Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Hawker Siddeley HS 748 LV-HHB Report on the accident 35 km North of Cutral-Có (Neuquén Province), Argentina, on 14 April 1976

Translation of the report by the Argentine Civil Aviation Accidents Investigation Board

ADDENDUM

This report has been produced by the Civil Aviation Accidents Investigation Board of the Republic of Argentina and the views expressed in it do not necessarily represent those of the Secretary of State for Trade or the Chief Inspector of Accidents.

Department of Trade

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List of Aircraft Accident Reports issued by AIB in 1977

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YEAR 1976

REPUBLICA ARGENTINA

Argentine Air Force

Air Regions Command

Civil Aviation Accidents Investigation Board

INVESTIGATION OF CIVIL AVIATION ACCIDENTS CASE No. 797.678

Aircraft	:	AVRO (Hawker Siddeley) 748 – Registration Mark LV-HHB
Owner	:	Yacimientos Petrolíferos Fiscales
Crew	:	Pilot - Senor Omar Carbone Co-pilot - Sr Juan José Peduzzi Steward - Sr Sixto Rojas
Place of accident	:	35 km North of Cutral-Có (Neuquén Province)
Date	:	14 April 1976, at 1625 hrs local time*
Classification	:	'SERIOUS'
Investigators	:	Investigator-in-charge - C J Bondio Operations investigator - U J Ciancio Technical investigator - D A E Garegnani

*3 hours should be added to Argentine local time to obtain Greenwich Mean Time (GMT).

Note: This report is reproduced without the large number of diagrams and photographs referred to in the texts of the two metallurgical studies which are embodied in it.

INTRODUCTION

Personnel taking part:

Investigating Commission –

Investigator-in-charge : Major (R) Ingeniero Aeronáutico Don Carlos José BONDIO
Operations Investigator : Flight Inspector Don Umberto Juan CIANCIO
Technical Investigator : Técnico Aeronáutico Don Alejandro Eduardo GAREGNANI

Experts –

Metallurgy expert : Ingeniero Don Roberto KUGUEL
Structures expert : Ingeniero Aeronáutico Don Gerardo Luis VENTURA
Meteorology experts : Licenciado Don Ernesto CUARANTA, and Don Roberto MARESCO.

In this matter it is fitting to point out that the Argentine State has tried, as far as it was able, to give facilities to the accredited representatives of the British Government in the mission which the aeronautical authorities of that State entrusted to them. This was on a cooperative basis, for Argentina did not support, and expressed its reservations on the Amendment to Annex 13 – which gives the State of manufacture of the aircraft the right to participate in the investigation – unless the appropriate authorisation is given specially. We do that of course for aircraft registered in other contracting countries involved in accidents in our territory or waters under our jurisdiction.

This stand by the Argentine has been reiterated at all conferences of the AIG* Division and was confirmed at the latest of these, which took place in Montreal (Canada) in 1974 and resulted in Amendment 5 to Annex 13 (4th Edition).

In the present case, although the aircraft was of our registration, there was nothing to prevent agreement to a request by the aeronautical authorities of the United Kingdom and, as a request was received which was considered acceptable – in view of the manner and circumstances of the accident – and within the spirit of Annex 13, all facilities were granted including, in this case, the representative of the manufacturer, subject of course to the decisions of the State in charge of the investigation.

It was thus possible to develop mutual cooperation, which we consider was to the benefit of the investigation.

2. The following were present as accredited representatives of the British Government:

C C Allen – Senior Inspector of the Accidents Investigation Branch (AIB),
D F King – Senior Inspector (Engineering), A I B, and
F M Jones – Senior Engineer of the Royal Aircraft Establishment (RAE),

and the following as engineers from Hawker Siddeley Ltd:

W C Heath, and
J Haworth.

