the bodies of all the victims but they presented post-mortem characteristics from which the inference was that the burns took place after death.

(b) Action taken by the Ministry of Transport and Civil Aviation

47. News of the accident was received by the Accidents Investigation Branch of the Ministry of Transport and Civil Aviation at 12:00 hours on the 10th January, 1954, and both the Senior Inspector of Accidents, Mr. Nelson, and the Senior Investigating Officer, Mr. Morris. left for Italy that evening.

48. On arrival Mr. Nelson got into touch with the Commission which had been convened by the Italian aviation authorities and went with the Commission to Elba. Some days later it was agreed that the responsibility for the investigation of the accident should be handed over to the Accidents Investigation Branch of the British Ministry of Transport and Civil Aviation but Colonel Miniero and Signor Roveri, who have attended this Inquiry, were appointed accredited representatives to the British investigators and gave them every possible assistance. The Minister of Transport and Civil Aviation was also in touch with the Admiralty and it was arranged that the Commander-in-Chief Mediterranean, Admiral Earl Mountbatten, would cause an intensive search to be made for the wreckage. The Chief Inspector of Accidents, in accordance with normal practice, arranged for the wreckage recovered to be sent to and examined at R.A.E. Mr. Nelson and Mr. Morris remained in Elba, examined the Wreckage recovered and arranged for its transport back from Elba to the mainland and thence to Rome, whence it was flown direct to the United Kingdom, but certain very large pieces had to be sent by sea.

(c) Naval search for wreckage

49. Commander Forsberg was placed in charge of the operations. Special vessels, H.M.S. Barhill and H.M.S. Sea Salvor, were fitted up to carry 200 tons of heavy moving gear. An observation chamber, television gear, all toothed grab and other equipment were obtained from England and the necessary modifications to the vessels were made in the dockyard at Malta. This was all done in under a fortnight and the two vessels and H.M.S. Wakeful, in which the television equipment was installed, arrived off Elba on the 25th January, 1954.

50. The search was prosecuted at depths varying between 70 fathoms and 100 fathoms. It is noteworthy that this was the first occasion on which television equipment had been used for this purpose. The first date on which anything was located on the bottom by television was the 12th February. 1954. I need not recount in detail the history of the search. Suffice is to say that by the 23rd March, 1954, only the floating wreckage, the pressure dome, and parts of the rear fuselage and the engines and wing centre section had been recovered and that thereafter the search continued until by the end of August, 1954, about 70 per cent. of the empty weight of the aircraft, made up of about 70 per cent. of the structure, 80 per cent. of the power plant and 50 per cent of the equipment, had been recovered. I have included as Appendix V a table, which was put in evidence, showing the dates of recovery of the main portions of the wreckage and the dates on which they reached Farnborough. Diagrams (Figures 2 and 3) give a striking impression of the amount of material which was ultimately recovered, though they relate only to the external structure. Figure 4 is a photograph showing the reconstruction of the fuselage and tail unit from the wreckage and Figure 5 is a photograph showing the reconstruction of the front fuselage.

51. The amount of wreckage recovered was greatly in excess of the expectations entertained in March, 1954, when the decision to allow the Comets to fly again was taken. A remarkable fact was the small amount of damage which had been caused to the structure either by immersion in sea water or in the process of salvage.

(d) The Abell Committee

52. Immediately on receiving news of the accident B.O.A.C. had decided to suspend their normal Comet passenger services, for the purpose of carrying, out a detailed examination of the aircraft of the Comet operational fleet in collaboration with A.R.B. and de Havillands and to this end the Chairman of

B.O.A.C. had called a meeting at London Airport for the 11th January, 1954, which was attended by representatives of B.O.A.C., the Accidents Branch of the Ministry of Transport and Civil Aviation, de Havillands, the de Havilland Engine Company Limited and A.R.B. As a result of that meetings a committee under the chairmanship of Mr C. Abell, the Deputy Operations Director (Engineering) of B.O.A.C., and composed of representatives of A.R.B., B.O.A.C. and de Havillands, was appointed to consider what modifications were necessary before B.O.A.C. could properly seek the agreement of the Minister of Transport and Civil Aviation to the resumption of passenger services by Comet aircraft. The Committee proceeded to consider what possible features or combination of features might have caused the accident. According to the evidence of Mr. Abell. they came to the view that **possible main causes of the accident were as follows :**

(a) Flutter of control surfaces. This is a term used to describe a type of vibration of a surface, which may be dangerous and may arise from one or more of several causes such as the failure of some part of the mechanism connecting the control surface to the hydraulic power unit which operates it in flight, or to the development of play or backlash in the mechanism. It was decided to make a special inspection of the whole of the mechanism and of the control surfaces and mass-balance arms.

(b) Primary structural failure. They considered, in particular, the possible effects of gusts, in causing abnormally high loads, and surveyed all parts of the structure of which there was any suspicion in the light of previous experience.

(c) Flying controls. For each hydraulic power unit operating a control surface there is an output circuit connected to the control surface, and an input circuit connected to the pilot's control in the cabin. Many possible sources of malfunctioning both of the hydraulic power units themselves and of these mechanical circuits were examined and special investigations initiated.

(d) Fatigue of the structure. They had in mind more particularly fatigue of the wing, because about the time of the Elba accident cracks had appeared near the edge of the wheel-wells, on the under-surface of the wing of the first prototype which was under test at R.A.E., after the equivalent of about 6,700 flying hours. They re-examined also one or two other parts of the structure at which they felt fatigue effects might be appearing.

(e) Explosive decompression of the pressure cabin. They had no reason to suspect the primary structure of the cabin itself. They reviewed the records of damage by, for example, the steps used to load the aircraft, and the methods of repairing such damage by schemes approved by de Havillands. Their main concern, however, was the window panels, where they thought it necessary to consider possible defects which might cause weakness not revealed in the tests made during design at de Havillands.

(f) Engine installation. Their main preoccupation here was with the possibility of fire and investigations were made at a number of points in order to remove every cause of possible fire risk which they could imagine.

53. As a result of the inspections and tests which followed the meetings of the Committee, a large number of modifications were made both to the power plants and to other parts mentioned above. At the conclusion of their work the Committee still regarded fire as the most likely cause of the accident. But one modification deserves special mention since it shows the care which was taken to avoid the possibly serious consequences of failure of a turbine blade. although there existed no evidence of such a failure in all previous experience.

The only recommendation specifically directed to fatigue related to the wing as mentioned above. One modification and two special inspections were called for. Mr. Abell said that the possibility of fatigue in the wing structure due to gusts was believed to be much more likely than fatigue in the pressure cabin since this is subject to much less frequent chances of load. At this stage neither Mr. Bishop nor Mr. Harper of de Havillands suspected that the failure of the cabin structure by fatigue or otherwise was a primary cause of the accident. They still regarded the 18,000 repeated loadings as removing any doubt about the fatigue life of the cabin.

(e) Resumption of Comet services

54. On the 17th February, 1954, Mr Abell forwarded to the Operations Director of B.O.A.C. a report and papers showing in detail all the inspections, investigations, modifications and other work which had been carried out since the Comet aircraft had been temporarily removed from service by B.O.A.C. on 11th January, 1954. On the 19th February the Chairman of B.O.A.C. forwarded the above-mentioned report and papers to the Minister of Transport and Civil Aviation stating in the course of his letter that, on the assumption that no further indication of the cause of the accident emerged prior to the completion of the inspection and modification work, B.O.A.C. considered that all such steps as were possible before putting the aircraft back into passenger service should have been taken.

55. The position was also considered by A.R.B. On the 4th April Lord Brabazon wrote to the Minister saying :

"*Although no definite reason for the accident has been established, modifications are being embodied to cover every possibility that imagination has suggested as a likely cause of the disaster. When these modifications are completed and have* *been satisfactorily flight tested, the Board sees no reason why passenger services should not be resumed.*'"

56. In the meantime the Minister of Transport and Civil Aviation, who had not revoked the Certificate of Airworthiness of the Comet fleet had asked A.S.B. for advice on the resumption of the Comet passenger services. On the 5th March Air Chief Marshal Sir Frederick Bowhill, the Chairman of A.S.B., minuted the Minister as follows :

" *2. The Board has considered all the available information resulting from recent investigations and has noted the nature and extent of the modifications planned as a result. It realises that no cause has yet been found that would satisfactorily account for the Elba disaster, and whilst the Calcutta disaster is completely accounted for if the aircraft is supposed to have encountered a gust of very great severity (which would have broken any other aircraft) we cannot eliminate that the accident might have been due to some other cause which was possibly common to both disasters. Nevertheless, the Board realises that everything humanly possible has been done to ensure that the desired standard of safety shall be maintained. This being so, the Board sees no justification for imposing special restrictions on Comet aircraft.*

3. The Board therefore recommends that Comet aircraft should return to normal operational use after all the current modifications have been incorporated and the aircraft have been flight tested."

57. Acting on this advice the Minister gave permission for flights to be resumed and the first Comet aircraft to resume passenger service took the air on the 23rd March, 1954.

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PART X
THE ACCIDENT TO G-ALYY

58. On the 8th April, 1954, Comet aircraft G-ALYY, which was on charter to South African Airways, crashed near Naples while on a flight from Rome to Cairo. I am making a separate Report on that accident. It is sufficient for the purpose of this Report to record that the accident occurred at approximately the same height and after approximately the same lapse of time after departure from Rome as in the case of Yoke Peter. On receiving news of the accident B.O.A.C. decided immediately to suspend all Comet services until more was known and on the 12th April, 1954, the Parliamentary Secretary to the Ministry of Transport and Civil Aviation informed the House of Commons that the Minister, after consulting A.R.B. and A.S.B. and discussing the matter with the Chairman of A.R.B., had withdrawn the United Kingdom Certificate of Airworthiness from all Comet aircraft.

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PART XI
INVESTIGATION OF THE ACCIDENT TO G-ALYP AND G-ALYY

(a) Investigation by R.A.E.

59. The loss of Yoke Peter and Yoke Yoke presented a problem of unprecedented difficulty, the solution of which was clearly of the greatest importance to the future, not only of the Comet, but also of Civil Air Transport in this country and, indeed, throughout the world. Accordingly, shortly after the Naples accident, the Minister of Supply instructed Sir Arnold Hall the Director of R.A.E. to undertake at R.A.E. a complete investigation of the whole problem presented by the accidents and to use all the resources at the disposal of the Establishment. This provided an opportunity of showing what can be done by a close collaboration between a private firm and R.A.E. with the unique facilities at its disposal. It will be seen hereafter that full use was made of that opportunity by R.A.E. and de Havillands.

60. R.A.E. made a complete review of the conclusions which had been reached by the Abell Committee, and particularly of the implications arising from the fact that there had been two accidents in what appeared to be similar conditions, each occurring at about the time when the aircraft was nearing the top of its climb. They thought it necessary to satisfy themselves about the structural integrity of the aircraft, in particular of the cabin and the tail and to consider in more detail possible sources of explosion and loss of control. They also considered that flight tests would be required in order to investigate the possibility of flutter of control surfaces (see para. 52 (a)). It soon became evident that it was probable that more wreckage would be recovered than had at first been expected. The wing centre section was received on the 5th April (the engines had been recovered and sent by air to de Havillands on the 21st March), and the front part of the cabin arrived on the 15th April. But at the time when their attention became directed to fatigue of the pressure cabin they were influenced chiefly by the apparent similarity of the circumstances of the two accidents, and by the fact that the modifications carried out after Elba seemed to rule out many of the other possible causes.

61. On the 18th April Sir Arnold Hall decided that a repeated loading test of the whole cabin ought to be made. He said that he regarded this as one of a number of lines of inquiry which had to be pursued and that he felt it to be necessary to study every possible cause in detail.

62. The normal method of testing pressure cabins up to the point when they fail under pressure is similar to that used for vessels such as boilers. They are filled with water, and more water is pumped in until the desired difference between the internal and external pressure is reached. This method has two advantages over the use of air. Water is relatively incompressible, so that failure when it occurs produces only a mild form of explosion. The origin of the failure can be determined and the structure can generally be repaired and tested again. If air were used instead of water, the failure would be catastrophic (equivalent in the case of the Comet's cabin to the explosion of a 500 lb bomb). Such a test would be dangerous, the cabin would be destroyed, and the evidence of the origin of the failure should almost certainly be lost. It is however necessary to prevent unrepresentative loading of the cabin structure by the weight of the water. This is ensured in practice by immersing the whole cabin in a tank, and filling the tank and the cabin simultaneously with water. Pressure in the cabin is then raised by pumping in water from the space outside it. Cycles of loading, to the same or different levels of pressure as desired are applied by a suitable routine of pumping.

63. By a remarkable effort, to which de Havillands and the firms who built the tank (see Figure 6) contributed to the full and by the use of all the resources of R.A.E., repeated loading tests began early in June on aircraft G-ALYU (Yoke Uncle). The object of the tests was to simulate the conditions of a series of pressurised flights. To this end the cabin and wings were repeatedly subjected to a cycle of loading as far as possible equivalent to that to which they would be subjected in the period between take-off and landings. In addition to one application of cabin pressure, fluctuating loads were applied to the wings in bending to reproduce the effect of such gusts as might be expected in normal conditions, although the contribution of gust loads to the stresses in the cabin structure, compared with that made by the internal pressure, was in general small. Moreover, the programme of tests included, at intervals of approximately 1,000 " flights " a proving test in which the pressure was raised to 1.3 P (11 lb./sq. in.). It must be understood that there are other sources of fluctuation, load and. therefore, of fatigue to which no precise value can be attached. No attempt was made to represent these in the test. Examples are vibration due to irregular airflow, vibration due to the engines and the jet efflux and fluctuating loads occurring during take-off and landing.

64. Yoke Uncle had made 1.230 pressurised flights before the test and after the equivalent of a further 1.830 such flights, making a total of 3,060, the cabin structure failed, the starting point of the failure being the corner of one of the cabin windows (see Figures 7 and 8). The fact that the failure occurred during one of the proving tests to 11 lb/sq. in. is not thought significant since the crack would have spread in very much the same way after a few more applications of the working pressure. Examination of the failure provided evidence of fatigue at the point where the crack would be most likely to start, namely near the edge of the skin at the corner of the window (see Figures 9 and 10). This was revealed by the discoloration due to algae in the water which made it clear that the crack had endured several pressurisations before it spread catastrophically. It is important to note here that the sources of fatigue mentioned above, which were not reproduced in the tank test, all tend to increase the burden of fatigue and that, therefore, the life of a fuselage deduced from the test is longer than would be expected in service. It is not possible to do more than estimate the magnitude of this effect but it was suggested by Dr. Walker that a "life" of 3,060 flights in the test might be equivalent to about 2.500 in practice.

65. It is convenient to note here that Comet G-ANAV, which had been sent to R.A.E. to undergo flight tests (unpressurised) on a number of matters which could only be explored in flight, made its first flight on the 23rd June. A large amount of miscellaneous wreckage was arriving at R.A.E. during the whole of this period and was being stored out and examined by the Accidents Investigation Section under Mr. Ripley.

66. The failure of the cabin of Yoke Uncle marks the point at which the character of the investigation changed to one in which the problem of fatigue in the structure of the cabin began to dominate all others, although many possible sources of trouble were continually investigated during the whole of the summer. In the main their results were negative so far as the accidents were concerned though they revealed points which needed and will receive attention. The inference suggested by the tank test, that the primary failure of Yoke Peter was the bursting of the pressure cabin, was confirmed by a close examination of the wreckage and by the experiments referred to in the next following paragraphs of this Report.

67. The character of the damage caused to the structure was such that it became possible to determine with a high degree of probability the manner in which the various fragments struck the sea, mainly because of the very high local pressures produced by the impact with the sea. Moreover, it rapidly became clear that the intense fire which had existed was confined virtually to the centre part of the wing, leaving the outer parts of the wing and the front and rear parts of the cabin untouched. These considerations led to the conclusion that it was probable that the main part of the aircraft fell into the sea in a small number of relatively large pieces, one of which was on fire (see Figure 11). Most of these pieces had fallen in a surprisingly small area. This conclusion was in agreement with the evidence of the farmer at Elbas who saw fragments, one of which was on fire, falling into the sea. This led to a line of experiment which produced remarkable results. Models were made of the Comet in light wood, suitably ballasted, and projected in the air at the appropriate speed. They were released from a kite balloon at a height above the ground corresponding to that at which it was believed the Comet structure failed, reduced in proportion to the scale of the model. The model was so constructed that it would break at the point where the failure of the cabin was suspected, namely in the neighbourhood of the wing. The outer parts of the wing (only one of which had been recovered), were also separated from the centre part. The descent of the fragments was photographed, and it was found that they fell in a manner which agreed faith the deductions which had been made from the evidence mentioned above.

68. Simultaneously with this work, further experiments in the water tank were made on the cabin of Yoke Uncle, after the first failure had been repaired by de Havillands. Until then, owing to the need to discover whether the cabin had, against all previous belief, a relatively short life under repeated loading, no attempt had been made to measure the stress in the material of the skin at points where it might be expected to be higher than the average. One reason for this omission was that the number of places coming within this description is large, and it would have taken a long time to install the necessary strain gauges and other associated equipment. But it now seemed highly probable that the stress near the corners of the windows was higher than had been believed by the designers, and the strain gauges were therefore fixed to the surface of the skin, at various positions near the corners of typical windows, including the windows corresponding to the one which had failed but on the other side of the cabin.

69. A discussion of the evidence bearing on the reliability of the estimates of the stress at the edge of the window will be found in paragraphs 118 to 129. It is sufficient here to say that I am satisfied that the highest stress in the skin, at the edge near the corner of the window of Yoke Uncle, was probably over

40,000 lb./sq. in. when the pressure difference was 8.25 lb. / sq. in. and that the general level of the stress in the skin in these regions was significantly higher than had been previously believed. In the light of known properties of the aluminium alloy D.T.D. 546 or 746 of which the skin was made and in accordance with the advice I received front my Assessors, I accept the conclusion of R.A.E. that this is a sufficient explanation of the failure of the cabin skin of Yoke Uncle by fatigue after a small number, namely, 3.060 cycles of pressurisation.

70. In considering the possible bearing of this result on the accidents at Elba and Naples, it is necessary to recognise that there are inevitable differences between individual aircraft structures built to the same drawings. The nature and extent of these depend on a number of factors such as variations in the thickness of metal sheet of nominally the same gauge, and local regions of high stress due to the methods employed in joining the various parts, such as rivets, bolts, etc. If a number of such structures are tested under repeated loading, there will be appreciable differences between the number of cycles of application of given loading before failure occurs. Experience suggests that there will be a variation of at least 9 to 1 in the number of cycles necessary to produce failure when the general level of stress is high, and the number of cycles undergone before failure therefore low. If a large number of specimens could be tested, it would undoubtedly be found that the weak and the strong were relatively few in number, and that the majority would be more or less evenly distributed round a mean value. But it is impossible from a single test to say where, in the total range to be expected from general experience, a particular specimen lies.

71. At the time of the Elba accident Yoke Peter had made 1,290 pressurised flights and at the time of the Naples accident Yoke Yoke had made 900 pressurised flights. Sir Arnold Hall said in evidence that in the light of the experiment on Yoke Uncle, and of the measurements and calculation of stress referred to above he considered that the cabin of Yoke Peter had reached a point in its life when it could be said to be in danger of failure from fatigue, and that the Cabin of Yoke Yoke would similarly be in danger. Dr. Walker said that he did not regard the picture presented by the three failures (on the assumption that these were all due to the same fundamental cause) as surprising, since the three results taken together are consistent with general experience of the strength under repeated loading of a number of nominally identical structures, in which the stress level is high. They lie within a range of just over 3 to 1, whereas experience suggests a total range of at least 9 to 1.