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*Accidents Investigation Group

1. Details of the Facts

1.1 History of the flight

The aircraft was making a staff-transfer flight for the YPF* State Enterprise; it began in Cutral-Có (Neuquén Province) at 1400 hours on 14 April 1976 and the aircraft landed 40 minutes later on a Company landing strip in the place known as Rincon de los Sauces in the same province (see Annex I).

When the operations of disembarking passengers and putting down freight had been completed, the aircraft took off for Cutral-Có with 31 passengers and 3 crew.

Flight clearance was effected by the Flight Steward. The documents could not be recovered after the accident and there were no duplicates on the ground. However it was possible to establish that take-off occurred at 1555 hrs.

During the return flight, some moments before the accident, the Commander was in communication on the VHF equipment with the Commander of Avro aircraft registered LV-HHG, Senor Agustin Perez, flying nearby from Cutral-Có to Colonia Catriel (see Annex I); the conversation concerned the scheduling of flights for the next day, as the other aircraft was also in the YPF fleet. At no time could it be detected that any abnormal situation prevailed on the flight by LV-HHB.

At 1623 hrs, HHB contacted Cutral-Có and asked for information on the local state of the weather and estimated landing at 1633 hrs.

At 1625 hrs, a group of YPF workmen working at the place known as Meseta Buena Esperanza saw the aircraft returning from Rincon de los Sauces to Cutral-Có. Senor Humberto Yapura said in his statement that at the time they had stopped work as it was time for their mealbreak and he and Senor Livio Navarrete were exchanging their impressions on the aircraft in sight, to see whether it was a Twin Otter or an Avro. When it passed over where they were, they saw it was the Avro and immediately after '..... they saw the starboard wing separate and then part of the tail and the rest corkscrewed to earth'. He said then that after impact with the ground, a column of smoke was seen. They estimated the height of the aircraft before the accident to be between 1500 and 2000 metres and that the weather was good.

When they learned of the accident which had just happened, all the staff on campsite and drilling preparation for YPF went to the site; they used the vehicles available (motor-scraper, small truck etc) but when they reached the site, which was scarcely two kilometres away, they could do nothing as all the occupants of the aircraft had died as a result of the impact and subsequent fire. Using a radio set from the Camp, they gave details of the occurrence to the YPF Plant at Plaza Huincul.

The aircraft accident happened at 69° 10'W, 34° 41' S; the ground is about 750 m above sea level and the surface is undulating.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	3	31	–
Non-fatal	–	–	–
Unhurt	–	–	–

*Yacimientos Petrolíferos Fiscales

1.3 Damage to aircraft

The aircraft was totally destroyed; the following parts were recovered from the wreckage: incomplete starboard wing and tailplane, pieces of the structure of the starboard wing adjacent to the engine nacelle, nose-wheel door and parts of the upper and lower wing skin.

1.4 Other damage

There was no other damage.

1.5 Crew information

The aircraft was commanded by Omar Carbone, Argentine, age 33 years, holding Airline Transport Licence No. 1375; his medical rating expired on 10.8.1976. His total flying experience was 4,576 hours and he had flown 1,762 hours on the accident aircraft. On the day of the accident, he had flown 2hrs 10min and his rest periods had been normal. His co-pilot was Senor Juan José Eifel Roque Peduzzi, Argentine, age 40 years, holding Airline Transport Licence No. 1348. His medical rating expired on 9 June 1976. His total flying experience was 7,268hrs 40min and he had flown 1,280 hours on the accident aircraft. The Steward was Senor Sixto Rojas, Argentine, age 25 years.

1.6 Aircraft information

Aircraft : Avro (Hawker Siddeley 748).
Type 748, Series 1, model 105.
Serial number 1540.

Date of construction: 6 March 1962.

Registration: LV-HHB.

Powerplant : Rolls Royce Dart Mk. 514 (2).

Position No. 1: serial No. 15046.
" No. 2: " " 15056.