72. At this stage in R.A.E. 's attack on the problem, it seemed unlikely that any more wreckage would be recovered which would throw light on the problem which was now obviously the chief one. But after a further review of the whole of the circumstances of the flight of the aircraft and the distribution of the wreckage on the sea bed, R.A.E. reached the conclusion that search in a wider area was justified. Whatever the cause of the bursting, it seemed probable that the disruption of the aircraft would have resulted in some relatively large pieces of the structure being blown clear. These might well have fallen some distance away from the main pieces of wreckage, all of which, as mentioned above, were found within a remarkably small area. It was therefore decided to make a search of an area some miles long in the sea below the path of the aircraft working towards Rome from the area where the main items were recovered. As the depth of the sea increased rapidly in this direction, the only practicable method was trawling.

73. As a result of the new search R.A.E. received a piece of cabin skin, which had been found by an Italian fishing boat. It was identified as coming from the centre of the top of the cabin approximately over the front spar of the wing (see Figure 12). It contained the two windows in which lie the aerials which are part of the A.D.F. (Automatic Direction Finding) equipment. At the same time R.A.E. received a part of the aileron of the port wing (see Figures 13 and 16) and a part of the "boundary layer fence" fitted to the leading edge of the port wing not far from the tip (see Figures 14 and 16).

74. The latter parts provided important evidence about the bursting of the cabin. There were marks on them which were identified as made by pieces from the cabin itself. Taken together with the paint mark on the leading edge of the centre section not far from where the outer wing broke off, which was identified as caused by the piece of the cabin wall containing the first window (escape hatch) (see Figures 15, 16 and 12), they established that the cabin burst catastrophically in the neighbourhood of the front spar of the wing when the aircraft was flying substantially normally.

75. By examination of the piece containing the A.D.F. windows and the adjacent pieces (see Figure 12) it was established that it was here that the first fracture of the cabin structure of Yoke Peter occurred. In general terms, it took the form of a split along the top centre of the cabin along a line approximately fore and aft passing through corners of the windows as shown in Figure 17. The direction in which the fracture spread was determined by examination of the lines of separation of the material.

76. A development drawing of the wreckage recovered from the part of the cabin over the wing spar is shown in Figure 18. Apart from the area on top of the cabin around the A.D.F. windows, which is shown cross-hatched, the remainder was recovered with, and in many cases remained attached to, either the front fuselage, the wing centre section, or the rear fuselage. These three groups are distinguished by different hatchings, as indicated in the diagram. In the light of all this evidence, I accept R.A.E. 's conclusion that the first fracture of the cabin occurred near the rear A.D.F. window and spread fore and aft from it.

77. I do not consider it possible to establish with certainty the point at which the disruption of the skin first began. But I consider that it is probable that it started near the starboard aft corner of the rear A.D.F. window, at a point where examination by experts showed that fatigue had existed, at the edge of the countersunk hole through which a bolt passed (see Figure 19)

78. The only alternative point suggested was the opposite (port forward) corner of the same window. Here the fracture passed through a small crack in the reinforcing plate, about 0.2 in. long, made accidentally during the build, of the aircraft. This had been dealt with by de Havillands in accordance with their procedure for dealing with any departure from the strict requirements of their drawings which might appear during the manufacture of their aircraft. All such matters were required to be reported to the Technical Office, and each was dealt with as a special case by a qualified expert. In this case approval was given to the use of the normal process of "locating" small cracks in the skin of an aircraft by drilling small holes at their ends. Advised by my Assessors I see no reason to doubt that this would have been a satisfactory method of dealing with the crack in question had it not been for the fact that the stress in this region was relatively high. It was suggested that such a crack might be a possible place of origin of fatigue but no witness was able to identify any evidence of fatigue at the material point.

79. It is my opinion that the fundamental cause of the failure of the cabin structure was that there existed around the corners of the windows and other cut-outs a level of stress higher than is consistent with a long life of the cabin, bearing in mind the unavoidable existence of points, within the areas of generally high stress, at which it will be still further raised by relatively local influences, such as the countersunk hole near the starboard rear corner, and the small crack with its "locating" hole near the port forward corner. I find it impossible to say definitely, on any evidence before me, which of these operated first. But, since the existence of fatigue near the bolt hole is established, I think it the more probable.

(b) Investigation by the de Havilland Engine Company Limited

80. The R.A.E. investigation did not deal with the engines. The history of their recovery and investigation is as follows.

81. The centre section of the wing of Yoke Peter was recovered from the sea on the 15th March. It was severely damaged by fire and by impact with the water. It contained the four Ghost engines substantially intact with the exception that the turbine disc of No. 2 engine (port inner) was missing. The shaft on which it had been mounted had broken near the hub to which it was bolted and it had escaped through a large gash in the exhaust cone. The disc has not been recovered.

82. The engines were removed and examined superficially by an engineer from de Havillands Engine Company Limited. They were then sent by air to that company's works where they arrived on the 21st March and were dismantled and examined in detail.

83. Dr. Moult, Chief Engineer of the de Havilland Engine Company Limited, said in evidence that there were no signs consistent with seizure of any engine, or of any excessive internal heat, or of any failure having occurred before the break-up of the aircraft. The extensive fire damage was all external to the engines. The four compressor impellers were intact on their shafts.

84. The turbine discs from Nos. 1, 3 and 4 engines showed no signs of failure. No blades were missing from them. In No. 2 engine, there was no evidence of penetration of the shroud ring surrounding the turbine, either by a blade or by the complete disc. There was no evidence of failure of any blade in any of the engines.

85. Examination of the hubs to which the turbine discs of Nos. 1, 3 and 4 engines were bolted showed that all were on the point of failing. Cracks were found in the same regions as those which had resulted in the fracture of No. 2 engine, which led to the loss of the disc.

86. The remarkable similarity of the damage to the turbine shafts of all four engines pointed to a common cause external to the engines, and further examination showed that the most probable cause was a sudden and very rapid rotation of the whole wing about a transverse axis, nose downwards, while the engines were still running normally. Such a rotation, being about an axis at right angles to the engine shafts, would produce gyroscopic couples tending to bend the shafts in a sideways direction, that is, in the plane of the wing. Since the clearances between the discs and the stationary parts surrounding them are small, signs of rubbing would be expected in definite regions. Examination showed such signs in each engine.

87. From this evidence the conclusion was reached that the engines had run, though only for a short time, possibly a few hundred revolutions after a sudden nose-down rotation of the wing and had not stopped suddenly. Further examination showed other evidence consistent with this, namely the absence of any deformation in the splines on the turbine shafts. This also suggested that by the time the whole of the centre section, including the engines, hit the surface of the sea, the engines were no lancer rotating.

88. The whole of the remaining extensive damage to the engines was considered to be due to impact with the surface of the sea. It was in the main confined to the upper parts of the engines, and was therefore consistent with the deductions from the examination of the centre section of the wing itself, which showed everywhere evidence of the wing having hit the sea upside down.

89. In order to investigate the conditions which were now thought to have caused the failure of the turbine hubs, tests were made on a Ghost engine supported in a framework which was pivoted about a horizontal axis some distance above the engine, so that it could swing in a vertical plane, like a pendulum. The engine was run at normal speed, and was pulled sideways, thus raising it from its lowest position. When released, it accelerated under the combined influence of its weight and the thrust from the jet. The rate of rotation round the transverse axis could be varied by releasing it from different heights. It was found that when this reached a value of nearly 180∞ a second (corresponding to the centre section of the wing turning upside down in about one second) the turbine disc hub broke and the engine slowed down and stopped without any further substantial damage. Examination showed the same type of failure and symptoms, as were found on the four engines of Yoke Peter.

90. The examination of the engines, combined with the striking evidence of this experiment, confirmed de Havillands in the view that no part of the engines was in any way the cause of the failure of the aircraft. Dr Moult said that in their previous experience of Ghost engines of the same type as those used in the Comet, they had had no records of any blade failures. The modifications made to the aircraft as a result of the Abell

Committee's discussions, consisting of fitting high tensile steel plate round certain parts of the engines in the plane of the turbine discs, was regarded by him as possibly a wise precaution, in view of the need to guard against every source of trouble which could be imagined. At the time it was put into effect, with the other modifications decided by the Abell Committee, the engines from Yoke Peter had not been examined.

91. In the light of all this evidence and these considerations, I accept Dr. Moult's conclusion that there was no failure of any part of any engine which could have been the cause of the failure of Yoke Peter. The fire which damaged the engines externally was in my opinion subsequent to and not a cause of the disintegration of the aircraft.

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PART XII
THE R.A.E. REPORT

92. The Report (which was part of the evidence before the Court) is divided into 12 parts. The first part contains an outline of the investigation and states the opinion R.A.E. formed as to the cause of the accident. I have included the first part which is intelligible without reference to the other parts, as an appendix to this Report (Appendix VI). Para. 4 thereof which states the opinion of R.A.E. is in the following terms:_

"we have formed the opinion that the accident at Elba was caused by structural failure of the pressure cabin, brought about by fatigue. We reach this opinion for the following reasons:_

* **(i)** The low fatigue resistance of the cabin has been

demonstrated by the test described in Part 3, and the test result is interpretable as meaning that there was, at the age of the Elba aeroplanes a definite risk of fatigue failure occurring (Part 3).
* **(ii)** The cabin was the first part of the aeroplane to fail in the Elba accident (Part 2).
* **(iii)** The wreckage indicates that the failure in the cabin was of the same basic type as that produced in the fatigue test (Parts 2 and 3).
* **(iv)** This explanation seems to us to be consistent with all the circumstantial evidence.
* **(v)** The only other defects found in the aeroplane (listed in Section 3) were not concerned at Elba. as demonstrated by the wreckage.

Owing to the absence of wreckage, we are unable to form a definite opinion on the cause of the accident near Naples, but we draw attention to the fact that the explanation offered above for the accident at Elba appears to be applicable to that at Naples."

It should be added that the medical evidence as to the state of the bodies recovered was consistent with the conclusion thus reached.

93. The "other defects" mentioned in subpara. (v) quoted above are:_

* **(a)** relatively low resistance of the wing to fatigue;
* **(b)** possibility of fuel from the fuel tank venting system entering the trailing edge area of the wing near the jet pipe shrouds;
* **(c)** risk of internal damage during refuelling to the outer wing tanks under conditions which, though abnormal, may sometimes have occurred in practice.

94. I shall return to these defects after I have stated my opinion on the major conclusion of the Report.

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PART XIII
THE COURT'S CONCLUSIONS AS TO THE CAUSE OF THE ACCIDENT

(a) The main finding in the R.A.E. Report

95. The opinions expressed in the Report were supported by the evidence of Sir Arnold Hall, Dr. Walker and Mr. Ripley. Their conclusions were accepted by de Havilland and B.O.A.C. All parties appearing at the Inquiry paid a warm, and in my opinion well-deserved, tribute to the Report and to all who had co-operated in the work done at R.A.E. As I have already indicated and for the reasons I have given I have accepted the main conclusion of the Report that the cause of the accident to Yoke Peter was the structural failure of the pressure cabin brought about by fatigue.

(b) The alternative suggestion made by Mr. B. Jablonsky

96. The only rival Suggestion was made by Mr. Jablonsky. His experience of structural problems in aeronautics has been concerned mainly with propellers having blades of highly compressed wood. He is, therefore, familiar with adhesives, and with the problems which have to be overcome in using them to make components.

97. In the construction of the Comet wide use is made of a metal-to-metal adhesive known as Redux, mainly for the purpose of attaching members, generally known as "stringers", to the skin both of the wing and of the cabin. In the cabin there are about forty stringers more or less evenly spaced around the circumference and running longitudinally. They are not structurally continuous from end to end, the largest uninterrupted length being about 25 ft. de Havillands were pioneers in using Redux for such purposes in aircraft structures, and have had long experience of it. It is in effect an alternative to the conventional riveting.

98. Mr. Jablonsky's argument proceeded on the following lines:_

* **(a)** The skin of the cabin is exposed under service conditions to a large variation in temperature. He suggested a range of 80∞C on the around in the tropics to -55∞C at about 40.000 ft. The rate of climb of the Comet is fairly high and the temperature of the skin might change over this range in about 30 minutes. The stringers, however. although inside the skin, are outside the insulating lining of the cabin and therefore not exposed to the full temperature of the warm cabin air. His argument contemplated a difference in temperature between skin and stringer of as much as 60∞ or 70∞C. This would have the result that the skin would contract relative to the stringer in the direction of the cabin's length. The adhesive would therefore, be subjected to a shear stress which might be sufficient to cause it to fail.
* **(b)** Even if this did not cause the adhesive to fail statically (that is on the first occasion when such a difference of temperature between the skin and the stringers occurred) frequent repetition of the shear stress might produce fatigue in the adhesive, and cause it to fail.
* **(c)** Mr. Jablonsky recognised that the dependence on temperature level of the properties of Redux is well known. He suggested, however, that frequent and rapid variations of temperature would reduce its strength substantially .
* **(d)** It is generally recognised that the satisfactory use in

engineering structures of any form of adhesive (or, indeed, of processes essentially similar such as the welding or soldering of metals) can be ensured only by the development and maintenance of higher standards of workmanship and process inspection than are necessary in the use of riveting. While Mr. Jablonsky recognised that de Havillands' production technique for Redux had been developed after many years' study of its properties, and that their experience of its use in other aircraft had been highly satisfactory, he suggested that it was not a process sufficiently reliable for use in the primary structure of a pressure cabin.

99. Mr. Jablonsky said in evidence that in his inspection of the wreckage at R.A.E. he had seen examples of failure of the "glue line" which had satisfied him that weakness in it was primarily responsible for the failure of the structure of the cabin.

100. I deal below with these points separately:_

* **(a)** During the experiments made in flight on Comet G-ANAV at R.A.E., measurements were made of the difference in temperature between the skin and the stringers in typical positions in steady flight at cruising altitude. They led to the conclusion that the maximum probable steady difference in temperature is about 10∞C. I am advised that the shear stress in the Redux caused by the relative contraction between the skin and the Stringers due to a temperature difference of this order would be well within its capacity.
Mr. Jablonsky did not agree that any reliable inference about the conditions on an operational climb could be drawn from these experiments. I recognise that this comment has some force but I base my conclusions on this aspect of his criticism on the more general considerations set out in paragraphs 101, 102 and 103 below.
* **(b)** No evidence was submitted of the effect, on the fatigue

strength of a Redux joint, of the level of temperature of the adhesive. But I am advised that the wide experience of its use by de Havillands in the structures of other aircraft, where alternations of load on the glue line have certainly existed in numbers far in excess of any likely to have been experienced in the cabin structure of the Comet, and over a wide range of temperature of the Redux itself, is satisfactory evidence that this is not a probable cause of failure of the Redux joints in the Comet's cabin.

* **(c)** de Havillands made special tests to investigate the effect on topical joints of repeated alternation of temperature between 60∞C and -50∞C. I am advised that these show that alternations of temperature within this range have no appreciable effect on the strength of a Redux joint.
* **(d)** At my request, de Havillands submitted a statement which summarised the history and present state of their production methods in the use of Redux, with particular reference to its application to the construction of the Comet Mr. Povey, the Director responsible for production, gave evidence on the point. I am advised that this statement and evidence show that de Havillands fully appreciated the importance of this aspect of the use of an adhesive in essential structural components and that the methods they have devised, including process control and inspection. tests of samples of every joint, and periodic stripping of complete stringers from the skin, provide all the assurance that could reasonably be required.

101. However, the final test of a process of this type is recognised to be experience in service. No evidence was produced of any failure of de Havillands' methods of dealing with the same problem in aircraft such as the Hornet and the Dove, in both of which Redux is widely used. Moreover, inspection of Yoke Uncle at R.A.E., both before and after it was tested under repeated loading, showed no signs of any deficiency in the glue line. It must be remembered that before it was delivered to R.A.E. for tests, this aircraft had done 3,521 hours of flying on B.O.A.C. services, experiencing the conditions of temperature, and of temperature variation between the skin and the stringers, contemplated by Mr. Jablonsky.

102. Finally. examination of the wreckage led Mr. Ripley to conclusions contrary to those inferred by Mr. Jablonsky. for reasons which he explained in detail.

103. It has been established to my satisfaction that the rear part of the fuselage substantially intact, hit the surface of the sea at high speed, open end downwards. This caused the equivalent of an explosion in it, whose effects were naturally most acute near the open end (see Figures 3 and 4). I am advised that the failure, under these circumstances, of the adhesion between the skin and the stringers cannot be regarded as evidence of the failure of the adhesive to meet the requirements of the normal use of the aircraft. There was in this neighbourhood abundant evidence of the failure of all the methods of attaching the various structural components to one another. Moreover, the numerous places where the skin had parted from the stringers exposed the glue line to examination and Mr. Ripley said that he had been unable to find any sign of any unsatisfactory features in the process employed by de Havillands, or of any weakness in the adhesive.

104. In the light of these considerations I have no hesitation in rejecting Mr. Jablonsky's suggested alternative cause of the failure of the cabin.

(c) Mr. Tye's evidence

105. The only other witness who did not completely accept the suggestion advanced in the Report was Mr. Tye. He did not dispute that the primary cause of the accident was the bursting of the cabin structure, but he expressed himself as not entirely satisfied that fatigue was the cause of that disruption. He appears to have proceeded on the basis that the 9,000 hours (3,000 flights) at which Yoke Uncle burst could be regarded as a fair average life for the fuselage and to have been impressed by the improbability, on this basis, of both Yoke Peter and Yoke Yoke failing from fatigue after only about 3,000 hours (1,000 flights). He was unable, however to suggest any other cause. He admitted that he could find no evidence either (a) of excessive internal pressure in the cabin or (b) of excessive stresses in the cabin structure due to external action such as gusts or failure of the control system. He agreed also that he could not name any alternative cause of the failure which R.A.E. had failed to consider.

106. Bearing in mind that Mr. Tye is the Chief Technical Officer of A.R.B. and as such will be responsible for advising A.R.B. when an application is made for a new Certificate of Airworthiness for Comet aircraft, his caution is understandable, but I have the duty of expressing my conclusion on the evidence. I rely in this connection on an answer given by Mr. Tye to Sir Lionel Heald which seems to me to represent the proper approach for me to adopt in the circumstances of the case. Mr. Tye said "I think in concluding on the likelihood of the cause one has to take the thing as a whole: one has to take the tank test evidence and say that that shows that fatigue is possible, although on my argument not necessarily probable, that is the tank test by itself; one then has to look at the other half of the matters namely, all the other possible causes, and if in the process of eliminating possible causes you become completely confident that you have eliminated every other possible cause, then you are driven to say that the possible fatigue rises to the most probable cause." Applying these observations to what was done in the course of the investigations by R.A.E. and by the de Havilland Engine Company Limited and to the evidence given in the Inquiry before this Court, I unhesitatingly come to the conclusion that

R.A.E. were right in their conclusion that the accident at Elba was caused by structural failure of the pressure cabin in the region of the A.D.F. window, brought about by fatigue. In reaching this conclusion I am fortified by the advice I have received from my Assessors.

(d) The possibility of over-pressurisation

107. I considered nevertheless that although the R.A.E. Report contained a full investigation of the equipment used for controlling the pressure in the cabin, including both an examination of the possible causes of mal-functioning and of the condition of the equipment recovered from the wreckage, de Havillands should be asked to produce further evidence directed towards establishing that the precautions taken in the Comet installation, to ensure that the pressure could not rise appreciably above the normal working pressure, were reliable. Mr. Wilkins, an Assistant Chief Designer of de Havillands, who was responsible for this aspect of the designs gave evidence on the matter, and a statement was produced by de Havillands summarising the method of operation of the essential controlling and safety valves. Messrs. Normalair Limited, the firm responsible for the pressurisation control equipment, also produced full information about the essential parts. Taken together with the R.A.E. Report, this additional evidence satisfies me that the possibility of the development of excessive internal pressure in the cabins of an amount sufficient to endanger its structure, was so remote that it can be excluded as a probable cause of the bursting of the cabin.