Flying hours:

Engine 1: Overall 19,484:35; Since last overhaul 192:55, cleared to 23,492 hrs
" 2: " 18,407:40; " " " 6,030:55, " " 18,476 "
Aircraft: " 25,759:35; " " " 15,848 hrs.

Latest 1200-hr inspection: 513hrs 35min before accident
Hours since 50-hour inspection: 13hrs 20min.

Name and address of Owner:

Yacimientos Petrolíferos Fiscales
Sarmiento 778
Capital Federal.

Certificate of Airworthiness and validity: No. 3411.

The aircraft had been involved in a previous accident on 1 August 1966, after 9,913hrs 55min overall; the damage suffered was detailed in the investigation file: 'Wing skin examined. Fuselage deformed, twisted and dented. It shows flexing of the fuselage, and wrinkles on skin and frame immediately before and after the central section of the wing'.

Load:

Fuel	1,200	kg
Oil (2x24-litre tanks)	41.2	,,
3 Crew	240	,,
Passengers, 31x80	2,480	,,
Hand luggage	248	,,
Methanol	120	,,
Variable load	4,308	,,

1.7 Meteorological information

The report of the National Meteorological Service for the area of the accident was as follows: Cloud-cover 6/8 Nimbo-stratus and alto-stratus. Ceiling 2000/2500 metres 3/8 Cumulus and strato-cumulus at 1200 metres. Horizontal visibility 15/20 km. Slight showers. Surface wind South-West 20/25 k/h. The QAM[1] for Cutral-Có given by VHF[2] to pilot Carbone was: 'Wind 180°, speed 4 knots, visibility 15km. Overcast, ceiling estimated 800 metres. QNH[3] 1008mb. Temperature 18°C.

In the knowledge that an aircraft of Aerolineas Argentinas (AA) had flown over the area at a time coinciding with that of the accident, the aircraft was identified as the Boeing 737 on flight 216 between Mendoza and San Carlos de Bariloche, commanded by Captain Carlos Gregorio Meza. He was questioned on the en-route weather and said he had taken off from Mendoza at 1605 hrs and reached abeam Neuqúen at 1650 hrs at FL 260; the state of the weather relating to turbulence was below the values of 'moderate turbulence'. At 1735 he landed at San Carlos de Bariloche where conditions were normal for visual flight.

Another important contribution in determining the state of the weather in the area of the accident comes from pilot Casey. When he learned of the accident, he took off from Cutral-Có at 1640 hrs in command of Cessna 402 LV-JSZ and flew over the location of HHB's wreckage trying to guide parties setting out to rescue victims. Concerning the state of the weather, he said that there was stratus cloud with 1500/2000m ceiling and visibility 25/30km. He did not observe significant turbulence and on landing about one hour after take-off, visibility and ceiling were somewhat restricted at Cutral-Có aerodrome through slight continuous rain.

On 21 April 1976 at 1000 hrs, a meeting was held at the Aviation Accidents Investigation Board, to effect an analysis of the weather in the area of the accident. The National Meteorological Service was asked through its staff to notify all the details which they held and their opinion to confirm or amend the data available at that stage of the investigation. The meeting was presided over by Comodoro (R) Don Mario Santamaria; the British Delegation were present with Accident Inspectors Mr C C Allen and Mr D F King and Mr J Haworth from Hawker Siddeley Aviation Ltd, as were the Head of Operations of the Aviation Division of Yacimientos Petroliferos Fiscales, Senor Papas, the pilot of Avro LV-HHG, Senor Agustin Perez, and staff of the Board taking part in the investigation.

Sr Ernesto Cuaranta (Licentiate in Meteorology) and Meteorologist Sr Roberto Maresco produced the exposition and confirmed that the weather matched the report which the investigating commission held – i.e. that there was an unstable situation caused by the movement of a cold front but at no time could severe turbulence be detected.

1.8 Aids to Navigation

The flight was conducted without local radio aids; the aircraft in the accident was equipped with ADF[4] and VHF. The Company uses the air transfer for its staff and has

[1] *QAM: the latest available meteorological observation.*
[2] *VHF: very high frequency radio equipment.*
[3] *QNH: the altimeter sub-scale setting such that the instrument will indicate airfield elevation when the aircraft is on the ground at that station.*
[4] *ADF: automatic direction-finding equipment.*

an organisation suitable for visual flight operations. Neither Cutral-Có nor Rincorn de los Sauces has radio equipment. To get the state of the weather at Cutral-Có, there is a VHF operated by YPF staff.

The accident aircraft had maintained communication with aircraft LV-HHG, and two or three minutes before the accident with Cutral-Có VHF. At no time was there any indication that anything unusual was happening.

1.9 Communications

Communications with Cutral-Có VHF and with aircraft LV-HHG were normal; these are the only sources of information which the aircraft had on its flight.

1.10 Aerodrome information

Not relevant to the accident.

1.11 Flight recorders

Not carried.

1.12 Information on the wreckage of the aircraft and impact

The distribution of the parts may be seen in Annex II attached.

1.13 Medical and pathological information

Not prepared.

1.14 Fire

Fire occurred when the aircraft struck the ground.

1.15 Survival aspects

There were no survivors. When the first rescue parties arrived, the passengers and crew were found to be dead due to impact of the aircraft with the ground.

1.16 Tests and research

In view of the complexity and urgency of the matter, an approach was made to the National Institute for Industrial Technology [INTI] ; the Head of the Department of Mechanics, Ing. Roberto Kuguel, is a specialist of known ability in materials fatigue. All the parts that could be recovered from the accident and considered worth analysing – starboard tailplane, starboard wing, miscellaneous wreckage, etc – were taken to the hangar of Aerolíneas Argentinas and the YPF at Ezeiza, where they were available for preliminary examination.

It should be noted that the principal remains of the aircraft, except for those sections referred to above, were left in place after the accident (in view of the degree of damage and the inclusion of human remains). They were consolidated and covered with earth, using heavy earth-moving machinery.

Once the distribution of the pieces had been understood, a classification was made of those that showed signs of failure or of being part of the failures; in this task, in addition to staff of the Accidents Investigation Board, important assistance was received from the following British specialists: 1 – Mr Allen and Mr King (Senior Inspector – Engineering) of the Accidents Investigation Branch of the Department of Trade in the United Kingdom and Mr D J Haworth for the manufacturer, Hawker Siddeley, and 2 – INTI staff, the person in charge being Ing. Kuguel. The INTI produced the metallurgical report which is in the investigation file and which is partially quoted below:

Metallurgical Study No. 1

The main aspects of the INTI study signed by Ing Kuguel are as follows:

'**Data on the specimen:** For reasons which will be given later, the investigation was focussed on the panels constituting the wing skin. The materials used were BS[1] L72 and BS L73[2] for the two panels involved. The former was for the cut-out reinforcing plate (referred to below as 'reinforcing plate') and the other for the lower skin of the wing.[2] L72 is an aluminium alloy, covered with a coating of practically pure aluminium (alclad). The composition of the core is given in Table 1 below, in columns 1 and 2.

Table 1 : Chemical composition of the core material (L72)

Element	*Min* (1)	*Max* (2)	– (3)
Copper	3.8	4.8	4.15
Magnesium	0.55	0.85	0.78
Silicon	0.60	0.90	0.73
Iron	–	1.0	0.40
Manganese	0.4	1.2	0.69
Nickel	–	0.2	0.001 approx*
Zinc	–	0.2	0.08
Lead	–	0.05	0.05 approx*
Tin	–	0.05	–
Titanium and/or chrome	–	0.3	0.005 approx* (titanium)
Aluminium		The rest	
Gallium	–	–	0.03 approx*
Vanadium	–	–	0.005 approx*

* – *spectrographic qualitative determination.*

Heat treatment consists of a solution treatment, heating to 505°± 5°C and cooling in water at a temperature not exceeding 40°C, followed by ageing at ambient temperature for not less than 48 hours. The mechanical properties resulting from the tensile test are shown in Table 2, column 1.