(e) Certain defects referred to in the R.A.E. Report

108. I turn now to the other defects discovered by R.A.E. and already referred to in paragraph 93 of this Report, I see no reason to differ from the conclusion reached by R.A.E. that none of these defects was in any way the cause of the accident.

109. It is clear that the separation of both port and starboard outer wings from the centre section (see Figure 11) was not the primary cause of the accident, for there is ample evidence from the distribution of paint marks and scratches on both wings that they were made by parts of the cabin structures and form a pattern (see Figure 16) which is consistent only with the whole wing having been intact when they were made. For the same reason, the known point of fatigue weakness in the wing skin near the edge of the wheel-wells is not suspect. Moreover the fracture of the wings occurred some distance outside this region.

110. As regards escape of fuel from the fuel venting system, examination of the wreckage disclosed that fire did not start until alter the disruption of the cabin. It is cIear, therefore, that escape of fuel from the tank vents during take-off or climb had nothing to do with the accident.

111. Turning to refuelling, the danger apprehended could only occur by a concatenation of five events. The risk was, therefore, said to be a remote one and in any event in the present case R.A.E. state that examination of the Elba wreckage made it plain that even if the aircraft had sustained damage of the type indicated in Part 6 of the R.A.E. Report (which deals with this subject), such damage was not the cause of the accident to Yoke Peter. There had, however, been a recorded instance of trouble due to this cause and it is to be observed that de Havillands have indicated their intention of devising a method of removing the possibility of damage of this kind (see Appendix VIII).

(f) The possibility of damage by jet efflux

112. During the operation of B.O.A.C. services, there had been some experience of small damage to the cabin skin, due to the buffeting by the efflux from the jet engines. This damage was partly in front of and partly behind the pressure dome of the cabin. As soon as it was observed, a systematic inspection was made of all Comets, and where any signs of cracking were detected a repair was made according to a scheme specially devised by de Havillands. Internal inspection showed that the buffeting was also causing slight loosening of the joint between the stringers and the skin in this region, and rivets were therefore inserted in order to ensure that this would not give rise to danger.

113. This point of possible weakness was under continuous observation. The steps taken to deal with it may be considered to be satisfactory, particularly since, where the repair had been carried out, no further trouble occurred.

114. It is, however, recognised by de Havillands that a situation in which it is known that such cracks are likely to occur is unsatisfactory, and among the improvements they intend to make on future Comets is one which they believe will reduce the cause of this damage, namely, a slight change in the direction of the jet pipes at their exits, with the object of diverting the jets away from the sides of the cabin.

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PART XIV RESPONSIBILITY

(a) Introductory

115. No suggestion was made that any party wilfully disregarded any point which ought to have been considered or wilfully took unnecessary risks. Buts in the course of the evidence, questions were put which make it necessary for me to consider a number of points in the light of the conclusion I have already expressed as to the cause of the accident.

(b) Criticism of de Havillands' design work

116. Dealing first with the period prior to the commencement of the scheduled passenger service on the 2nd May, 1952, the calculations made by de Havillands were criticised and it was suggested that the tests they carried out were inadequate to guard against the risk of fatigue in the cabin structure. In support of this contention particular reference was made to certain calculations included in paragraph 4 of Part 3 of the R.A.E. Report and to other calculations produced by Sir Arnold Hall in the course of his evidence. It is, however, to be observed that the primary object of de Havillands was to lay the foundation for extensive tests which they regarded as the soundest basis for the development of a project rather than to arrive at a precise assessment of the stress distribution at the corners of the cabin windows.

117. I do not think that they can justly be criticised for this approach to the problem. In arriving, at this conclusion I have been assisted by a Memorandum which has been prepared for me by my Assessors and which confirms the impression I formed from the evidence of the witnesses that de Havillands were proceeding in accordance with what was then regarded as good engineering practice. I am also satisfied that in the then state of knowledge de Havillands cannot be blamed for not making greater use of strain gauges than they actually did or for believing, that the static test that they proposed to apply would, if successful, give the necessary assurance against the risk of fatigue during the working life of the aircraft. The

Memorandum to which I have referred is included as paragraphs 118 to 129 of this Report.

(c) Memorandum by Assessors

118. During the design of the Comet de Havillands did not make use of calculations in an attempt to arrive at a close estimate of the stress distribution near the corners of the cabin windows. We have examined such of their calculations as had a bearing on this question; these led to the stress of 28,000 lb./sq. in. mentioned by Mr. Harper. It is clear that this stress refers to an area of the skin in the neighbourhood of the corners, and may fairly be said to be an average value over a width of 2 or 3 inches. de Havillands believed that their method was satisfactory for the purpose they had in mind, namely, the design of a test specimen. They did not consider that a closer estimate of the highest value of the stress could be made by any method which they would regard as reliable. They preferred to rely on tests of specimens designed on the basis of their calculations.

119. Since their estimate of the general level of stress in the region investigated was less than half the ultimate strength of the material (about 65,000 lb/sq. in.) they were confident that they could demonstrate by static test that there would be no failure at twice the working pressure, and that there would be a considerable reserve in hand. Their tests of panels about 3 ft. square, including, a window, substantiated this view.

120. We note, however, that in these tests the panel was supported on the face of a stiff steel "pressure box", and not in conditions truly representative of those which existed near the window in the pressure cabin itself. It is not possible to say what the effect of this would be. de Havillands were reassured by the results of the tests, in which the specimen withstood nearly 20 lb./sq. in. without failure.

121. de Havillands used the same approach to the design of the whole pressure cabin. The static tests which they made on the two parts of the pressure cabin, respectively 26 and 24 ft. long, gave them confidence in the integrity of the whole cabin. Since they believed, with general support from then current practice and opinion, including that of A.R.B., that this basis of design and static tests would give ample assurance against risk of failure under repeated applications of the working pressure, and other known causes of fatigue, they felt that the cabin was good for the life of the aircraft (say 10,000 pressurised flights, or 10 years).

122. Here again, however, we note that the test sections of the cabin differed from the cabin as fitted to the aircraft in several respects. In the first place, each was incomplete, and incapable of sustaining pressure if it had not been fitted with a stiff bulkhead at the open end or ends. It is not possible to say whether the constraint which these bulkheads imposed on the structure would make it stronger or weaker than when it formed part of a complete cabin. But it must be recognised that the stresses in the structure near the bulkheads would be appreciably affected by the constraint, and the reliability of deductions about the strength of the cabin would thereby be reduced. Secondly neither section was fitted with the complete number of windows, etc. Moreover, the windows of special interest in this Inquiry, which were in the front test section, were rather near the bulkhead mentioned, so that the stresses in the skin round them might have been appreciably different from those in similar places in the complete cabin.

123. The increasing attention which de Havillands gave, during the period mid 1952 to end 1953, to the fatigue life of pressure cabins has been mentioned in paragraphs 21 to 24. In their repeated loading tests the front test section of the cabin survived 16,000 applications of just over the working pressure. They felt confident that the Comet's cabin would have a safe life well beyond their target of 10 years in service.

124. The repeated loading test on Yoke Uncle at R.A.E. led to an unexpected failure after some 3,000 applications of load. Though this was about three times the life of Yoke Peter at Elba or Yoke Yoke at Naples it was surprisingly short and led directly to the inference that there were high local stresses. Steps were, therefore, taken at R.A.E. to measure the stresses near the corner of the window, using strain gauges placed as near as possible to the edge of the skin where the failure started. These measurements led to an estimated stress of 43,000 lb/sq. in. at the edge at the normal pressure difference of 8.25 lb./sq. in.

125. This estimate of the stress was regarded by de Havillands as unreliable, partly because the process of deriving it from the experimental measurements involved some extrapolation, but also because it would imply that in their own test to twice the working pressure, there was a local stress of double this amount, namely 86,000 Ib/sq. in., which is some 30 per cent. above the ultimate strength of the material. This apparent paradox can be explained by recognising that it neglects to take account of the effect of the ductility of the material in relieving "stress concentrations" (see on this subject paras. 148 to 153 below).

126. Calculations were made by Sir Arnold Hall to explore the problem in the light of such theoretical solutions as were known of the problem of stress distributions round a cut-out of the shape of the cabin windows, in a cylindrical shell of metal under pressure. These calculations were not put forward as exact, but, with due allowance for the fact that the window frame, and the cabin stringers and hoop frames, would influence the result they supported the reasonableness of the estimate made from measurements on Yoke Uncle.

127. It is our view that the two results taken together point strongly to the conclusion that the stress in the skin at the edge of the window near the corner was far higher than had been suspected by de Havillands, and was probably over 40,000 lb/ sq. in. under the normal pressure difference.

128. In the course of the Inquiry much attention was paid to an estimate, given in Part 3, para. 6 of the R.A.E. Report on the tests on Yoke Uncle, of the stress which might be predicted on the basis of their measurements by strain gauges, as probably existing in flight. The figure "70 per cent. of the ultimate strength" was obtained by adding to the 43,000 lb/sq. in. (mentioned above) due to the working pressure, another 2,700 lb / sq. in. due to other known loads, leading to a total of 45,700 lb/sq. in. This was contrasted with de Havillands' own estimate of 28,000 lb/sq. in. It has already been pointed out that de Havillands' figure relates to an average over a considerable distance near the corner of the window, and due only to the working pressure, whereas the estimate made by R.A.E. relates to a particular point where the stress would be expected, on general grounds, to reach a maximum. A direct comparison between them is therefore misleading. Having regard to the different approach the two figures cannot be said to be inconsistent.

129. It is natural that de Havillands and R.A.E. should have approached the problem of the "safe life" of the pressure cabin of the Comet from different points of view. de Havillands were the designers and looked at the problem as designers would, having confidence in their methods based on their experience. R.A.E. had had virtually no previous knowledge of the design background of the Comet, since it is a civil aircraft and their connection with it before the 8th April, 1954, was primarily advisory in character and was wholly concerned with fatigue of the wings. In the early stages of the Inquiry there was, therefore, a sharp disagreement between them on the interpretation of their calculations and tests. These differences of opinion diminished in the course of the Inquiry as greater mutual understanding developed. While there are still minor points on which they do not quite see eye to eye, a situation which is by no means unusual in technical problems of such difficulty, there is now no longer any substantial disagreement between them. Our own interpretation of the situation, so far as it can be determined by existing evidence, is set out above, and we believe that it would be accepted by de Havillands and R.A.E.

(d) Criticism of de Havillands repeated loading tests in 1953

130. Another criticism of de Havillands was connected with the repeated loading tests carried out by them in 1953. When the R.A.E. test revealed the short life of the cabin structure of Yoke Uncle the question arose as to how to reconcile the result of that test with the result of these earlier repeated loading tests. Sir Arnold Hall suggested that the explanation might well be that the 1953 tests were carried out on a nose section which had previously been subjected to static tests up to a differential pressure of 16.5 lb/sq. in. and that the effect of such a test might be to prolong the life of the specimen subjected to it. Mr. Harper said that he was aware of this possibility but he considered that if there was any increase in life of the nose section attributable to pre-loading the tests so amply covered the life of the aircraft both at the time of the tests and for the immediate future that de Havillands could safely accept the test as satisfactory. In the then state of knowledge I think this conclusion was reasonable.

(e) de Havillands' method of dealing with cracks

131. There is one other question bearing on responsibility to which I must refer. This concerns certain cracks, revealed by the examination of the wreckage (see para. 78), which had occurred in the process of manufacture and had been dealt with by location. Sir Arnold Hall said that such manufacturing cracks might form foci for fatigue and thus shorten the life of the structure. It was suggested in cross-examination that the fatigue which led to the disintegration of Yoke Peter had originated in these cracks, that they ought not to have been dealt with as they were and that accordingly some responsibility ought to attach to de Havillands for allowing the aircraft which contained them to be put into service.

132. It will be convenient to deal with the subject of cracks generally before giving my opinion on the specific question of responsibility mentioned above. This course may also enable the whole matter to be viewed in proper perspective. Public concern may have been aroused by what was said during the Inquiry and it is important that groundless fears should be allayed.

133. I am advised that it has been the general experience that certain parts of the structure of aircraft develop cracks as the result of fluctuation of load, vibration or casual damage and that the external skin, whether in the wings, tail or fuselage is particularly vulnerable. Cracks which occur during manufacture do not differ materially, in their significance, from those which may develop subsequently save, of course, that their presence may indicate an unsatisfactory manufacturing process.

134. It is the ordinary practice to make careful inspection of the structure, both during manufacture and subsequently, particularly in regions known to be specially susceptible and, if cracks are found, to deal with each case on its merits in the light of a now very wide experience of the problem. Where frequent inspection shows that a particular crack is likely to spread, it is dealt with by a carefully considered repair scheme, either prepared by the designers or by the operators in collaboration with the designers. However if after such repair the crack continues to spread it is considered as a matter of major concern possibly requiring a radical modification to the design to reduce the stress which gave rise to it.

135. For small cracks in regions not highly stressed the method of location is generally found to prevent further spread, provided that care is taken to ensure the inclusion of the end of the crack in the hole drilled. All witnesses who dealt with this matter in the Inquiry were agreed that location was a reasonable method of dealing with such cracks.

136. I am also advised that most aircraft experience cracks due to one or more of the causes mentioned above and that it would, indeed be hardly practicable to insist on a standard of design and construction which would preclude completely the possibility of any crack in the skin.

137. The methods employed by de Havillands in dealing with manufacturing cracks were in no way different from those used to deal with other deviations from the strict requirements of the drawings to which the aircraft was being built. Defects whether discovered by the workman or the inspector would be dealt with by the procedure known as "Concession" procedure which varied according to whether the defect was classed as major or minor. Mr. Povey said that manufacturing cracks were required to be dealt with as major defects with the result that "Concession Notes" containing the proposals for dealing, with them would have to go forward to the Chief Inspector and, if approved by him, would have to be submitted to the Design Department for final approval. In the case of Yoke Peter three cracks were discovered in the reinforcing plates of the A.D.F. windows. The action taken, which was approved by the Chief

Inspector and the Design Department, was "splits have been located with a 1/16th dia. drill hole". According to the then current engineering practice this action would have been appropriate had the stresses been as low as de Havillands believed them to be, but was, in fact inappropriate as the region concerned was one in which there were high stresses. However, as I have already stated in paragraphs 116 and 117 my opinion that de Havillands cannot be blamed for their ignorance of the true state of affairs, it follows that no responsibility attaches to them.

138. The evidence disclosed other cracks in Comet aircraft. Thus in the wreckage of Yoke Peter there was a crack in the skin at the starboard front corner of the rear A.D.F. window. This had been located at both ends. No Concession Note was available in relation to this crack and it would appear that there had been a defect in the operation of the Concession procedure. Although this crack had spread during the life of the aircraft beyond one of the points at which it had been located, the actual fracture did not take place there nor was there any sign of fatigue. Other clacks were referred to in Yoke Uncle and Yoke Yoke but in no case was there any evidence that the crack had contributed to the failure of the aircraft.

139. I need not pursue further the question of manufacturing cracks of this type since the statement put in on behalf of de Havillands (see Appendix VIII) records that if in future a crack does occur at any time either in manufacture or subsequently during the life of an aircraft no repair scheme for such a crack will be sanctioned unless it ensures that, after it has been carried out, the part of the aircraft concerned will be as strong and will have as long a life as it would have had, had there been no crack.

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PART XV
FUTURE

(a) Statements on behalf of the Attorney-General and de Havillands

140. By s. 9 (12) of the Civil Aviation (Investigation of Accidents) Regulations 1951 the duty is imposed on me of making such recommendations as I think fit with a view to the preservation of life and the avoidance of similar accidents in future. I have been greatly assisted in that part of my task (a) by the statement as to future policy made by Sir Lionel Heald on the 12th November, 1954 on behalf of the Attorney-General after consultation with the Ministry of Transport and Civil Aviation and A.R.B.: (b) by the statement put in by Sir Hartley Shawcross on the 23rd November, 1954 recording the action which de Havillands now propose to take to deal with the problem of fatigue and with the other defects referred to in the Report of R.A.E. These statements are of such importance that I have attached them to this Report as Appendices VII and VIII. I respectfully agree with the course therein proposed to be adopted.

(b) Further suggestions directed to guarding against fatigue

141. The problem of securing an economically satisfactory safe life of the pressure cabin of an aircraft needs more study, both in design and by experiments if the lightest possible safe structure is to be achieved. This is recognised by de Havillands in their policy in regard to the future of the Comet (Appendix VIII).

142. In Appendix IV para. 4 (iii), reference is made to the problem which arises owing to the variation among the lives, under a given loading cycle, of nominally identical parts, known as "scatter". In the pressure cabins of aircraft there are probably a number of causes of scatter. Tests of a large number of specimens are however virtually impracticable and, in order to ensure a safe life well above the minimum that is economically acceptable to an operator, methods must be devised of ensuring that design combined with a reasonable programme of tests can guarantee that the pressure cabins of transport aircraft will be entirely safe.

143. The policy which de Havillands propose to adopt for the Comet is directed to achieving this end, primarily by reducing both the general level of stress and the local excesses, due to all known causes, above the general level of stress. The knowledge which has been acquired as a result of the investigation of the accident to Yoke Peter, and the tests made on Yoke Uncle at R.A.E., strongly suggests that steps should be taken to determine by calculation, by tests of typical parts of the cabin, and by tests on one or more complete cabins, both the distribution of stress throughout the structure in considerable detail, the influences which determine both the highest static load which it will sustain, and its life to failure under repeated loading. In the present state of knowledge, it is likely that two complete cabins will have to be tested one under static loads and one under cycles of repeated loads.

144. From the evidence of Sir Arnold Hall and from advice I have received from my Assessors it became clear that there exist methods of calculating, the stress distribution in the structure of a pressure cabin which could with advantage be employed more widely. Moreover the result of R.A.E.'s investigation satisfied me that in tests of pressure cabins or parts of them the stress distribution should be determined by wide use of strain gauges. This procedure will enable the calculations used in the design to be verified or amended, and will lead to a fuller understanding of the problem.

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

(c) Use of available Government facilities

146. In the course of the evidence there was some suggestion that prior to 1954 inadequate use was made in the development of the Comet of the unrivalled facilities available at R.A.E. to the civil aircraft industry. This may have been exagerated. Be that as it may, in view of the importance of that industry to the national economy it is essential that in future manufacturers should be aware of, and should make full use of, such facilities as the research establishments of the Ministry of Supply can offer. The Court was informed that in practice there had been close personal association between members of the staffs of A.R.B. and R.A.E. and that R.A.E. was represented on the Airworthiness Requirements Co-ordinating Committee of A.R.B. It is desirable, nonetheless, to strengthen the liaison between A.R.B. and all the research establishments of the Ministry of Supply and it might be worth considering whether, when the Council of A.R.B. is being strengthened in accordance with the statement made by Sir Lionel Heald (see Appendix VII), it should not also receive such additional reinforcement as will encourage the full use by manufacturers, operators and A.R.B of all available facilities.

(d) Avoidance of flight by unlicensed crew

147. Reference has been made in paragraphs 35 and 36 to the fact that the Engineer Officer of Yoke Peter was not in possession of a valid licence at the time of the accident. I was informed by Counsel for B.O.A.C. that their system for ensuring the prompt renewal of licences had been overhauled and that adequate steps have been taken to prevent a recurrence of this lapse. It is clearly of the first importance to ensure that no aircraft flies save with a crew not only fully qualified in knowledge and experience but also properly licensed.

(e) Suggested scientific and technical investigations

148. There are certain scientific and technical matters on which, acting on the advice of my Assessors, I recommend that research can usefully be undertaken, in the interest of increasing knowledge of the problems of the design of pressure cabins. The first arises from the influence of the ductility of the aluminium alloy from which the skin of the cabin is made, on the manner in which the stress distribution in the skin is related to the difference between the internal and external pressure on the cabin. It is perhaps simplest to look at this problem in the light of the situation which develops as the pressure in the cabin is increased from the working pressure P up to the value somewhat below that at which it fails under a static test.