Table 2 : Mechanical properties of material L72

	(1)	(2)	(3)	(4)	(5)
Proof stress, 0.1%	23.6	23	20.3	28.8	21.0
Tensile strength, kg/mm^2	39.4	46.4	46.1	47	43.5
Elongation, %	15	18.1	18.4	14.4	13.6

The values in column 1 are taken as minima.

1 British Standard
2 The Argentine authorities have been advised that all references to material L73 in Metallurgical Study No.1 should read 'L72' which was used for both the panels involved.

Appearance of the damage:

Study of the fractured zone presents difficulty: a series of circumstances has made the main wreckage of the aircraft inaccessible until now and the remainder of the wing which was recovered is seriously affected by the impact.

Certain worthwhile fragments are also missing. The separation area covers basically from rib 134 (beginning of the fuel tank) to 114 (engine outer rib). The photographs in figs 1 and 2 show the state of the half-wing as they were found. Fig 3 shows these sections and fig 4 gives a detail of the rib and the adjacent parts. It is thought certain that the lower part of the skin tore first, as a result of lift stresses, and therefore the analysis focussed on the panels forming it, ie the lower skin and the cut-out reinforcing plate.

The photographs in figs 5, 6 and 7 show (a) the sector from the forward stringer to station 12, (b) the sector from station 12 to No 3 and (c) the sector from No 3 to the aft stringer. The photo from forward stringer to station 12 shows concertina folds, with 4 folds of practically 180° (see photo fig 8) which have produced typical ductile splits (faces at 45°). The fractured suface is shown in the photo fig 9. Also, incipient fatigue is seen at a rivet hole (fig 10): this is piece 14 on p.26 of Hawker Siddeley's 'Structural Repair Manual' for the Avro 748; the 6th rivet from the forward stringer.

The area from station 12 to station 3 shows fatigue areas on both sides of the rivet hole; see photo fig 11. The fatigue zone towards the forward stringer is missing. The area station 3 – aft stringer also shows a ductile-type break. See also photo fig 12.

Examination, Evaluation and tests

Macroscopic examination

Examining the fractures referred to in the section above, the following main characteristics may be enumerated:

(a) at the reinforcing plate of the cut-out (item 11 'doubling plate' in fig 7 of 'Outboard Engine Rib' in Hawker Siddeley's Structural Repair Manual for the 748) marks of fatigue were seen on both sides of a rivet hole close to the cut-out, with a length of approximately 0.5 and 1.5 cm (see photos figs 11 and 18).

(b) an incipient fracture zone also referred to above and shown in fig 10, with a circular development of approximately 0.5 cm – see Appendix 2.

(c) an extensive zone of delamination, at the upper skin level with rib 134, figs 19 and 20.

(d) the remaining fractures, both in the plate and in the stringers, show the typical trace of ductile fracture: faces at 45°. This applies to more than 95% of the exposed surfaces of the fractures encountered.

Mechanical Tests

Tensile Tests were performed on two test pieces taken from the plate identified in paragraph (a) above: one in the direction of the wing axis and the other normal to it. Iram standard 102 was used to determine the length and breadth of the calibrated zone; the large number of rivets in the portion available made it impossible to say whether the other dimensions conform to the standard.

The test was carried out on an Instron machine, with 5,000kg maximum load and servo-controlled indicators and with load control through a load cell, giving a precision of 0.25% of the value of full load. For determination of the 0.1 limit, the graph method specified in Iram standard 755 was used; a mechanical strain gauge (Amsler make) was used for this, with a measuring base of 40mm and a precision of 1/100mm. The machine was equipped so that, with a plunger, it was possible to mark each 1/100mm deformation of the test piece as shown on the dial of the strain gauge. Knowing the value of the load to the degree of precision indicated, a graph could be constructed of tension/specific deformation (or load/absolute deformation) and so determine the 0.1 limit. Figs 21 and 22 show the graphs so prepared for test pieces 1 and 2.

The mechanical properties so determined are given in columns 2 and 3 of Table 2. The equipment and the test machine are shown in the photos in figs 23, 24 and 25. The photos in fig 26 show test piece 1, and in figs 27 and 28 is No.2, both of these broken.

For comparison purposes, tensile tests were performed also on two virgin test pieces of L72. In this case, Iram standard 766 type 'B' was used for the characteristics of the material and the limits of dimensions. The results are given in Table 2 (columns 4 and 5).

Chemical Analysis

A sample taken from the reinforcing plate was chemically analysed, in order to confirm it matched the supposed quality of L72. The results are in Column 3 of Table 1.

Metallography

Metallographic tests were performed on various samples, with the following results:

(a) L72 reinforcing plate – core: The structure of the alloy is formed of a solid solution of aluminium and an intermetallic compound of Al_2Cu and Mg_2Si. Photomicrograph 29 (500x), etched with Keller reagent, core zone.

(b) L72 reinforcing plate – cladding: The thickness of the cladding varies from 0.10 to 0.125mm on the edge at the concave face and from 0.125 to 0.175mm on the edge at the convex face. Photomicrograph 30 (200x), etched with Keller reagent, taken at an area of the edge at the convex face. In some areas of the edge at the concave face, corrosion and separation of the cladding were observed.

(c) L72 Virgin plate – core: The structure of the alloy is formed of a solid solution of aluminium and intermetallic compound of Al_2Cu and Mg_2Si. Photomicrograph 31 (200x), etched with Keller reagent, core zone.

(d) L72 virgin sheet – cladding: The thickness of the cladding varies from 0.075 to 0.10mm. Photomicrograph 32 (200x), etched with Keller reagent.

(e) skin panel L73 – core: The structure of the alloy is formed of a solid solution of aluminium and intermetallic compound of Al_2Cu and Mg_2Si. Photomicrograph 33 etched with Keller reagent.

(f) Lower skin panel L73 – cladding: The thickness of the cladding varies from 0.20 to 0.24mm and separation of one coating of cladding was observed. Photomicrograph 34, etched with Keller Reagent.

(g) L73 lower skin panel – core: The structure of the alloy is formed of a solid solution of aluminium and intermetallic compound of Al_2Cu and Mg_2Si. Photomicrograph 35, etched with Keller reagent, core zone.

(h) L73 lower skin panel – cladding: The thickness of the cladding varies from 0.15 to 0.20mm and separation of a coating of cladding was observed. Photomicrograph 36, etched with Keller reagent.

ANALYSIS

We analyse below the evidence available at this time.

On the accident

From all the information supplied, it is evident that the damage occurred during flight; it was not preceded and/or accompanied by any abnormal stress either from turbulence or manoeuvre.

Analysis of the history of the aircraft and the area affected

(a) The aircraft in question, an Avro 748, dates from the end of the fifties. It is a low-wing, two-spar machine, with two Rolls Royce Dart 514 turbo-prop engines. The structural materials used are aluminium-copper alloys (BS standard) L72, L73 and L65, having a low crack-propagation rate.

(b) From the information given in '2', it is seen that from the chemical and mechanical point of view, the reinforcing panel – the principal object of this investigation – meets the specifications of the standard acceptably. It should be noted that the aircraft in question (LV-HHB) was involved in three 'events' during its service. The first two were insignificant in their results: they were on 31 March and 30 August 1962, with 0.25% and 5% damage respectively.