149. In the first place it is essential to appreciate that, although it would from many points of view be desirable that the stress in the skin should be the same everywhere, in practice considerable variations are unavoidable. There will, therefore, be points, generally near to the cut-outs, where the stress is appreciably higher than the average, and it is on these points that the designer's attention is naturally focussed when considering, the strength of the structure.

150. As the pressure difference in the cabin rises from P to, say, 1.5 P the stresses everywhere will rise in the same proportion. But as the pressure difference approaches, say, 2 P the stress in the more highly stressed regions will reach that at which the material is no longer elastic. Its extension will then be of a plastic nature, that is to say, one which does not disappear when the stress which caused it is removed. Over most of the skin the stress will remain within the range in which the material is still elastic and the removal of the pressure will restore this part of the skin to its original dimensions. But in areas where the stress was high there will remain a permanent stretch. The pre-loaded cabin is therefore physically different from a new one, if the pre-load has exceeded a certain level.

151. Although the permanent extension of the material in the areas where it has stretched plastically, but without fracture, is small and undetectable by visual inspection, it may have a profound effect on the distribution of stress in the material when the working pressure is applied a second time. Without going into details, the general nature of this will be to reduce markedly the stress in the areas where it was previously greatest. The stress concentration in such areas is therefore relieved.

152. This is a process whose general nature is understood, and there are examples where it has been deliberately used in order to improve resistance to fatigue. It has indeed been suggested that it might be used in such structures as a pressure cabin. But there are obvious difficulties, not to say dangers, in applying it. Nevertheless, the subject should undoubtedly receive more study, if only to ensure that tests during design are not rendered unreliable by failure to appreciate its significance.

153. Though there can be no direct proof, there is no doubt that the phenomenon described above provides at any rate a partial explanation of the apparent anomaly presented by the failure of the pressure cabin of Yoke Uncle at R.A.E. after 3,000 cycles, in spite of the survival of the test specimen of the forepart of the cabin to over 16,000 cycles when tested by de Havillands. The maximum pressure difference which had ever been applied to Yoke Uncle was 1.33 P. whereas the test specimen had been subjected to two applications of 2 P in addition to nearly twenty of between P and 2 P.

154. The second question which needs study may be put shortly as follows: what is the true static strength of the complete Comet cabin ? Reasons have been given in paras. 120 and 122 why the tests made on sections of the cabin may have been somewhat misleading. A test conducted in the tank at R.A.E., with the most comprehensive exploration of the stress distribution, would be invaluable. Not only would it clear up such uncertainties as remain from our Inquiry, but, in conjunction with the repeated loading, tests already made on Yoke Uncle, would provide an invaluable body of information for the basis of design of future pressure cabins

155. The remaining question which requires study relates to the system used to operate the aircraft controls. Most of the evidence On this subject was concerned with the alleged excessive "break-out" force and indicated a difference of opinion, among pilots, as to whether the existing system was satisfactory in this respect, though none suggested that the alleged defect had in any way contributed to the accident. A different criticism was made by one of the Assessors to the Indian Court of Inquiry into the accident to G-ALYV and apparently prompted that Court's second recommendation, which was as follows: "That consideration should be given to the desirability of modifying the flying control system of the Comet aircraft in order to give the pilot a positive 'feel' of airloads exerted on the control surfaces." Only a passing reference was made to this before me. As advised by my Assessors, I am satisfied that the characteristics of the control system of the Comet should be reconsidered by de Havillands and by A.R.B. in the light of both the criticisms which have been made.

(f) Observations on certain suggestions made in the course of the Inquiry

156. I cannot conclude this part of my Report without mentioning two suggestions made during the Inquiry which, after full consideration, I feel unable to recommend.

157. The first of these arose out of some criticism which was made of the system whereby inspection of aircraft parts is delegated by A.R.B. to manufacturers. By this system, the operation of which is set out in an A.R.B. pamphlet on "The Approval of Inspection Organisations and the Maintenance of Airworthiness", manufacturers' own inspectors have the duty of supervising all the work done in building civil aircraft. This inspection organisation is supervised by A.R.B. through their own inspectors to ensure that it is adequate. A.R.B. inspectors do only such detailed inspection of work as is needed to assure themselves that the system is working satisfactorily. Evidence was given by Mr. Povey illustrating how this system worked at de Havillands.

158. The suggestion was made that the system for inspection would be more satisfactory if all the lnspectors were responsible direct to A.R.B. and not to manufacturers, or alternatively that there should be a duplicate system of inspection whereby both manufacturers and A.R.B. would have inspectors. Reference was also made to the method of inspection of shipping by Lloyd's as an example of how such a system might work but no evidence was produced as to this method. I cannot, therefore, form any conclusion on the suggested analogy.

159. It is plain that there would be inherent dangers in duplication. Responsibility for the quality of his product must rest with the producer. It is, therefore, essential for the producer to have his own system of inspection. Any additional system would add to expense, but not, it was argued to safety.

160. I have come to the conclusion that the present system of inspection by manufacturers approved and supervised by A.R.B. is essentially satisfactory. It is, of course subject to human errors, but it has the beneficial effect of creating a sense of responsibility in manufacturers without which aircraft could not be designed and built to the requisite standard of reliability and safety.

161. The second suggestion arose out of some criticism which was levelled at A.R.B. on the ground that their flight testing organisation is relatively small compared with similar flight test teams at aircraft firms and at the Ministry of Supply Experimental Establishments. A suggestion was, therefore, put forward that A.R.B. flight testing and aircraft approval would be made more effective if an active pilot were appointed to their Council and if civil aircraft were sent to a Ministry of Supply test establishment where a much wider and more experienced opinion on flying qualities could be obtained from a larger organisation, instead of the somewhat restricted assessment at present available to A.R.B.

162. Although I am satisfied that there is no reason to criticise the flight testing of the Comet I as carried out by de Havillands and A.R.B., I think serious consideration should be given to the possibility of obtaining the best available opinion on the flight characteristics of future airliners particularly when they incorporate novel features in design which effect those characteristics. As I have mentioned in para. 146 of this Report, such facilities are available in Ministry of Supply Establishments, and the importance of the civil aircraft industry to the economy of this country seems to warrant making the fullest use of those facilities.

163. With reference to the suggested appointment of an active pilot to the Council of A.R.B., there are clearly difficulties in such an arrangement since the pilot would be unable to do his job as an airline pilot and at the same time be available to give his advice to the Council. I have no reason to believe that the present representation on the Council has been in any way lacking in the past and I hesitate to recommend any change. If an active pilot were to be appointed the post would have to be made a whole time paid employment and it would not be long, before he ceased to possess the qualifications upon which those who advocated the appointment laid stress. On the whole I think it is better to rely on the Minister to secure that the person he nominates to the Council as possessing professional experience as a pilot of civil aircraft is always someone who is reasonably up-to-date.

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PART XVI
QUESTIONS AND ANSWERS

My answers to the questions submitted on behalf of the Attorney-General are as follows:_

Question 1

What was the cause of the accident?

Answer.

The cause of the accident was the structural failure of the pressure cabin brought about by fatigue. See para. 95.

Question 2.

If several factors caused the accident what were such factors and to what extent was each contributory?

Answer.

This does not arise.

Question 3.

Was the accident due to the act or default or negligence of any party or of any person in the employment of that party?

Answer.

The accident was not due to the wrongful act or default or to the negligence of any party or of any person in the employment of any party.

Question 4.

At the time of the accident:

Question 4 (a).

Had the aircraft been maintained in accordance with the current approved maintenance schedules? If not, did any defect in maintenance affect the safety of the aircraft or contribute to the accident?

Answer.

Yes. The second part of the question does not arise.

Question 4 (b).

Was the aircraft airworthy so far as could reasonably have been then ascertained ?

Answer.

Yes.

Question 4 (c).

Was there a valid Certificate of Airworthiness in respect of the aircraft?

Answer.

Yes.

Question 4 (d).

Was there a valid Certificate of Maintenance in respect of the aircraft?

Answer.

Yes

Question 4 (e).

Was the radio station of the aircraft serviceable and was there a valid Certificate of Serviceability in respect thereof ?

Answer.

Yes.

Question 4 (f).

Was the aircraft properly loaded and trimmed within the limits specified in the Flight Manual?

Answer.

Yes.

Question 4 (g).

Were all members of the crew properly licensed and adequately experienced to make the flight? If not, did any defect in the licence of any member of the crew affect the safety of the aircraft or contribute to the accident?

Answer.

All members of the crew were adequately experienced to make the flight but the flight engineers Engineer Officer F. C. Macdonald was not properly licensed to make the flight (see paragraph 35). This defect did not affect the safety of the aircraft or contribute to the accident.

Question 5.

Upon consideration of all facts disclosed by this Inquiry what steps should be taken to increase .the safety of civil aircraft?

Answer.

See Paragraphs 140-155 of this Report.

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Report by COHEN., W. S. FARREN., W. J. DUNCAN., A. H. WHEELER.
1st February, 1955.

IMPORTANT NOTE : *The information contained is this report remains the property of the Ministry of Transport and Civil Aviation and may not be distributed without their written approval.*

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[Orders] [Comet] [Planes] [Pictures] [Technical data] [Cargolux] [Caravelle] [B764/A332] [A3XX] [Beluga] [Registrations] [Links] [Marc] [E-mail] [Sign guestbook] [View guestbook] [Updates]

Comet history   The history of the first jet airliner
Comet variants   From the 1st prototype to the Mk5

http://surf.to/comet: Comet crashes and accident reports

All Comet crashes : Summary of all De Havilland Comet accidents.
All hull-losses : Summary of all De Havilland Comet incidents.
Descriptions : Detailed descriptions of all Comet accidents and incidents.
Available Comet accident reports : List of available De Havilland Comet accident reports.

http://surf.to/comet: Official accident report of Comet IV G-APDN

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Civil aircraft accident report 1/72

Accident investigation branch - Department of Trade and Industry

Dan Air Comet 4 G-APDN.

Report on the accident which occurred in the Sierra del Montseny, in the Municipal District of Arbucias (Gerona) Spain on 3 July 1970.

Translation of the report published by the Spanish Air Ministry, Madrid October 1971
London : Her Majestyís stationery office 1972

0. Figures

Flight pad of G-APDN

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1. Investigation
1.1. History of flight

The aircraft was operating a regular Dan-Air charter flight from Manchester to Barcelona. It took off from Manchester for Barcelona at 1608 hrs. The routing specified on the flight plan was via Airways UA1, UA34, UB31 and Point Berga. Because of ATC delays in the Paris area the aircraft was cleared to proceed via UA25 to the Cognac VOR (1725 hrs) - Agen VOR - Toulouse VOR (1743 hrs), joining UB31 at point 'B'. G-APDN was then cleared by French ATC to descend from FL370 to FL220. At 1753 hrs the pilot established contact with Barcelona ACC on 124.7 MHz and after reporting that he had passed the Spanish frontier requested clearance to descend further; it was cleared to descend from FL220 to FL90.

At 1757 hrs G-APDN reported passing the Barcelona FIR boundary and that it was leaving FL160, and gave an ETA of 1801 hrs for Point Berga. At 1759 hrs the pilot received instructions to contact Barcelona Approach (APP) on 119.1 MHz; a few seconds after changing to that frequency G-APDN was instructed to turn left on to heading 140∞. The pilot acknowledged the turn and reported that he was leaving FL130, and immediately afterwards gave an ETA for Sabadell of 1807 hrs.

At 1800 hrs APP requested confirmation of this estimate and the pilot corrected it to 1805 hrs. On receiving this information, APP cancelled the turn on to 140∞ and told the pilot to proceed to Sabadell. At 1801 hrs, G-APDN reported leaving FL100 for FL90. APP enquired whether it had DME on board and the pilot replied that it did not. G-APDN was then cleared to descend to FL60.

At 1802 hrs, APP instructed the pilot to turn left on to 140∞. The pilot acknowledged this instruction and informed ATC that he was leaving FL85 for FL60. Immediately after this transmission, APP requested confirmation that G-APDN was passing Sabadell, and the pilot replied 'in about 30 seconds'; 15 seconds later the pilot said 'Barcelona, G-APDN passing Sabadell'. APP acknowledged the message and added 'radar contact, continue descent to 2,800 feet, altimeter 1017, transition level five zero'.

At 1803 hrs G-APDN requested information on the duty runway, APP replying that the duty runway was 25, which the pilot acknowledged. At 1805 hrs, APP requested aircraft altitude and G-APDN reported passing 4,000 feet. At 1807 hrs APP called the aircraft for confirmation that it was still on course; G-APDN did not reply to this transmission, nor to other calls which were subsequently made.

The site of the accident was: Latitude 41∞47'45" North, Longitude 02∞27'34" East, and it occurred between 1805 and 1806 hrs, in daylight. The altitude of the site is about 3,900 feet.

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1.2 Injuries to persons

Injuries Crew Passengers Others

Fatal	7	105	-
Non-fatal	-	-	-
None	-	-	-

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1.3 Damage to aircraft The aircraft was destroyed.
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1.4 Other damage Destruction of 125 acres of a privately owned beech wood, valued at approximately 25,000 pesetas.
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1.5 Crew information

Captain Alexander George Neal, aged 48, held a valid British Airline Transport Pilot's Licence, with a current instrument rating, endorsed to fly Comet, Britannia and HS 104 aircraft in command. His licence was issued on 6 February 1967 and was valid until 5 February 1972. He passed his last instrument rating renewal flight test on 17 March 1970. He passed his last periodic medical examination on 3 March 1970 and there were no medical restrictions on his licence. Captain Neal was trained as a pilot in the Royal Air Force and had previously been employed as a first officer by British Eagle. He joined Dan-Air as a first officer in March 1969 and was promoted to captain in May 1970. At the time of the accident he had flown a total of 7,427 hours as a pilot. He had accrued a total of 605 hours on Comet aircraft, 29 hours being in command. The flight on which the accident occurred was his first flight to Barcelona as commander. Previously he had made one flight into Barcelona, on 19 May 1970 during his command and route check.

First Officer David Shorrock, aged 41, held a valid British Airline Transport Pilot's Licence endorsed for Comet, Britannia and BAC 1-11. His licence was issued on 18 July 1968 and was valid until 17 July 1973. He passed his last instrument rating renewal flight test on 18 March 1970. He passed his last periodic medical examination on 26 June 1970. He was required to wear spectacles to correct his near vision when exercising the privileges of his licence. Mr Shorrock was trained as pilot at a civilian flying school and had previously been employed by British Eagle. He joined Dan-Air as a first officer on BAC 1-1 1 aircraft in April 1969 and converted to the Comet in March 1970. At the time of the accident he had flown a total of 4,765 hours as a pilot of which 189 had been in Comet aircraft.

The flight engineer, Mr David Walter Stanley Sayer, aged 40, held a British Flight Engineer's Licence endorsed for Comet 4 and DC-7B aircraft. His licence was issued on 20 August 1969 and was valid until 21 August 1970. He passed his last periodic medical examination on 7 August 1969. Mr Sayer was originally a ground engineer with Dan-Air before qualifying as a flight engineer on DC-7B aircraft in July 1967. He converted to the Comet 4 in December 1969. At the time of the accident he had flown a total of 1,275 hours as a flight engineer, 218 hours being in the Comet 4. He was considered to be a very competent engineer.

Air Hostesses: Miss S Hinde, Miss H P Barber, Miss C A Maddock and Miss A Vickers.

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1.6 Aircraft information

G-APDN was a standard production HS Comet 4 originally acquired by BOAC in April 1959; Dan-Air bought it from that company in 1969. The certificate of airworthiness was last renewed in the transport category (passenger) on 13 May 1970 and was valid until 12 May 1971. Although the original of the aircraft's certificate of airworthiness could not be recovered, the British commission states that the certificate was in order.

A certificate of maintenance was issued by Dan-Air Engineering on 11 June 1970, after a Check 1 inspection, valid for 62 days or 638 hours. At the time of the accident the aircraft had flown 257 hours since the certificate of maintenance was issued. The total airborne hours of the aircraft were 25,786 since manufacture the aircraft had been maintained in accordance with an ARB approved schedule. It has been calculated that at the time of the impact the weight was below the maximum total weight authorised and that the centre of gravity was within the prescribed limits.

The aircraft was equipped with duplicated flight instruments, both general flight instruments and the Smiths flight director system. Each pilot had two radio magnetic indicators (RMI), one for presenting VOR information and the other for ADF. The commander's altimeter was of the three-pointer barometric type, whereas the copilot's was of the direct reading digital type incorporating a flasher unit and an altitude switch when the height indicated was below 10,000 feet.

The radio equipment carried by the aircraft was as follows:

Marconi AD 307   HF/RT   duplicated
Marconi AD 305/704   VHF COM   duplicated
Marconi AD 712   ADF   duplicated
Marconi AD 704/706   ILS/VOR   duplicated
Marconi AD 708   MARKER   single
Echo E 160   SEARCH RADAR   single
Marconi AD 2300A   DOPPLER   single
Bendix TRA 61 AL   TRANSPONDER   single
Marconi 28800   SELCAL   single

Ultra UA 56   INTERCOM   single

Examination of the company records shows that the Doppler had been out of action since 20 June 1970. This equipment is classified as an allowable deficiency and is not a mandatory requirement.

There had apparently been a series of defects on number 1 VOR set. On 1 July 1970 a controller socket was replaced. A continuity check revealed an open circuit. This was rectified and the VOR was again serviceable. On 2 July 1970 number 1 VOR would not change frequency. The set was changed and the installation then worked normally, according to information received from the British sources. Although it is impossible to be certain that the VOR set was working properly at the time of the accident, it is certain that after the set was changed the aircraft flew four consecutive sectors, apparently without any defect in the equipment.

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1.7 Meteorological information

The Sierra del Montseny, lying some 65 kilometres to the NE of Barcelona Airport, was covered by cloud, due to the phenomenon known as 'barrage' effect. The cloud mass showed little vertical development, consisting of stratus and stratocumulus. On the mountain top, known as Turo de l'Home (1,712 metres) situated about 4 kilometres in a straight line to the south of the accident site, and 500 metres higher, there is a meteorological observatory at which the following data were recorded at the time of the accident: pressure at sea level, 1,018 mbs, falling; temperature 9∞C; dew-point temperature, 9∞C; wind SW, 10 knots; mist, visibility nil; sky not visible on account of mist; orographic precipitation in the form of intermittent drizzle, 1 litre/metre2 having been recorded in the last twelve hours.

The condensation level to windward was 600 meters and the cloud clining to the mountain extending on the leeward side down to levels of between 800 and 1,000 metres. The surrounding valleys, away from the direct influence of the high mountains, showed light to medium cloud cover, with scattered cumulus; visibility was reduced by haze, except towards the coastal regions where visibility could be described as good.

Because of the nature and type of the observed cloud, the light southerly winds both at the lowest atmospheric levels and at mountain-top level, and because of the standard distributions which gave the following upper winds and temperatures 850 mbs 340∞ 20 knots 9∞; 700 mbs 330∞ 25 knots 5∞; 500 mbs 310∞ 30 knots 9∞ and 300 mbs 290∞ 40 knots 20∞; the question of the formation of turbulent air movements and mountain waves has not been taken into account because if they did exist they would have been weak and of no importance to air navigation.

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1.8 Navigation aids

There are various aids available in the region for an instrument approach to Barcelona Airport. Those relevant to the accident now being investigated are: Sabadell NDB, Barcelona VOR, Perpignan VOR and Gerona VOR. All these aids were operating normally on the day of the accident.