(c) The third event was on 1 August 1966 at Buenos Aires City 'Aeroparque' airport, producing 20% damage to the fuselage. The accident occurred during a conversion flight and the manoeuvre executed was a landing in critical conditions, consisting of a sudden loss of lift a few metres off the ground. Consequently, a hard touch down occurred. The effect was corrugation of the fuselage on both sides, between the door and the tail, in an area close to the frames of the central section of the wing.

Reading of report No. 2356 of the (Argentine) AIB and of the repair carried out by the manufacturer of the aircraft does not show that the accident had effects bearing on the damage studied here.

Analysis of the damage

At present, the following statements are considered as true (see '3' and the ad-hoc-photos):

(a) Separation of the wing was level with rib 114 (engine outer rib).

(b) In this area, there were already fatigue cracks, referred to above (4(a)).

(c) Separation of the skin followed the fatigue-cracking (4(a)).

(d) This separation was 'ductile', that is through simple over-stress (4(d)).

(e) The forward stringer shows delamination, as does the upper skin (4(c)).

(f) The corresponding rib broke up; part separated with the wing and part with the rest of the aircraft. It was there that the fatigue noted in 4(b) was observed.

(g) Separation was observed of the cladding on the under and upper panels and corrosion in the reinforcing plate.

(h) There are rivets broken by shearing and others by tearing, in a sequence not established.

(i) First impact with the ground was at the edge of the corner at the forward stringer; therefore the folding observed in the under panel was earlier than the fall, probably through aerodynamic stress.

(j) It does not appear that the fatigue cracks are old, nor need they be. T. Swift (ASTM STP 486 – 1971 – p.171) says, for example '..... it should be remembered that if fatigue cracks occur in service, they generally form after many years of service'. The page quoted is reproduced in the Appendix.

CONCLUSIONS

(a) The only irregularity noted at present is the defect of the material in the critical zone of fracture, shown by delamination and fatigue cracks.

(b) It does not appear that this cracking was caused by excessive stresses due to manoeuvre or turbulence. Nor has it been shown that there was any irregularity in the checking or maintenance service which the aircraft received.

(c) The crucial point is to decide whether the defects shown in (a) are significant enough to produce such a degree of damage. An answer to this question would require:

  (i) knowing the history of and structural calculations for the aircraft.

  (ii) checking the assumptions of structural reliability against the damage encountered.

  (iii) possibly searching for more pieces of evidence among the wreckage of the aircraft.'

At a later stage, on the occasion of further journeys undertaken by British personnel, the following took part: The Head of Stress Section of Hawker Siddeley, and an engineer from the Royal Aircraft Establishment, Farnborough.

When INTI had carried out the appropriate tests and written (15 June 1976) its preliminary report, the principal parts were released to the British authorities who appointed a study group, led by Mr P J E Forsyth, of the Materials Department of the Farnborough establishment. Whilst studies were continuing in the United Kingdom, Ing. Kuguel went to discuss their progress, representing the Accidents Investigation Board.

During the preliminary discussions at Farnborough, and Ing. Kuguel's stay there (see report in the file), an analytical study was carried out to determine the reduction of the strength of the wing when it suffered fatigue cracks in the skin over approximately 37 inches of rib 114. In these circumstances, it was concluded that a load of 2.5g would have been required to cause the wing to break. It should be pointed out that in this case, cracking or breaking of stringers was not allowed for.

During the progress of these studies, the manufacturer issued the following Notices: Alert Bulletins 57/30 (27 4 76); 57/31 (7 5 76) and 57/34 (Aug 76); these are detailed in the file, together with some comments which are quoted in later paragraphs.

Meanwhile, inspection of the Avro 748 aircraft in Argentina had been arranged and many noteworthy features were found. We should mention that some of the principal ones were on aircraft LV-HHF and LV-IEE which required, in the case of IEE, paint-stripping and jacking of the wing and nacelle etc. to be detected. On HHF, the size of the crack located was some 70cm in length. This crack is awaiting study and, naturally, metallographic testing will cast light on its origin and characteristics. For further details, the appropriate information may be studied: it is in the investigation file.