Barcelona ACC/APP also had ASR-5 radar equipment in use, the main characteristics of which are:

* range 60 nm
* accuracy in azimuth: +- 0.5∞ error
* accuracy in range within 3%
* theoretical coverage up to 40,000 feet and from 20,000 feet at 60 nm; 12,000 feet at 50 nm; 5,000 feet at 35 nm; 2,000 feet at 20 nm and 1,000 feet at 10 nm.
* The usable range scales are: up to 6 nm with range circles of 2 nm; up to 10 nm with 2 nm; up to 20 with 2 nm, up to 40 with 5 nm and up to 60 nm with 10 nm.

The obstacle clearance chart (MOCA) is attached as Annex 1. Local instructions for use of the radar are attached as Annex 2. Barcelona VOR underwent routine inspections in flight on 2 April 1970 and 9 September 1970, without any corrective measures being required, as stated in the records of the Calibration Service (Servicio de Calibracion). Sabadell NDB was also inspected in flight as a routine measure on 5 June 1969 and 31 July 1970, its condition being regarded as GOOD by the aforementioned service, only some interference from the NDB CST (Costix)(MAJORCA) being observed in the first of these inspections.

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1.9 Communications

Communications between G-APDN and Barcelona Control Centre were clear, with the appropriate terminology being used throughout. According to data exchanged, neither Barcelona ACC nor Barcelona APP noticed any abnormality in the flight of the aircraft. Defects have been observed in the tape recording when ACC was talking on 124.7 MHz. When the frequency was changed to 119.1 MHz communications between G-APDN and APP were properly recorded on the Barcelona Control tape.

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1.10 Aerodrome and ground facilities

These are not a factor.

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1.11 Flight recorders

The aircraft carried a MIDAS type CMT/SC flight recorder. Using all the traces of the parameters of time, speed, altitude, pitch attitude, heading and vertical acceleration, during the last eight or nine minutes of the flight, the track of the aircraft was reconstructed on the map (Annex 3). This showed a close correlation between the aircraft's manoeuvres and the information exchanged between Barcelona Control and the aircraft, and that the track of the aircraft was not correct, deviating the whole time to the east of airway UB31. The accident occurred at 1805.30 hrs and the aircraft was descending, operating completely normally, at a true airspeed of 410 km/h.

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1.12 Wreckage of the aircraft

The accident site was on the beech-covered north-east slopes of the Les Angudes peak (1,704 metres), at an altitude of about 3,800 feet, in the municipal district of Arbucias (Gerona). The heading of the aircraft before impact was approximately 145∞, and its flight path was descending between 5∞ and 10∞ as indicated by the path cut through the trees by the aircraft. Later, two goniometers (direction finders) were found which indicated a heading of 142∞. On detailed examination of the crash it was ascertained that the longitudinal axis of the aircraft at the moment of impact was at an angle of approximately 45∞ up from the horizontal, ie roughly equal to the angle of the mountain slope, it being noted that the main side marks were produced by the auxiliary fuel tanks and not by the fuselage. The fuel tanks exploded and started a fire.

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1.13 Fire

There was an explosion and fire on impact with the ground.

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1.14 Survival

As soon as the site of the disaster was known, amongst those who went to the spot were forces of the Civil Guard of 413 Command, Gerona; No 13 Company of the Fourth Group Ninth Brigade of the Red Cross, Barcelona; 110 firemen from the Municipality of Barcelona, 38 militiamen from the Municipality of Barcelona, 25 Red Cross volunteers from the Barcelona Mobile Squad, personnel from the near-by townships of Viladrau and Arbucias (Gerona) and San Celoni (Barcelona). There were also civil and military authorities from the Provinces of Barcelona and Gerona, and an examining magistrate from Santa Coloma de Farnes (Gerona), provincial medical officers from Barcelona and Gerona and members of the staff of Dan-Air Limited. A British commission was appointed to collaborate with the Spanish authorities in investigating the cause of the accident. There were also British technicians and a pathologist, an Anglican priest, the British Consul and Vice-Consul in Barcelona, along with 77 soldiers with NCO's and Officers of CIR No 9 from San Clemente de

Sasebas (Gerona).

Due to the uneven terrain, the steepness of the slope and the dense vegetation, a bulldozer and excavator shovels had to be used to widen paths and open up a new one to facilitate evacuation of the victims. Since the Spanish health authorities reported that "it was technically impossible for the remains of the bodies to be embalmed and preserved, due to the extreme mutilation and scattering of the remains as a result of injuries of exceptional violence caused by an explosive shock-wave, and that death was presumably instantaneous in every case", the court ordered the bodies to be removed and taken to the municipal cemetery at Arbucias where they were burned.

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1.15 Tests and investigations

One spoiler (air brake) was extended and the other was retracted, but it was impossible to establish whether the latter had been closed by the impact although this appears most likely in view of the manner of operation of these brakes.

The main landing gear was retracted. No flaps were extended. Safety belts were in use. The life-jackets were not removed from their normal position. The turbine and compressor blades showed evidence of heavy abrasion as a result of their having been functioning normally. The accident took place at 1805.30 hrs this figure being obtained from data in the flight recorder.

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1.16 Procedure followed by Barcelona APP

When the aircraft established radio contact with Barcelona APP on a frequency of 119.1 MHz, the latter in order to identify the aircraft instructed it to turn on to 140∞, then cancelled this turn when the aircraft revised its ETA for the Sabadell beacon; this took place between 1759 hrs and 1800 hrs. Later, at 1802.20 hrs, and for identification purposes, APP again instructed G-APDN to turn on to 140∞ and the aircraft did so. At about 1802.25 hrs APP asked the aircraft if it was over Sabadell - since APP radar showed an echo with characteristics similar to those which the Comet should produce in terms of direction and speed - and the aircraft confirmed 'passing Sabadell', where upon the controller authorised descent to 2,800 feet, this altitude being authorised on the 'minimum radar altitudes chart' of Barcelona Control Centre.

1.17

In the investigation into the causes of the accident current ICAO regulations have been borne in mind, particularly paragraphs 3.5.2.2 of Annex 2 and Part II, 1, Note 2 and Part X, 1.6 of ICAO Doc. 4444 (RAC/501/9).

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2. Analysis and Conclusions
2.1 Analysis

From a study of the recording tape from Barcelona Control; from the plan obtained from the graph taken from the transcription of the flight data recorder tape (black box) from the wrecked Comet 4, G-APDN (Annex 3); from the reports on the aircraft and its crew; and from the UIR chart for south west France and other documents relating to the flight, it is deduced:

That due to heavy traffic in the Paris area, the aircraft was diverted from the route laid down in the flight plan drawn up in

Manchester (UA1, UA34, UB31 and Point Berga), and, on the instructions of French ATC, followed the route Nantes VOR - Agen VOR - Toulouse VOR - Point 'B.' (situated on the axis of the airway UB31) - Barcelona VOR. Take-off from Manchester was planned for 1600 hrs, but took place at 1608 hrs.

The aircraft did not follow airway UB31, which is the route to Barcelona for that zone, since at 1756.18 hrs it was still in the Bordeaux FIR on a heading of 193∞, the direction of the above airway being 181∞.

At 1757 hrs, the aircraft reported 'over the boundary', which was taken to mean that it was entering the Barcelona FIR (it had already reported this at 1753 hrs, according to the Barcelona ACC tape) and did so approximately 30 km to the east of the centre of airway UB31, still on the previous heading of 193∞ and giving at that time an ETA for Point Berga at 1801 hrs. This estimate would have been correct if it had been 'ABEAM BERGA' since at its calculated speed of 8 kilometres per minute (according to data from the flight recorder) it would have been 4 minutes away if it had been heading towards Berga; but it was impossible for the aircraft to reach that reporting point, since at 1801.30 hrs it was level with Point Berga and 26 kilometres to the left, still on a heading of 193∞.

When radio contact was established on a frequency of 119.1 MHz with APP, the controller instructed the aircraft to turn on to 140∞; the aircraft began the turn as shown on the map at Annex 3, only covering a distance of approximately 4.5 kilometres. The pilot revised his ETA for Sabadell, making it 2 minutes earlier. The controller cancelled the turn and it will be observed from Annex 3 that the aircraft gradually cancelled the turn, proceeding on its previous heading from 1802.18 hrs.

At 1802.30 hrs, for identification purposes, APP Barcelona again instructed G-APDN to turn to the left on to 140∞; the pilot of the aircraft confirmed this instruction and reported that he was leaving FL85 for FL60. At approximately 1802.48 hrs, at the request of APP, the aircraft reported passing Sabadell, without having reached that point, since it can be observed on the map at Annex 3 that it was still 52 kilometres away. This message, 'passing Sabadell', transmitted by the aircraft, and also the fact that by coincidence the APP controller had observed an echo on the radar screen over Sabadell, led to the aircraft being informed that radar contact had been made. Neither Barcelona ACC nor the Aeroclub of Sabadell have been able to clarify the reasons for the above-mentioned echo, but this does not rule out the possibility that it was caused by an aircraft flying over Sabadell on a VFR flight plan. At this time the controller authorised descent to 2,800 feet, the minimum altitude indicated on the radar chart for this sector.

The bearing and speed of the echo were similar to those expected from a Comet.

At 1803 hrs, G-APDN requested the duty runway and APP replied that No. 25 was in service. This the pilot acknowledged. At 1805 hrs, APP requested an altitude reading and the aircraft replied 'passing 4,000 feet'. At 1807 hrs, APP requested G-APDN to confirm it was maintaining its heading, but the aircraft did not reply.

The displacement of the aircraft's track to the east cannot be attributed to deviations of the Barcelona VOR signals, since if such a considerable defect had existed it would have been detected by numerous flights which have used and continue to use this VOR. Furthermore as has previously been stated, on 2 April 1970 the appropriate official service carried out a check and found the equipment within the permitted tolerances and therefore no adjustments were made.

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2.2 Conclusions and probable causes

2.2.1

From the time the aircraft reported passing Toulouse VOR (if correct) it can be seen that it did not continue on UB31 after the BRAVO intersection point, but followed a line considerably to the east of that airway. This error persisted right up to the moment of the accident, and the information on ETAs and times of passing Point Berga and Sabadell NDB was also incorrect, as was the time given for passing the UIR boundary which was given twice with an interval of some 3 minutes.

2.2.2

Barcelona VOR was functioning correctly according to information from the Flight Air Inspecting Services, and from the absence of unfavourable reports on the functioning of the radio aid in question.

2.2.3

Consequently, the aircraft's continuing displacement to the east could have come about as a result of some defect of the aircraft equipment, bearing in mind that from Toulouse VOR positions had to be determined by intersection of radials.

2.2.4

The pilots should have reported to Barcelona APP that they were passing to the east and not above Point Berga. The fact that this information was not given, together with an inexact ETA for Sabadell, made it difficult for the controller to identify correctly the aircraft on the radar screen.

2.2.5

To sum up, it can be deduced that the combination of erroneous information regarding reporting points, together with the existence of a radar echo over Sabadell NDB (coinciding with the report from the aircraft of passing that reporting point), led both the aircraft and APP to believe, erroneously, that the aircraft was already over Sabadell; this was an involuntary error (on both sides: ATC and aircraft) which was physically impossible to correct when Air Traffic Control realised it.

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3. Recommendations

3.1

Emphasis should be given to the need for commanders of aircraft flying on a new route to verify successive positions of the aircraft using all the aids available on board, rather than relying on the evidence of any one of them.

3.2

It would perhaps be desirable that the rules laid down by ICAO for radar identification should be revised, to prevent similar situations occurring. The Spanish authorities, for their part, have already made suitable provision in this respect, so that identification can be properly checked by more than one method.

3.3

Radio installation charts which are used for navigation purposes (radio navigation charts) should incorporate spot heights of the significant points along the route to be followed.

Madrid October 1971

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Aerolineas Argentinas, Comet IV, LV-AHR, accident at Campinas Airport, Sao Paulo, Brazil, 23 November 1961,

Report released by The Brazilian Air Ministry

Circumstances

The flight had originated at Buenos Aires, Argentina. At Vira Copos (Campinas) Airport, Brazil, the engines were started at 05:20 hours and the aircraft took off for Trinidad (alternately

Barbados) at 0538 hours. After reaching an altitude of about 100 m, the aircraft lost altitude, collided with a eucalyptus forest and was destroyed. Twelve crew and forty passengers died in the accident, which occurred at approximately 05:40 hours .

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Investigation and Evidence

The Aircraft

It had flown a total of 5 242 hours, 2 242 of which had been flown since the last overhaul and about 6 hours since the last 90-hour inspection. It was not possible to check the maintenance reports regarding the 30 days prior to the accident.

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The Crew

A pilot-in-command, co-pilot and ten other crew members were aboard the flight . The pilot-in-command was sitting in the right-hand seat, presumably acting as instructor at the time of the accident.
He had flown the following hours:

total flight time : 12 550 hours
as pilot-in-command or instructor : 11 246 hours
by night : 5 791 hours
in the same type aircraft : 1 612 hours
as pilot-in-command or instructor in the same type of aircraft : 584 hours
He held a valid IFR rating.

The co-pilot was sitting in the lefthand seat and had no flight time registered as pilot-in-command on this type of aircraft. It was, therefore, believed that he was receiving instruction as such.
His previous experience was:

total flight time : 13 427 hours
in the same type of aircraft : 1 074 hours
as pilot-in-command in this type of aircraft : zero hours
by night : 2 833 hours
instrument flight : unknown
He also held a valid IFR rating.
It was not believed that the accident was caused by fatigue as the crew had only flown about 3 hours during the preceding 24 hours .

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Weather conditions

It was not believed that the weather situation contributed to the accident. It was a dark night due to 7/8 stratocumulus at 400 m and to 8/8 coverage by altostratus at 2 100 m.

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Weight at take-off

At time of take-off the aircraft was estimated to weigh 71488 kg. The maximum authorised weight was 72575 kg, i.e. 1087 kg below the maximum allowed.

The centre of gravity was within the prescribed limits.

From the time of starting the turbines to the actual take-off about 528 kg of fuel were consumed thus increasing to 1 615 kg the balance in favour of safety. According to the control tower's testimony the take-off run was approximately 2 000 m. According to the dispatch estimate it should have been 2 240 m.

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Take-off run

From tests with LV-AHU, another aircraft the same type as LV-AHR, it was concluded that the take-off run took about 40 seconds.

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Climbing angle

In view of the control tower operator's testimony, the conclusion was reached that the aircraft's climbing angle was around 4.5 deg. The aircraft reached an estimated altitude of 100 m. Taking into account the minimum climbing angle of 4.5 deg, the aircraft should have reached an altitude of 120 m, which corroborates the control tower operator's statements.

Comparing the above with the results obtained during the LV-AHU test flight, it was concluded that from the beginning of the take-off run up to 120m, LV-AHR took about 55 seconds. Then it should have reached the indicated airspeed of 170 kts. At that moment LV-AHR was midway between the take-off point and the first impact point. So taking into consideration the remaining runway (1 240 m and the distance from the end of the runway to the first impact point (1 930 m), the aircraft flew 3 170 m.

The point where the aircraft started losing altitude could not precisely be stated ... however, it may be estimated as the middle distance between the point where the aircraft became airborne and the first impact point.

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Comet IV flight instructions

According to the instructions, when a speed of 170 kts is reached, the pilot must control the "elevator change gear". When changed from "coarse" to "fine" the aircraft's nose has a tendency to drop, which has to be counteracted by using the manual trim tab. It was believed that the unit was under control when the accident occurred.

From analysis it was deducted that the aircraft, LV-AHR, hit the eucalyptus tree in a nearly horizontal attitude, which leads to the conclusion that the pilot, a short time before, when noting the loss of altitude, attempted to regain climbing attitude but due to the action of the elevator travel limiting unit in the "fine" position, the aircraft took longer to regain it. This must have been the reason why, at the moment of collision with the tree, the aircraft was still flying in a horizontal attitude.

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Reconstruction of the last part of the flight

One hundred and twenty meters after the first impact point the pilot put the aircraft in a climbing angle of approximately 25 deg. This conclusion was reached as the eucalyptus trees were burned from the top down, probably by turbine exhaust gas, and the elevator counterbalance collided with a eucalyptus tree and was then torn off. About 145 m after the first impact point the aircraft collided with a larger eucalyptus tree and fire in the left wing pod tank resulted.

Moments later a further impact occurred with another eucalyptus in the No. 1 reactor area. The aircraft began sinking . Due to terrain declivity the aircraft touched the ground about 303 m from the first impact point. The aircraft slipped, ultimately collided with a ground obstacle, and exploded. Many fuselage parts found 120 m from the first impact point showed no signs of fire.

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Probable Cause

It was presumed that the co-pilot was under flight instruction. If such was the case, the instructor, who was pilot-in command, may have failed to brief or supervise the co-pilot properly.

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Observations of the Government of Argentina as the State of Registry of the Aircraft Concerned

Argentina has determined in the light of information it has gathered, that the cause of the accident was "Failure to operate under IFR during a take-off by night in weather conditions requiring IFR operation and failure to follow the climb procedure for this type of aircraft; a contributory cause was the lack of vigilance by the pilot-in-command during the operations."

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IMPORTANT NOTE : *The information contained is this report remains the property of the Brazilian Air Ministry and may not be distributed without their written approval.*

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British European Airways Corporation, Comet IVB, G-ARJM, accident at Esenboga Airport, Ankara, Turkey, 21 December 1961,

Report released by The Ministry of Communications, Turkey and by the UK Ministry of Aviation

Circumstances

The aircraft was on a scheduled flight from London to Rome, Athens, Istanbul, Ankara, Nicosia and Tel Aviv. From Istanbul the flight was operated by British European Airways on behalf of Cyprus Airways. The operating crew, employed by BEA, consisted of a captain and two first officers. Also aboard were four cabin staff employed by Cyprus Airways and 27 passengers.

The trip to Ankara was normal. The time between landing and starting engines at Ankara was 46 minutes during which light snow was falling. (At take-off the aircraft had a light covering of snow on the upper surface of its wings, however, this deposit had no bearing on the accident).

The radio-telephony tape recording showed that the aircraft taxied out along the short taxiway, then back-tracked up the runway to its take-off position on runway 21 at the intersection with the longer taxiway. The runway length available from this position was 9 027 ft. Take-off weight was 53 465 kg, i.e. 18 185 kg below maximum permissible weight or 1 085 kg below the regulated take-off weight.

The takeoff run as to distance and time was quite normal, as also were rotation and unstick. The first abnormality occurred a second or two after unstick when the aircraft rapidly assumed an excessively steep climbing angle. One witness put the angle achieved as about twice the normal, another as 45 deg to 50 deg There was also evidence from witnesses of a wing drop and of variations in the engine noise during this climb. The aircraft stalled with the left wing down at a height of about 450 ft then sank to the ground in a relatively flat attitude. The accident site was 1 600 m and on a bearing of 214 degT from Esenboga Tower. The accident occurred at 21:43 hours GMT.

G-ARJM was almost completely destroyed by impact and fire. All 7 crew and 20 passengers were killed. Six passengers were seriously injured.

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Investigation and Evidence

The Crew

The operating crew held valid licences. The captain had flown a total of 13 240 hours including 785 hours on Comet aircraft.

The Aircraft

It had valid certificates of airworthiness, registration and maintenance and had been maintained in accordance with the approved maintenance schedule. The aircraft's weight and centre of gravity were within the permissible limits.

There was no record of any defect or repair during the recent operation of the aircraft which could be considered to have any bearing on the accident.

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Weather conditions

At 21:50 hours GMT (i.e. 7 minutes after the accident) the weather conditions were
surface wind: calm; visibility: 2 km;
weather: snow; 6/8 stratus at 600 ft.; 6/8 Ns at 2 500 ft; 8/8 As at 7 000 ft.;
temperature 0 degC,

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Navigational Aids

All the ground navigational aids and radio-telephony channels were checked after the accident and were found to be functioning satisfactorily. The ILS was not operational and had been notified as such by Notam.

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The Accident Site

The ground at the scene of the accident sloped up at an angle of 2 or 3 deg, and the aircraft struck on a heading of 180 degM without yaw with the left wing down and the fuselage parallel to the ground. The nature of the damage, the marks on the ground and the disposition of the wreckage all indicated that the aircraft had a low forward speed coupled with a high rate of descent at the moment of impact.

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Technical Examination

External examination of all flying control surfaces revealed no evidence of any damage or abnormality. No evidence was found of any control or electrical failure or emergency such as pilot's seat slippage or fouling of the control column, nor was there any evidence of fire or structural failure prior to the impact with the ground.

Flaps were in the take-off position (i.e. 20 deg) dive brakes were in, and the landing gear "down" and locked. No evidence of any malfunction of the engines was found, however two of the three booster pumps in each of the No. 4 fuel tanks should have been switched on for take-off but all were found switched off. This failure to follow the fuel management drill may have brought about fuel starvation of the two outer engines when the climb became steeper than normal, but it did not contribute to the accident as a stall was by then inevitable and any subsequent recovery impossible because of lack of height,

The captain's director horizon was examined by the Royal

Aircraft Establishment, Farnborough (England). it was found that the pitch pointer "spider" was being obstructed by the upper left dial mask screw, which had unscrewed sufficiently for its head to be in the plane of movement of the "spider". To attain this position, the screw had to be three and a half turns from the fully tightened condition. Examination of the screw head, the washer and the surface around the screw hole in the dial mask flange showed that the screw had not been tightened down fully during the assembly of the instrument. Local disturbance of the paint of the flange suggested that the assembly was tightened to within about half a turn from the fully tightened state.

Checks have shown that complete obstruction to "spider" upward movement would have first occurred when the screw was one full turn from the condition as found. At this time the "spider" had to be below the screw position and since the "spider", and hence the pitch pointer, gives a direct indication of aircraft pitch attitude, then the aircraft had to be below 7.5 deg of pitch (the aircraft angle equivalent to the obstructed position of the pitch pointer).

The instrument had been installed in the aircraft during construction of the latter and there had been no reports of any malfunctioning of it since 12 October 1961 when the left vertical gyro was changed.

The inspection records showed that this instrument had been inspected at all the requested stages of manufacture. In the inspection procedure laid down by the manufacturers there is a specific item "check that MAIN MASK fixing screws are secure".

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Analysis

The position of the impact point in relation to the unstick point, the fact that the aircraft did not begin to assume an abnormally nose-up attitude until a second or two after unstick, and the fact that the landing gear was not selected up, together gave a strong indication that something unusual occurred immediately after unstick. From unstick the aircraft assumed an increasingly steep angle which reached about 45 deg, that is about twice the normal, before it stalled. The exact sequence of events and the actions of the crew during the brief flight cannot be established.

The only fault in the aircraft and its equipment that could account for the abnormally steep climb was the obstruction of the pitch pointer in the captain's director horizon, It is believed probable that the captain looked at this instrument for attitude information immediately after unstick and seeing the pitch pointer only about half way to the normal nose-up position on the pitch scale, applied more up elevator. Although this would have at once steepened his climbs there would have been no indication of it from the pitch pointer, It has been calculated that the time interval between unstick and the stall was approximately 8 to 10 seconds.

The evidence suggests that the outer engines may have begun to fail due to fuel starvation after the angle became excessive. But as the fuel starvation would have occurred very close to the stall and when recovery was impossible in the height available, it is not considered a contributory cause of the accident.

In the event that the co-pilot was at the controls for the take-off the accident would then have been brought about by the captain either telling the co-pilot to increase the climb or himself pulling back the control column, basing his action upon glance at his own director horizon.

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Safety harness of the crew

Only the lap straps of the crew's safety harness were fastened at impact, it is probable that the three pilots would save survived had they used the shoulder straps of their harnesses.

Probable Cause

The probable cause of the accident was the obstruction of the pitch pointer in the captain's director horizon which led him to make an excessively steep climb immediately following unstick.

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May-97
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incidents.
Descriptions : Detailed descriptions of all Comet accidents and incidents.
Available Comet accident reports : List of available De Havilland Comet accident reports.

http://surf.to/comet: Official accident report of Comet I G-ALYY

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Ministry of Transport and Civil Aviation

Civil Aircraft Accident
Report of the Court of Inquiry into the accident to
Comet G-ALYY on 08th April, 1954

THE CIVIL AVIATION ACT, 1949

THE CIVIL AVIATION (INVESTIGATION OF ACCIDENTS) REGULATIONS 1951

Report of the Public Inquiry into the causes and circumstances of the accident which occurred on the 8th April, 1954, to Comet aircraft G-ALYY

* AIRCRAFT: Comet G-ALYY
* ENGINES: Four de Havilland Ghost 50
* REGISTERED OWNERS: British Overseas Airways Corporation
* OPERATORS: South African Airways (under charter)
* CREW:
* Senior Captain W. K. Mostert - Killed
* First Officer B. J. Grove - Killed
* Navigation Officer A. E. Sissing - Killed
* Flight Engineer Officer A. R. Lagesen - Killed
* Radio Officer B. E. Webbstock - Killed
* Steward J. B. Kok - Killed
* Air Hostess P. Reitz - Killed
* PASSENGERS: 14 - All Killed
* PLACE OF ACCIDENT: Over the Mediterranean, S.E. of Naples.
* TIME OF ACCIDENT: 8th April, 1954, at about 19:10 G.M.T.

All times in this Report are G.M.T.

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PART I
INTRODUCTORY

(a) Matters in common with the Report on G-ALYP

1. In my Report of today on the accident to Comet aircraft G-ALYP (sometimes called Yoke Peter) I gave a short explanation of the constitution and functions of the Air Registration Board (A.R.B.) and of the Air Safety Board (A.S.B.) which I need not repeat here. It is also unnecessary for me to repeat the account I gave in that Report of the origin and history of the Comet aircraft.

2. As the two Inquiries were conducted together, the evidence in the Inquiry into the loss of Yoke Peter is the evidence in the present Inquiry. I need not, therefore, append any lists of the witnesses or parties represented at the hearings or the dates of such hearings.

(b) Arrangements with South African Airways

3. South African Airways are the national operators of the Government of the Union of South Africa. Air communication between London and South Africa was carried on under arrangements made between British Overseas Airways Corporation (hereinafter called " B.O.A.C. ") and South African Airways. I need not go in full into the history of the arrangements between the two operators. Suffice it to say that the arrangements were revised on the 3rd October, 1953 and it was agreed, amongst other things, that South African Airways should participate with B.O.A.C. in the operation of the standard class services between England and the Union of South Africa by operating Comet aircraft chartered from B.O.A.C. The Corporation trained the necessary South African Airways crews to carry out this arrangement. Amongst the aircraft so chartered to South African Airways was Comet G-ALYY (sometimes hereinafter called Yoke Yoke).

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PART II
THE ACCIDENT

4. Yoke Yoke left Ciampino Airport, Rome, at 18:32 hours on the 8th April, 1954 on a flight to Cairo. After taking off the aircraft from time to time gave its position by radio telephone to Rome Air Control at Ciampino and on the last such occasion at about 18:57 hours reported that it was abeam Naples and climbing to 35,000 ft. This position and those given earlier indicated that the flight was proceeding according to the B.O.A.C. flight plan. At 19:05 hours Cairo received a signal from the aircraft reporting its departure from Rome and giving its estimated time of arrival at Cairo. Thereafter no message was received from Yoke Yoke and all attempts to make contact failed.

5. A chart, which is Figure 1 of my Report on Yoke Peter, was prepared by a Navigating Officer of B.O.A.C. from all the information available, and shows the probable flight track of the aircraft. It also indicates the position in which bodies and wreckage were found on the day following the accident. It is evident from the chart that something catastrophic happened to the aircraft at about 19:10 hours when it must have been at or near the end of its climb to 35,000 ft.

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PART III
THE AIRCRAFT

6. Yoke Yoke was the same in all relevant respects as Yoke Peter. Details of Yoke Peter are given in my Report thereon and I need not repeat them here.

7. Yoke Yoke was granted a Certificate of Registration No. R.3221/1 on the 18th September, 1951 in the name of B.O.A.C. as owners and first flew on the 10th September, 1952. On the 23rd September, 1952 it was certified and approved by A.R.B. for the issue of its Certificate of Airworthiness and this Certificate, No. A.3221, was issued by the Ministry of Civil Aviation on the 30th September, 1952. After approval by A.R.B. on the 21st September, 1953 the Certificate of Airworthiness was renewed on the 23rd September, 1953 and was valid at the time of the accident.

8. After the accident to Yoke Peter on the 10th January, 1954, special checks, in addition to the routine Check 4 in accordance with the Approved Maintenance Schedules, were carried out on Yoke Yoke and a number of modifications were made affecting the airframe the controls and the fire detection and protection at the engines. On the 15th February, 1954, the fuselage was subjected to a proving test to 11 lb/sq. in. The aircraft was returned available for service on the 24th February, 1954.

9. On the 2nd April, 1954, following a Check 1 inspection in accordance with the Approved Maintenance Schedules, carried out at London Airport, a Certificate of Maintenance signed by duly licensed airframe and engine maintenance engineers and expressed to be valid for 75 flying hours, was issued. Further reference to this Certificate is made in paragraphs 21 and 22 of this Report. On the 7th April, 1954, an Aircraft Radio Station Certificate of Serviceability was issued and showed no items unserviceable.

10. At the time of the accident Yoke Yoke had had a total flying life of about 2,704 hours including 841 since the renewal of its Certificate of Airworthiness and including less than 75 hours since the issue of the Certificate of Maintenance on the 2nd April, 1954.

11. From examination of the airframe and engine log books and maintenance records it appeared that all routine inspections of airframe and engines had been regularly carried out within the limits of time specified by the Approved Maintenance Schedules and that the flying life of each of the engines since its last complete overhaul was within, and in two cases very well within, the approved life between complete overhauls. Save as mentioned in paragraphs 21 and 22 of this Report the evidence disclosed no irregularity in connection with any such inspection.

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PART IV
THE CREW

12. Senior Captain Willem Karel Mostert, who was in command of Yoke Yoke was born on the 27th April, 1916. Before joining South African Airways he had flown 2,812 hours in the South African Air Force and had served as a flying instructor. He joined South African Airways on the 10th June, 1946, was promoted Captain on the 1st November, 1946 and on the 15th June, 1949 became a Flying Instructor. On the 15th May, 1953, he became Senior Flying Instructor and on the same day was promoted to the rank of Senior Captain.

In June, 1953, Captain Mostert was transferred to the Comet Line of South African Airways and became the Comet Line Instructor. In South African Airways, captains who are appointed Line Instructors have to spend two-thirds of their time on route flying and one-third on instruction within the line. During his service with South African Airways Captain Mostert flew a total of 8,159 hours of which about 51 hours by day and 35 hours by night were flown in Comets within the six months preceding the accident.

13. Captain Mostert's last "six monthly check" prior to the accident was carried out on the 19th December, 1953 and his report was: "Proficient. (Very well executed flight)". He had not been involved in any previous accident. Captain Mostert was the holder of a Union of South Africa Air Line Transport Pilot's Licence No. 65A valid until the 11th June, 1954. A rating for Comet aircraft had been added to this licence by the British Ministry of Transport and Civil Aviation. I am satisfied that Captain Mostert was fully equipped to carry out his normal duties as a pilot and as a captain and to deal with emergencies.

14. The second pilot was First Officer Barent Jacobus Grove who was born on the 15th July, 1922. After service in the South African Air Force, in which he had flown a total of 1,640 hours, he joined South African Airways on the 29th January, 1953, as a First Officer and was posted to the Comet Line on the 26th February 1953. While with South African Airways First Officer Grove flew for a total of 54 hours, including about 47 hours in Comets during the 90 days preceding the accident.

There was no evidence of First Officer Grove having been involved in any previous accidents save as a result of enemy action. His last check took place on the 20th February, 1954, when he obtained a satisfactory pass. First Officer Grove was the holder of a Union of South Africa Senior Commercial Pilot's Licence No. 48 (S), valid until the 11th June, 1954, to which a Comet rating had been added on the 2nd March, 1954. I am satisfied that he was fully equipped to carry out his normal duties and to support his captain in emergencies.

15. Navigation Officer Albert Escourt Sissing was born on the 1st January, 1917. After training in the South African Air Force he joined South African Airways on the 16th October, 1946 and from then until his death had 4,840 hours flying experience including about 155 hours in Comets in 1953 and about 51 hours in Comets during 1954, all of the latter during the 90 days preceding the accident. At his last six monthly check, in March, 1954, he passed in Comet Refresher Flight Planning and Plotting. Navigation Officer Sissing was the holder of a Union of South Africa Navigator's Licence No. 17(N) valid until 1st December, 1954 and I am satisfied that he was a capable officer.

16. Radio Officer Bertram Ernest Webbstock was born on the 17th June, 1917. He joined South African Airways on the 23rd April, 1946 and after spending some time on the London service passed a Comet course on the 20th June, 1953 and thereafter flew only in Comets. His total flying hours were 4,373 of which about 98 hours were during the 90 days preceding the accident. He was passed as proficient in his Comet check on the 5th October, 1953. Radio Officer Webbstock was the holder of a Union of South Africa First Class Flight Radio Operator's Licence No. 348 valid until the 30th April, 1954 and I am satisfied that he was a capable officer.

17. Flight Engineer Officer August Ranwald Lagesen was born on the 22nd May, 1920. He had wide experience of several types of aircraft both during the war and after rejoining South African Airways on the 16th February, 1945. There was no positive evidence relating to his flying hours prior to the 11th May, 1950 but such records as were available suggested that up to that date he had flown a total of about 4,300 hours. After the 11th May, 1950 he had a total flying time of 2,290 hours 35 minutes. He had flown about 203 hours in Comets including about 141 hours during the 90 days preceding the accident and had completed a Comet Conversion Course on the 2nd September, 1953, a Comet Refresher Course on the 19th December, 1953 and a further refresher course and flight training programme on the 21st March, 1954. He was examined on the 19th December, 1953 and found proficient. Flight Engineer Officer Lagesen was the holder of a Union of South Africa Aircraft Maintenance Engineer's Licence No. 387, valid until the 26th February, 1955, and Flight Engineer's Licence No. 10 valid until the 22nd February, 1955. I am satisfied that he was a capable officer.

18. Air Hostess Pamela Reitz, who was born on the 16th February, 1932 and Steward Jacobus Bruwer Kok, who was born on the 18th December, 1918 had both flown extensively with South African Airways.

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PART V
THE PASSENGERS AND CARGO

19. Yoke Yoke carried 14 passengers all of whom were killed in the accident. There was nothing in the cargo which could have been relevant to the cause of the accident and I am satisfied that, despite the off-loading of a small bag of aircraft spares at London after the Load Sheet had been completed, the aircraft was loaded and trimmed within the prescribed limits.

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PART VI
PRE-FLIGHT INCIDENTS

20. Yoke Yoke, in common with the rest of the Comet fleet of B.O.A.C., had been grounded by B.O.A.C. after the accident to Yoke Peter. The circumstances in which Comet services were resumed are fully stated in paragraphs 54 to 57 of my Report on the accident to Yoke Peter and I need not repeat them here.

21. Yoke Yoke arrived at Ciampino on the 7th April from London and was due to depart from Ciampino the same evening. However, on completion of refuelling it was discovered that the centre tank contents gauge showed no reading although the tank was full. The fault was eventually traced to a co-axial cable for which a replacement had to be flown from England and the departure of the aircraft was consequently delayed for about 24 hours.

While the fault was being traced a number of bolts were found lying about in the port wing of the aircraft and further inspection revealed that an equal number of bolts were missing from the inspection panel providing access between the rear spar and the wheel-well wall and that the remainder of the bolts securing the panel, though in position, were not properly tightened. The missing bolts were replaced and all were properly tightened. The maintenance engineer who supervised this work was satisfied from visual examination and from the readiness with which the missing bolts were refitted that no distortion of the panel or adjacent structure had occurred during the absence of the bolts.

22. As has been stated in paragraph 9 a Check 1 inspection was carried out on Yoke Yoke before the issue of the Certificate of Maintenance on the 2nd April. It is quite clear that it must have been during that inspection that the panel was removed and incorrectly refitted and I was informed that disciplinary action had been taken against the inspectors concerned.

23. The arrangements for safeguarding the aircraft during its stay at Ciampino were the subject of a great deal of evidence. For the greater part of this period Yoke Yoke was under observation by B.O.A.C. officials whose duties, however, were not primarily concerned with security. For the rest of the time it was guarded by an Italian Finance Guard whose main duty was to prevent smuggling. In all the circumstances I consider it unlikely that any unauthorised person gained access to the aircraft.

24. Apart from the above-mentioned defects, the Refuel and Departure checks disclosed nothing unusual.

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PART VII
WEATHER CONDITIONS AT THE TIME OF THE ACCIDENT

25. From the take-off at Rome at 18:32 hours on the 8th April, 1954 until the time of the accident, which was approximately 19:10 hours, Yoke Yoke climbed through three moderately thick layers of cloud. In the top layer there may have been slight to moderate icing conditions but these would have been insufficient to cause anxiety. It is unlikely that any severe turbulence was encountered either during the climb through the cloud layers or in the clear air above. It can, therefore, be assumed that the state of the weather was not a contributory cause of the accident.

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PART VIII
ACTION TAKEN AFTER THE ACCIDENT

26. As in the case of the accident to Yoke Peter the assistance of the Royal Navy was invoked and on the 9th April, 1954, H.M.S. Eagle and H.M.S. Daring, proceeded to search for

Yoke Yoke. Avenger aircraft of H.M.S. Eagle were used to assist in the search as also were certain United States aircraft. A number of dead bodies as well as some aircraft seats and other wreckage were identified in the water and in due course recovered. The depth of water where the bodies and Wreckage were found varied between approximately 520 fathoms and 580 fathoms and the evidence established that at that depth the prospect of further recovery was hopeless.

27. The six bodies recovered were not examined by Professor Fornari, who had examined the bodies recovered at Elba, but four of them were examined at Uxbridge on the 12th April, 1954 by Dr. Teare, one was not subjected to autopsy and the other was examined by the Italian authorities.

These examinations did not disclose anything inconsistent with the view that the accident to Yoke Yoke was attributable to the same cause as the accident to Yoke Peter.

28. As a result of the accident to Yoke Yoke the Royal Aircraft Establishment (hereinafter referred to as R.A.E.) were directed to conduct a full investigation into it and the accident to Yoke Peter. In the absence of any wreckage from Yoke Yoke R.A.E. could only proceed with their investigations in the light of a priori reasoning and experiments and of conclusions to be drawn from the wreckage of Yoke Peter. I have dealt at length with the R.A.E. investigations and Report in my Report on the accident to Yoke Peter.

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PART IX
THE COURT'S CONCLUSION AS TO CAUSE OF ACCIDENT

29. R.A.E's conclusion as regards the cause of the accident to Yoke Yoke is expressed in the following paragraph: "Owing to the absence of wreckage, we are unable to form a definite opinion on the cause of the accident near Naples, but we draw attention to the fact that the explanation offered for the accident at Elba appears to be applicable to that at Naples". I agree with this conclusion and have only to add that it is impossible in the case of the Naples accident to be dogmatic that defects of the kind considered in paras. 108-144 of my Report on Yoke Peter were not contributory causes to the Naples accident. I am therefore glad to note that the programme of future action outlined by the de Havilland Aircraft Company Limited and set forth in Appendix VIII to my Report on Yoke Peter includes measures to deal with those defects.

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PART X RESPONSIBILITY

30. I have dealt at length faith this question in my Report on the accident to Yoke Peter. There is, however, one matter on which criticism was made which is applicable only to Yoke Yoke and that is the decision, after the accident to Yoke Peter, to allow the Comet passenger services to be resumed on the 23rd March, 1954. I have set out in paras. 52 and 53 of my Report on the accident to Yoke Peter the nature of the full investigation carried out by the Committee under the chairmanship of Mr. Abell, the Deputy Operations Director (Engineering) of B.O.A.C. and the modifications made on the recommendation of that Committee.

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

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PART XI
FUTURE

32. I cannot usefully add anything to what I have said on this branch of the Inquiry in my Report on the accident to Yoke Peter.

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PART XII
QUESTIONS AND ANSWERS

My answers to the questions submitted on behalf of the Attorney-General are as follows:

Question 1.
What was the cause of the accident?

Answer.

Owing to the impossibility of salvaging any appreciable part of the wreckage of the aircraft no positive answer can be given to this question but the fact that this accident occurred in similar weather conditions, at approximately the same height and after approximately the same lapse of time after take-off from Rome as that to G-ALYP makes it at least possible that the cause was the same as in that case. The state of the bodies recovered was, as in the case of G-ALYP, consistent with the accident being due to failure of the cabin structure owing to metal fatigue.

Question 2.
If several factors caused the accident what were such factors and to what extent was each contributory?

Answer.
I cannot usefully add anything to my answer to Question 1.

Question 3.
Was the accident due to the act or default or negligence of any party or of any person in the employment of that party?

Answer.
There was no evidence on which I could attribute the accident to the wrongful act or default or negligence of any party or of any person in the employment of any party.

Question 4.
At the time of the accident:

Question 4 (a).
Had the aircraft been properly maintained in accordance with the current approved maintenance schedules? If not did any defect in maintenance affect the safety of the aircraft or contribute to the accident?

Answer.

The aircraft had been properly maintained save that on arrival at Rome a number of bolts were found lying in the port wing of the aircraft and further inspection revealed that an equal number of bolts were missing from the inspection panel providing access between the rear spar and the wheel well wall and that the remainder of the bolts securing the panel though in position were not properly tightened. The missing bolts were replaced and all were properly tightened and I am satisfied that this defect in maintenance did not affect the safety of the aircraft or contribute to the accident.

Question 4 (b).
Was the aircraft airworthy so far as could reasonably have been then ascertained?

Answer.
Yes.

Question 4 (c).
Was there a valid Certificate of Airworthiness in respect of the aircraft?

Answer.
Semble yes. I do not find it necessary to deal with the legal question whether the default in reassembly referred to in paras. 21 and 22 of this Report had any effect on the validity of the Certificate of Airworthiness since I am satisfied that this default did not contribute to the accident.

Question 4 (d).
Was there a valid Certificate of Maintenance in respect of the aircraft?

Answer.
Semble yes. see my answer to Question 4 (c) on Certificate of Airworthiness.

Question 4 (e).
Was the radio station of the aircraft serviceable and was there a valid Certificate of Serviceability in respect thereof?

Answer.
Yes.

Question 4 (f).
Was the aircraft properly loaded and trimmed within the limits specified in the Flight Manual?

Answer.
Yes.

Question 4 (g).
Were all members of the crew properly licensed and adequately experienced to make the flight? If not did any defect in the licence of any member of the crew affect the safety of the aircraft or contribute to the accident?

Answer.
Yes. The second part of the question does not arise.

Question 5.
Was the Minister of Transport and Civil Aviation properly advised in March, 1954 that Comet services should be resumed?

Answer.
Yes. See paragraph 31 of this Report.

Question 6.
Upon consideration of all facts disclosed by this Inquiry what steps should be taken to increase the safety of civil aircraft?

Answer.
See paragraphs 140-155 of my Report on Yoke Peter.

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Report by COHEN., W. S. FARREN., W. J. DUNCAN., A. H. WHEELER.
1st February, 1955.

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Descriptions : Detailed descriptions of all Comet accidents and incidents.
Available Comet accident reports : List of available De Havilland Comet accident reports.

http://surf.to/comet: Official accident report of Comet I G-ALYZ

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B.O.A.C., Comet I, G-ALYZ, accident at Ciampino Airport, Rome, Italy, 26 October 1952,

Report released by I.C.A.O.

Circumstances

The aircraft was operating a scheduled passenger service from London to Johannesburg. The flight from London Airport to Rome was without incident. During the take-off from Rome on the second stage, the aircraft's normal speed failed to build up and after becoming airborne for a few seconds the Captain's immediate reaction was that there was a lack of engine thrust. He throttled back the engines at the same time as the aircraft came to rest near the airport boundary, and the aircraft sustained considerable damage and two passengers were slightly injured.

Investigation and Evidence

For take-off the aircraft was taxied to Runway 16 and lined up on the centre line; all pre-take-off checks were made and the elevator, aileron and rudder trim were set at the neutral position. The Captain's estimation of runway visibility was 5 miles but with no horizon. The flaps were lowered to 15 deg. and the windscreen vipers were both operating. The engines were opened up to full power and the isolation switches were set to "Isolate" The RPM were checked at 10.250 on all engines; fuel flows, engine temperatures and pressures were reported to be correct. The brakes were released and the aircraft made a normal acceleration. At an IAS of 75-80 knots, the nose wheel was lifted from the runway and a slight tendency to swing to starboard was corrected. At an IAS of 112 knots the Captain lifted the aircraft from the ground by a positive backward movement of the control column and when he considered that the aircraft had reached a safe height he called for "undercarriage up". At about the same instant the port wing dropped rather violently and the aircraft swung to port; the controls gave normal response and lateral level was regained. At this point the Captain realised that the aircraft's speed was not building up, although he made no reference to the ASI. A pronounced buffeting was felt which he associated with the onset of a stall and in spite of two corrective movements of the control column the buffeting continued. Before the First Officer had time to select undercarriage up, the aircraft came down on its main landing wheels and bounced. It was now plainly evident to the Captain that the aircraft's speed was not increasing and he was convinced that there was a considerable loss of engine thrust. He was also aware that the aircraft was rapidly approaching the end of the runway and a decision to abandon the take-off was made. The undercarriage struck a mound of earth as he was closing the throttles and the aircraft slid for some 270 yards over rough ground. The main undercarriages were wrenched off and considerable damage resulted; a large spillage of fuel occurred but fire did not break out. One passenger suffered slight shock and another sustained a cut finger.

Subsequent interrogation of the crew confirmed that all engines had given their maximum power and that fuel flows, temperatures and pressures had all been normal during the take-off. It was the belief of the First Officer that the nose wheel was lifted from the ground in the usual manner although the control column appeared to be "a fair way back". He also thought that the "unstick" was made by moving the control half way back from the neutral position and that it was held there until the port wing dropped. He also stated that he was unable to determine the attitude of the aircraft after the bounce as no runway lights were visible to him.

Due to darkness and due also to rain, no ground witness had a clear view of the take-off. One, however, who observed it from a point opposite the half-way position of the runway, considered that the aircraft's attitude was critical as it passed him. He continued to observe it as the nose was exceptionally high and he vas not aware that the aircraft became airborne.

An inspection carried out at the scene of the accident showed that the aircraft came to rest about 270 yards from the upwind end of runway 16 and 10 yards from the boundary fence; considerable damage had resulted. A large spillage of fuel from the port wing integral tanks had occurred but fire did not break out. Both inertia switches had tripped. The two crash switch operating levers functioned correctly and the methyl fire extinguisher bottles had discharged. The seats and their attachments in the crew and passengers compartments were undamaged. The crew's forward entrance door and the passenger's entrance door functioned normally as also did the emergency hatches.

The flaps were: in the lowered position of about 15 deg. and this corresponded to that indicated in the cockpit, The elevator, aileron and rudder trim indicators were in the neutral position. Wheel marks on the runway showed that the main landing wheels had been in contact with the runway over the last 30 feet of its length. The next contact was made on two mounds of earth, when this occurred the undercarriages were wrenched off and parts of these units damaged the tailplane. The port main plane hit the runway direction indicator which is mounted on concrete blocks and the wing tip and pitot head were torn off. The starboard inner engine steady strut had become detached at its forward end when the attachment bracket rivets had sheared due to impact forces. This detachment allowed the engine to rotate on its mounting trunnions through the mainplane skin and in a nose-down direction.

The nose wheel was forced upwards into its housing and the tail bumper unit was torn from the rear portion of the fuselage. The bumper attachment bracket was subsequently found in the wreckage trail, An examination of this bracket showed that the shoe was missing and that the bracket was deeply scarred. A search made along the runway revealed evidence of tail bumper marks which varied in length from 3 feet to 40 feet. These marks extended along the last 650 yards of the runway and showed that the aircraft's track was inclined a few degrees to starboard of the runway centre line.

The BOAC Training Manual recommends the following take-off technique:

"At 80 knots the nose should be lifted until the rumble of the nose wheel ceases. Care should be taken not to overdo this and adopt an exaggerated tail-down attitude with a consequent poor acceleration."

The normal fuselage incidence during the take-off ground run is about 2 to 3 deg. after the nose wheel has been raised just clear of the runway. To do this a backward stick movement of about 4 inches is required which is then reduced to 1 to 1.5 inches. The attitude of "unstick" is approximately 6 deg. to 6.5 deg. and to attain this the required stick movement at the time of leaving the ground is of the order of 6 inches back from the neutral position, after which the stick must be returned towards the pre-take-off position.

Take-off by the manufacturers have shown that a constant 6 deg. incidence of fuselage during the ground run gives good results for distance run and for climb-away behaviour. They have also shown that an increase of incidence to 9 deg. results in a partially stalled wing giving high drag which appreciably affects the aircraft's acceleration, and that the symptoms are noticeable to the pilot as low frequency buffet. The aircraft recovers from its semi-stalled position if the nose is pushed well down.

Figure shows a diagrammatic representation of the nose-up attitude of the aircraft in the correct position of unstick, i.e., 6 deg. to 6.5 deg. nose up. The Appendix also shows that for the tail bumper to touch the ground an angle of at least 11 deg. is required.

Probable Cause

The accident was due to an error of judgement by the Captain in not appreciating the excessive nose-up attitude of the aircraft during the takeoff.

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IMPORTANT NOTE : *The information contained is this report remains the property of ICAO and may not be distributed without their written approval.*

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Marc Schaeffer
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Comet history The history of the first jet airliner
Comet variants From the 1st prototype to the Mk5
Comet crashes Summary of all crashes & incidents
Accident reports Several Comet accidents reports
Picture gallery Picture collection of various Comet's
Comet flight 2002 Celebrate 50 years of jet service

Technical data Summary of all the Comet data

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http://surf.to/comet: Comet crashes and hull losses

All Comet crashes : Summary of all De Havilland Comet accidents.
All hull-losses : Summary of all De Havilland Comet incidents.
Descriptions : Detailed descriptions of all Comet accidents and incidents.

http://surf.to/comet: Comet accident reports

G-ALYP Crash : Official accident report of the G-ALYP crash.
G-ALYY Crash : Official accident report of the G-ALYY crash.
G-ARJM Crash : Official accident report of the G-ARJM crash.
G-APDN Crash : Official accident report of the G-APDN crash.
LV-AHR Crash : Official accident report of the LV-AHR crash.
G-ALYZ Crash : Official accident report of the G-ALYZ crash. *Added 16-Aug-99*
CF-CUN Crash : Article about the accident of the CF-CUN crash. *Added 16-Aug-99*

To set up the Comet crash page a major help came from **Harro Ranter** whom I would like to thank with this occasion.

http://surf.to/comet: Summary of all D.H. Comet crashes

In this table you will find the most important information related to all **De Havilland DH106 Comet** crashes. To compile this page, I used different sources. The detailed descriptions of the accidents are listed in separate sections.

Nr	Date	Type	Registration	SN	Operator	Fatalities	Location	Cause
1	26 Oct 52	Comet 1	G-ALYZ	6012	B.O.A.C.	0/8 + 0/35	Rome, Italy	Aircraft

2 03 Mar 53 Comet 1A CF-CUN 6014 Canadian
Pacific 5/5 + 6/6 Karachi,
Pakistan Aircraft
3 02 May 53 Comet 1 G-ALYV 6008 B.O.A.C. 6/
6 + 37/37 Calcutta,
India Aircraft
4 25 Jun 53 Comet 1A F-BGSC 6019 UAT 0/7 +
0/10 Dakar,
Senegal Pilot
5 10 Jan 54 Comet 1 G-ALYP 6003 B.O.A.C. 6/6
+ 29/29 Elba,
Italy Aircraft
6 08 Apr 54 Comet 1 G-ALYY 6011 South African
Airways 7/7 + 14/14 Stromboli,
Italy Aircraft
7 27 Aug 59 Comet 4 LV-AHP 6411 Aerolineas
Argentinas 1/6 + 1/44 Asuncion,
Paraguay Pilot
8 20 Feb 60 Comet 4 LV-AHO 6410 Aerolineas
Argentinas 0/6 + 0/0 Buenos Aires,
Argentinia Pilot
9 23 Nov 61 Comet 4 LV-AHR 6430 Aerolineas
Argentinas 12/12 + 40/40 Sao Paulo,
Brazil Pilot
10 21 Dec 61 Comet 4B G-ARJM 6456 British
European
Airways 7/7 + 20/27 Ankara,
Turkey Aircraft
11 19 Jul 62 Comet 4C SU-AMW 6464 United Arab
Airlines 8/8 + 18/18 Mt Kao Yai,
Thailand Pilot
12 20 Mar 63 Comet 4C SA-R-7 6461 Saudi Arabian
Government 9/9 + 9/9 Cuneo,
Italy Pilot
13 27 Jul 63 Comet 4C SU-ALD 6441 United Arab
Airlines 8/8 + 55/55 Madh,

India Pilot
14 22 Mar 64 Comet 4 G-APDH 6409 Malaysian Airlines
System 0/8 + 0/60 Singapore,
Singapore Aircraft
15 12 Oct 67 Comet 4 G-ARCO 6449 British European
Airways 7/7 + 59/59 Nicosia,
Zypria Bomb
16 14 Jan 70 Comet 4C SU-ANI 6475 United Arab
Airlines 0/9 + 0/5 Addis Ababa,
Ethiopia Pilot
17 09 Feb 70 Comet 4C SU-ALE 6444 United Arab
Airlines 0/9 + 0/14 Munchen-Riem,
Germany Pilot
18 03 Jul 70 Comet 4 G-APDN 6415 Dan-Air
Services 7/7 + 105/105 Sierra Montensy,
Spain ATC
Aircraft
19 07 Oct 70 Comet 4 G-APDL 6413 Dan-Air
Services 0/4 + 0/5 Newcastle,
GB Pilot
20 02 Jan 71 Comet 4C SU-ALC 6439 United Arab
Airlines 8/8 + 8/8 Tripoli,
Libya Pilot

http://surf.to/comet: Summary of other D.H. Comet incidents

Nr Date Type Registration SN Operator
Fatalities Location Cause
A 25 Jul 53 Comet 1 G-ALYR 6004 B.O.A.C. 0/0
Calcutta,
India Pilot
B 13 Sep 57 Comet 2R XK663 6027 RAF 192 sqn
0/0 Wyton,

GB Fire
C 01 Jan 68 Comet C2 7926M 6028 RAF 0/0 Lyneham,
GB Fire
D 28 Dec 68 Comet 4C OD-ADR 6445 Middle East Airlines 0/0 Beirut,
Lebanon Bomb
E 28 Dec 68 Comet 4C OD-ADS 6448 Middle East Airlines 0/0 Beirut,
Lebanon Bomb
F 28 Dec 68 Comet 4C OD-ADQ 6446 Middle East Airlines 0/0 Beirut,
Lebanon Bomb
G ?? ??? 70 Comet 4C XM829 06021 Stansted Airport 0/0 Stansted,
GB Fire

http://surf.to/comet: Details about all D.H. Comet crashes

In this section I summarized the information of the crashes which I collected from different sources. However errors are human, if you think that some information is not correct feel free to post me an . Don't forget to tell me your source.
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1. G-ALYZ / 6012 crash in Rome (Crew 0/8 & Passengers 0/35)

G-ALYZ was the last Comet 1 which was delivered to B.O.A.C. and the first one to be involved in a major incident. The plane with 35 passengers and 8 crew was in the takeoff phase and didn't get altitude. The plane overshoot the runway and stopped finally with broken landing gears. The plane was a hull loss. Initially Captain Foote was made responsible for this incident. It was stated that the plane was pulled up too fast, leading to an interruption of the airflow on the wings.

After the crash of CF-CUN it was found out that a considerable part of the wing lost its lift if the plane was pulled up too fast. A design change of the leading edge of the Comet wings was the solution to this problem. This change proved to be sufficient.

Photo Credit: *Aeroplane Monthly [Sep-89]. Thanks to Trevor Friend for contributing this picture. Added [15-Nov-98]*

Cause of the accident: design fault

[Official accident report of G-ALYZ]

[Back to the listing of all Comet crashes]

2. CF-CUN / 6014 crash in Karachi (Crew 5/5 & Passengers 6/6)

CF-CUN was the first Comet 1A for Canadian Pacific. On its delivery flight from England to Sydney the first fatal Comet crash occurred. In the early morning the 'Empress of Hawaii' didn't takeoff in Karachi. The plane collided with a bridge and took fire. None of the 11 people, including Captain Pentland survived this crash.

Initially the Captain was made responsible, but flight tests found out that a considerable part of the wing lost its lift if the plane was pulled up too fast. A design change of the leading edge of the Comet wings was the solution to this problem. This change proved to be sufficient.

Cause of the accident: design fault

[Accident description of CF-CUN]

[Back to the listing of all Comet crashes]

3. G-ALYV / 6008 crash in Calcutta **(Crew 6/6 & Passengers 37/37)**

G-ALYV was on a flight from Singapore to London. The aircraft was in the initial climb phase and at 10Kft it flew in a heavy tropical thunderstorm. The plane disintegrated in this thunderstorm. The remains of the Comet were found in an area of 20 km2.

The cause of the crash was an overload of the tail of the aircraft. Other crashes of the Comet make the weak structure of the aircraft a more likely reason.

Cause of the accident: design fault

See also the comments about this crash in the YP accident report.

[Back to the listing of all Comet crashes]

4. F-BGSC / 6019 crash in Dakar **(Crew 0/7 & Passengers 0/10)**

The Comet 1A registered, F-BGSC of the French company UAT -- Union Aeromaritime de Transport -- was as scheduled passenger flight in the landing phase to Dakar airport. It overshot the runway and crossed a -- 0.7 m deep and 22 m wide -- sandy culvert. As a result it came to rest 38.4 m later with a sheared landing gear. None of the passengers was injured.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

5. G-ALYP / 6003 crash in Elba (Crew 6/6 & Passengers 29/29)

G-ALYP was as flight BA781 on the way from Singapore to London. A fuel stop was made in Rome. Captain Gibson was in the command when the aircraft crashed at 25Kft. Since the crash occurred in daylight, whiteness could report three explosions. The remains of the aircraft were 150 meters deep in the sea.

Initially an engine explosion or a bomb was assumed to have led to this tragic event. All flights of Comet's were suspended. More than sixty modifications were done on existing Comet aircrafts, all possible causes were eliminated. At least that's what the experts thought at the time. Protections were added in the case of an engine explosion. New fuel pipes, fire and smoke detectors were added. On the 23 Mar 54 the Comet's were again allowed to takeoff.

Only the next Comet crash allowed to find out the real reason of this tragic event. More about it in the next section.

Cause of the accident: design fault

[Official accident report of G-ALYP]

[Back to the listing of all Comet crashes]

6. G-ALYY / 6011 crash in Stromboli (Crew 7/7 & Passengers 14/14)

G-ALYY was leased from B.O.A.C. to South African Airways. Flight SA201 was on its way from London to Johannesburg. After a fuel stop in Rome the plane took-off, but only 36 minutes later the radio-contact was interrupted in the area of Stromboli.

The next morning remains were found in the sea. Since the sea was at this place as deep as 1000 meters, no parts of the aircraft could be inspected. Only four days after the crash the Comet flights were again suspended, one of the reasons being the similarities to the YP crash. G-ALYY had only performed 2704 flighthours. A very intensive flight test program was performed in order to find out the reason of the YY and YP crashes, with no special conclusion.

Only after a very long expensive investigations, which included the assembly of the remains of the crashed YP and the underwater stress test of the YU Comet which came from B.O.A.C. Finally the fuselage of YU broke up on a sharp edge of the forward escape-hatch. After that this rupture was repaired the tests were restarted, but only shortly afterwards the fuselage broke up. This time the rupture started at the upper edge of a window and was three meters long.

The YP and YY crashes were due to metal fatigue, which took place because of the crystalline changes in the fuselage skin. They were amplified by the high speed and altitude the Comets were operated. The metal fatigue resulted in ruptures of the fuselage, this had as a consequence a terrible decompression at 33Kft, tearing up the plane with all known consequences.

Cause of the accident: design fault

[Official accident report of G-ALYY]

[Back to the listing of all Comet crashes]

7. LV-AHP / 6411 crash in Asuncion (Crew 1/6 & Passengers 1/44)

LV-AHP a Comet 4 of Aerolineas Argentinas was on final approach to Asuncion, Paraguay when it hit a hill top. One passenger and one crew member died. Further information is missing.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

8. LV-AHO / 6410 crash in Buenos Aires (Crew 0/6 & Passengers 0/0)

LV-AHO a Comet 4 of Aerolineas Argentinas was in the landing phase of a training flight. The aircraft was damaged beyond repair, due to a heavy landing, but none of the six crewmembers was killed.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

9. LV-AHR / 6430 crash in Sao Paulo (Crew 12/12 & Passengers 40/40)

The flight had originated at Buenos Aires, Argentina. At Vira Copos (Campinas) Airport, Brazil, the engines were started at 05:20 hours and the aircraft took off for Trinidad (alternately Barbados) at 05:38 hours. After reaching an altitude of about 100 m, the aircraft lost altitude, collided with a eucalyptus forest and was destroyed. Twelve crew and forty passengers died in the accident, which occurred at approximately 05:40 hours .

It was presumed that the co-pilot was under flight instruction. If such was the case, the instructor, who was pilot-in command, may have failed to brief or supervise the co-pilot properly.

Cause of the accident: pilot error

[Official accident report of LV-AHR]

[Back to the listing of all Comet crashes]

10. G-ARJM / 6456 crash in Ankara (Crew 7/7 & Passengers 20/27)

The probable cause of the accident was the obstruction of the pitch pointer in the captain's director horizon which led him to make an excessively steep climb immediately following unstick.

Cause of the accident: instrument failure

[Official accident report of G-ARJM]

[Back to the listing of all Comet crashes]

11. SU-AMW / 6464 crash in Bangkok (Crew 8/8 & Passengers 18/18)

SU-AMW, a Comet 4C of UAA -- United Arab Airlines -- was supposed to land as scheduled passenger a/c to Bangkok when it made a premature descent and struck Mt Kao Yai. None of the passengers survived this CFIT crash.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

12. SA-R-7 / 6461 crash in Cueno **(Crew 9/9 & Passengers 9/9)**

SA-R-7 was the private a/c of the Saudi Arabian Royal family. During a flight from Geneva to Nice the plane struck during the descent phase a mountain at 900 m. The crash occurred at Cuneo in Italy. Everybody on board of the a/c -- including members of the royal family -- died.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

13. SU-ALD / 6441 crash in Bombay **(Crew 8/8 & Passengers 55/55)**

SU-ALD was supposed to land in Bombay, India. The plane crashed at 20h20 in the sea while approaching the Bombay airport. This crash during the initial approach was probably due to a loss of control caused by the heavy rain and severe turbulence which took place at the moment of the crash. None of the passengers survived this crash.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

14. G-APDH / 6409 crash in Singapore **(Crew 0/8 & Passengers 0/60)**

G-APDH, a Comet 4 of MAS -- Malaysian Airlines Systems --

was as scheduled passenger plane on a flight from Kuala Lumpur to Singapore. Shortly after landing the right gear forging broke because of a fatigue failure. The Comet remained on the runway but fire broke out. None of the passengers was killed.

This crash was caused by a fatigue failure of the right gear forging.

Cause of the accident: fatigue failure

[Back to the listing of all Comet crashes]

15. G-ARCO / 6449 crash off Nicosia (Crew 7/7 & Passengers 59/59)

G-ARCO, a Comet 4 of British European Airways was flying Athens - Cyprus when it disappeared form the radar screens 10 minutes after it took off from Nicosia. Captain Gordon Blackwood had previously not informed of any technical difficulties. Since there were a lot of similarities to the YP and YY crashes, rumours were saying that this crash was again due to fatigue.

The analysis of the wreckage allowed to detect that the Comet 6449 was indeed teared up, following the detonation of a highly explosive device within the cabin. In addition this theory was reinforced by the fact that initially the General in command of the Cyprus army should have been on board. He cancelled in the last moment his flight. The political problems which existed at the time on the island make a terrorist act highly possible. The official accident report concluded therefore to a bombing.

Cause of the accident: bomb explosion

[Back to the listing of all Comet crashes]

16. SU-ANI / 6475 crash in Ethiopia (Crew 0/9 & Passengers 0/5)

SU-ANI was as flight MS755 on a flight from Khartoum to Addis Ababa-Bole in the final approach phase. The aircraft broke through clouds at 150ft, but was 200-300ft to the right of Runway 32. The Comet banked left, made some shallow turns and made a higher than normal landing flare half way down the runway. This caused the aircraft to stall; the left wing and pod fuel tank struck the runway and the Comet crashed.

This crash was caused by the fact that the pilot attempted to land from an unfavourable position, brought about by the fact that he had descended below weather minima before being able to establish visual ground contact.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

17. SU-ALE / 6444 crash in Munchen (Crew 0/9 & Passengers 0/14)

SU-ALE was taking off from Munchen-Riem, but due to buffeting, the take-off had to be rejected at a height of 30ft. The aircraft landed back, overran the runway and struck a fence. The undercarriage was torn off and a small fire started.

This crash was caused by buffeting probably caused by icing on the wings. In addition due to improper operation of the flight controls, the Comet over-rotated.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

18. G-APDN / 6415 crash in Spain (Crew 7/7 & Passengers 105/105)

G-APDN, a Comet 4 of Dan-Air Services was as a charter flight in the descent phase when it hit a mountain. All passengers and crewmembers died.

Cause of the accident: ATC and intrument failure

[Official accident report of G-APDN]

[Back to the listing of all Comet crashes]

19. G-APDL / 6413 crash in Newcastle (Crew 0/4 & Passengers 0/5)

G-APDL, a Comet 4 of Dan-Air Services was on a training flight when it landed wheels up. The aircraft was damaged beyond repair.

This crash was caused by the fact that the crew omitted to carry out the pre-landing checks while practising a flapless landing.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

20. SU-ALC / 6439 crash in Tripoli (Crew 8/8 & Passengers 8/8)

SU-ALC was as flight MS844 on a flight from Alger-Houari Boumediene to Tripoli and made its initial approach. The

Comet struck sand dunes at 395ft while making an ADF approach procedure turn for Runway 18.

This crash was caused by the fact that the captain decided to land while prevailing visibility was below company-minimum for that airport at night.

Cause of the accident: pilot error

[Back to the listing of all Comet crashes]

http://surf.to/comet: Details about all D.H. Comet incidents

In this section I summarized the information of the hull-losses which I collected from different sources. However errors are human, if you think that some information is not correct feel free to post me an . Don't forget to tell me your source.

A. G-ALYR / 6004 hull-loss in Calcutta (Crew 0/0 & Passengers 0/0)

G-ALYR, a Comet 1 operated by B.O.A.C. was damaged beyond repair because the aicraft was being taxied off a curving taxyway. Capt Willerton was faced with a design defect. At night the taxy lights were too dim to use safely, and the crews had to use the landing lights, which were high poer, and got hot. So they had to be alternated left and right to avoid a meltdown. The switches to do this were fitted on the left flight deck wall low down, and behind the captains seat. The taxy light switches were also there, and the layout was poor. It was easy to find the wrong switch. Also the nosewheel steering wheel was self centering, and if the hand was taken off it then the aircraft would turn.

In a left hand turn Capt. Willerton took his left hand off the steering wheel to select another landing light. The steering centered, and then the aircraft right wheel bogies ran off the paved surface. Capt. Willerton made the mistake of trying to get the aircraft back onto the paved surface, and when it did not respond he applied engine power on the two right engines. This caused the bogie struts to be forced up and into the wing structure causing much damage. Willerton was blamed, and lost seniority. Soon afterwards the switches were relocated to the upper front panel. Note that G-ALYR was returned to the UK for repairs.

Thanks to Capt. Peter Duffey *for the details of the report listed above.*
Photo Credit: *Aeroplane Monthly [Sep-89]. Thanks to Trevor Friend for contributing this picture. Added [15-Nov-98]*

[Back to the listing of all Comet hull-losses]

B. XK663 / 6027 hull-loss in Wyton (Crew 0/0 & Passengers 0/0)

XK663, a Comet 2R of the 192th RAF sqn was damaged beyond repair during a hangar fire. Unfortunately further details are missing.

[Back to the listing of all Comet hull-losses]

C. 7926M / 06028 hull-loss in Lyneham (Crew 0/0 & Passengers 0/0)

7926M, a Comet C2 of the RAF burnt during fire rescue training in 1968. Unfortunately further details are missing.

[Back to the listing of all Comet hull-losses]

D. OD-ADR / 6445 hull-loss in Beirut (Crew 0/0 & Passengers 0/0)

The Comet 4C of MEA registered OD-ADR was one of three destroyed by an Israeli commando attack on the 28th December 68.

[Back to the listing of all Comet hull-losses]

E. OD-ADS / 6448 hull-loss in Beirut (Crew 0/0 & Passengers 0/0)

The Comet 4C of MEA registered OD-ADS was one of three destroyed by an Israeli commando attack on the 28th December 68.

[Back to the listing of all Comet hull-losses]

F. OD-ADQ / 6446 hull-loss in Beirut (Crew 0/0 & Passengers 0/0)

The Comet 4C of MEA registered OD-ADQ was one of three destroyed by an Israeli commando attack on the 28th December 68.

[Back to the listing of all Comet hull-losses]

G. XM829 / 06021 hull-loss in Stansted (Crew 0/0 & Passengers 0/0)

Frame 06021, the former Air France Comet 1A, which was converted to 1XB specifications and last served as XM829 was donated to the Stansted airport fire services and destroyed by fire at Stansted in 1970. Sorry I don't have the precise date.

[Back to the listing of all Comet hull-losses]

http://surf.to/comet: Article about the Comet crashes

This section is taken from an article published in xx-xxx-1953 in Airways magazine.

Radical thougts on the Comet

Now that the Ministry of Transport and Civil Aviation has announced that there is to be a public inquiry into the causes of the accident to the Comet on January 10, it will be both useful and astringent to look back for a moment. By so doing some of the misfortunes suffered by this Comet which means so much to us may be viewed again as rationally as possible and brought into perspective in the light of present information.

There would be no point in minimizing the seriousness of this latest accident, but, at the same time, any tendency to connect it too closely in our minds with previous accidents must, at this difficult time, be prevented. It is true that of the 19 Comet 1s and 1As which have entered, or been about to enter, air-line service, five have been written off. Two of the accidents concerned involved no loss of life, and, more important still, three of the five were the result of known and fully understood causes.

Only two of the five accidents, therefore, need to have any air of mystery about them, but, unfortunately, the causes of two of the three fully understood accidents may tend to remain a little hazy in the eyes of the public. This should not be, but, at the time when the headlines were at their biggest and the public were most interested, no authoritative explanatory information could be made available about the aircraft's accepted characteristics. To ordinary people, a couple of Comets simply failed, for some reason or other, to become airborne.

Even though an official report about the first of these two accidents had already been issued when the second one occurred, the wording of this report was not such as to lead any reader straight to an understanding of both accidents.

U.A.T. Comet 1A F-BGSC

The third of these "understood" accidents received little attention in this country and concerned one of Union AÈromaritime de Transport's Comets. It was a mishap on the landing run at an African aerodrome and need only be mentioned here because the aircraft was considered, from the insurance point of view, to be damaged beyond repair.

So, before considering the two more recent tragedies, let us try to remove any remaining mystery from the sequence of these take-off accidents.

The Take-off Accidents

B.O.A.C. Comet 1 G-ALYZ

The first was suffered by a B.O.A.C. Comet, G-ALYZ, at Ciampino Airport, Rome, on October 26, 1952. It was dark and it was raining. The Comet failed to accelerate adequately, or even to become properly airborne, and the captain, considering that there must be a lack of thrust, abandoned the take-off.

No one was seriously hurt, but the aircraft was irrevocably damaged in the resultant crash landing. The report showed that the attitude of the Comet had, unknown to the crew, become very nose-high during the takeoff run, so much so that the wing was stalled or semi-stalled.

In the Corporation's Training Manual, as quoted in the report at that time, it was noted that "an increase of incidence to 9 deg. results in a partially stalled wing giving a high drag which appreciably affects the aircraft's acceleration .... " In fact, the tail-bumper of G-ALYZ had been scoring the runway, so the Comet's attitude was of the order of 11 deg., or more, noseup. At the take-off weight of 100,370 lb. it would never have flown at all in that attitude.

Following this accident a new take-off technique was apparently recommended for B.O.A.C. pilots and more attention was paid to this particular problem during the training of Comet pilots. The modified system involved lifting the nosewheel at the appropriate speed and afterwards letting it touch again, so that it could be felt on the runway until take-off safety speed had been reached. The Comet's controls are power-operated, and "feel" is provided by spring-loading from a neutral trimming datum.

Canadian Pacific Air Lines Comet 1A CF-CUN

The second of the two take-off accidents followed the same form, but the conditions were much more difficult this time and the accident disastrous. It occurred at Karachi on March 3, 1953, during the delivery flight of the first of the Canadian Pacific Air Lines' Comet 1As to its service base at Sydney.

No official report was published after the accident, but a summary was issued. This made it clear that the aircraft was at its limit of weight for the conditions existing. It was being taken off at 114.816 lb., which was very nearly the permissible maximum for the 1A Series, and the hours of darkness had been chosen so that the air temperature should be as low as possible. Even so, this was about 8 degC. above International Standard Atmosphere and water-methanol injection was being used to regain the power from the Ghosts for the take-off. There was no wind--and the Comet's take-off distance is sensitive to wind conditions.

In the words of the report summary, "the aircraft continued along nearly the whole length of the runway in a very nose-high attitude and never left the ground." The summary concluded with the words: "at this high weight strict compliance with the take-off technique would be necessary for a successful take-off."

It is tragic that good and experienced pilots should have been defeated, as they were at Rome and Karachi, by a new type of aircraft, but the Comets characteristics and power-operated controls were known and its technique of take-off understood. Later history has shown the Comet to be a "different" aircraft, but far from being a difficult one.

Calcutta and Elba

Long afterwards it was learnt that de Havillands had started experimenting with a new wing section before even the accident at Rome in 1952. No doubt this re-design was primarily intended as a development to permit the use of higher weights for a later Comet Series, but its advantages in the take-off case must have been much in the designers' and test pilots' minds. Meantime they had, supported by B.O.A.C. Comet pilots, adamantly resisted any suggestion that the control system should be altered. Its simplicity and other advantages apparently outweighed, in their view, any risks of over-control it might involve.

The two take-off accidents and the one almost unrecorded landing accident can now be put on one side in the knowledge that their reasons are well understood.

But the Elba accident--and, to a lesser degree, the Calcutta accident--are still in the present. They must be understood and explained as thoroughly as possible so that we can go on to the next stage of progress with clear minds and a full understanding of the means by which such accidents can be prevented in future. There will always be aeroplane accidents, but even the most timid traveller will accept this prospect-- just as he or she accepts the possibility of a train accident or of a sinking ship-- so long as the reasons are known and action known to have been taken.

B.O.A.C. Comet 1 G-ALYV

The sequence of events leading up to, and following, the Calcutta accident on May 2, 1953, will be remembered by the majority of people and only certain features need to be mentioned here.

The report of the Indian Court of Inquiry which had investigated the accident --and which included one experienced British assessor amongst the three who were appointed-- gave the "probable" cause of the Comets disintegration as: "severe gusts encountered in the thundersquail: or over-controlling or loss of control by the pilot when flying through the thunderstorm." An appendix, written by one of the assessors and giving a suggested sequence of events leading to the disaster, was described by the Court as being "plausible" but unproven.

Concurrently with the issue of this report B.O.A.C. and de Havillands, in a combined statement, made it clear that they did not agree that over-control or loss of control was a likely cause, and stressed the theoretical nature of any findings before a more detailed examination of the wreckage had been made.

The Indian report had, in fact, recommended that such an examination should be made.

No further information has yet been made publicly available about the results of this continued examination. So, following this very' natural resistance to the findings of the Court. This leaves the Calcutta accident still in the "unsolved" category. Since they each occurred on the climb it may be natural for many people interested in the Comet to tend to connect the Calcutta accident with that near Elba twelve days ago.

B.O.A.C. Comet 1 G-ALYP

Some considerable attention was paid in the Press last weekend to Sir Miles Thomas' statement that the possibility of sabotage in the case of the Elba accident "cannot be overlooked." This statement was natural enough in the circumstances, since such a cause is always a possibility in any such disaster, and efforts must obviously be made to follow up likely clues.

But the weight of the investigation will, no doubt, continue to be directed towards hat I believe to more practical possible causes. Among these could be the explosion of a kerosene-air mixture, or of hydraulic fluid vapour, and the medical evidence may go a long way towards confirming the likelihood of one or other similar possibility.

The very difficult feature of the Elba accident--that the aircraft fell into water--has also provided medical evidence which might not have been available if the wreckage had fallen on land. Unfortunately, latest reports say that the wreckage of G-ALYP is lying at a depth of the order of 600 ft. and salvage may not be practicable.

The fact that the Comets had been taken out of service by B.O.A.C. was a voluntary move so there was no reason why these aircraft should not be returned to service when they had been thoroughly examined.

Nevertheless, no one imagined it probable that signs of incipient structural failure would actually be found in the Comets under examination. B.O.A.C.'s maintenance and inspection is among the most thorough in the World, and if such signs were to be seen in any of the Comets in service it is likely that they would have been found during previous maintenance checks completed during the past few months.

But a full and careful inspection of all the Corporation's Comets was vital, both as a means of assuring the public and as an essential link in the series of checks which must be made towards a narrowing-down of the possible cause of the accident.

Air France and Union AÈromaritime de Transport had also removed their Comets temporarily from service last week and the former was making a thorough examination of at least one aircraft. The Royal Canadian Air Force, as military operators, were taking no action for the time being.

Last week-end Mr. A. T. Lennox-Boyd, Minister of Transport and Civil Aviation, flew out to Rome to observe the progress of the investigation there. He was due to return on Tuesday for the opening of Parliament.

Finally, let us remember, that the Comet is far from being the first or only civil aircraft to have suffered serious trouble, the cause of which could not be immediately diagnosed, in the earlier stages of its service life.

There was the case, for instance, of the DC-6. After one of these aircraft had been lost, with all its passengers and crew, following a fire in the air (October 24, 1947) another, flown by a different U.S. operator, was successfully force-landed after suffering similar trouble (November 11, 1947).

All DC-6s were then grounded while investigations were made. It was discovered that if, after transferring fuel between certain tanks, the immersion pumps were accidentally left "on," the resultant pressure build-up caused fuel to vent. This could be carried by the airflow straight into the air-intake of a combustion heater, causing a continuous fire which could not be controlled.

There have been other similar cases of trouble with civil transports which have afterwards continued, during their long lives, to be popular and successful aircraft.---H.n.w.

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