Metallurgical Study No. 2

The study carried out by the Royal Aircraft Establishment at Farnborough, which supplements that of the INTI, shows that the crack at the time of the fast separation of the wing was some 36 inches and involved skin, stringers and re-inforcing plate. The report is signed by P J E Forsyth and is as follows:

'1. INTRODUCTION

The Argentinian authorities have carried out an investigation into the causes of the above accident and their metallurgical investigator Dr R Kuguel, Head of the Department of Mechanics at INTI, has reported on his examination of the various pieces of wreckage available to him and considered relevant.

Dr Kuguel had found some evidence of fatigue failure (altogether about 2.5cm of crack length) but Hawker Siddeley Aviation could not accept that such a small crack could reduce the strength of this wing to a point at which it would fail under the prevailing conditions.

Following this situation, the Director of the Royal Aircraft Establishment was requested by Chief Inspector, Accidents Investigation Branch, to help by instituting an RAE investigation which would involve a new look at the wreckage evidence. Thus with the complete cooperation of the Argentinian authorities the pieces were released to RAE and Dr Kuguel came himself to sit in on the new investigation. (The remainder of the wing was held in the Argentine pending the results of this investigation, and has in fact been more recently studied in situ by a team from the United Kingdom).

The pieces that were received for metallurgical examination relate to the lower wing surface separation line, and it must be stated at this point that the wing had suffered considerable ground impact damage in this region. These pieces are shown in Fig 1, and Fig 2 illustrates the plan form of the area. The fracture line that was of particular interest is shown in the plan. This fracture line has been closely studied and the nature of the fracture diagnosed at various points.

2. EXAMINATION OF FRACTURES

2.1 Lower Wing Skin and Stringer 7 Reinforcing Plate (Material BS L72).
In spite of the crash damage and adhering soil it was evident that a considerable length of the available fracture surface in both the lower wing skin and the reinforcing plate at stringer 7 had impacted and fretted against its opposite face, and had therefore been separated over some period. There was also considerable evidence of fretting around rivet holes in various locations. From this one obtained an impression that this region of the structure had, for some period, been subjected to movement. Generally speaking this condition existed only between stringers 3 and 12 where both flat (fatigue fracture) and slant (either fast fatigue or tensile) fracture occurred; outward from these stringers both aft and forward the fracture, which was wholly slant, was free from rubbing and there was no evidence of movement having taken place at the associated joint surfaces. Within this crack run between stringers 3 and 12, which related to the whole width of the two central panels, (ie approximately 36 inches total length) there were, unfortunately, pieces missing. Firstly a considerable area of skin, forward of the cut-out, then a smaller piece to the rear of the cut-out, and the relevant pieces of stringers 4, 6, 8, 9, 10 and 11. Saw cuts had been made during the course of the first investigation, both in order to facilitate the fracture study and also to take two tensile tests pieces from the reinforcing plate. Figs 3 and 4 show reassembled pieces at the 3½ inch cut-out on the line of stringer 7, and Fig 5 shows an enlarged detail of the skin in Fig 1.

2.2 Stringer Fractures 3-12 and Associated Skin Attachment Points

Stringer 3 (BS L65 extrusion) showed evidence of several fatigue origins as shown in Fig 6 as did the skin at the two bolt hole attachment points. These origins are indicated at arrows A. It is clear from the crash damage observed that there could have been other fatigue origins that were subsequently obliterated. This region constitutes the furthest aft evidence of fatigue fracture on the lower wing surface separation line.

Stringer 4 (rolled BS L72 sheet)

The relevant piece of this stringer was missing but the skin at the lower boom attachment line rivet hole contained fatigue cracks as shown in Fig 7, arrows A.

Stringer 5 (rolled BS L72 sheet)

Both skin and stringer attachment points were available and Fig 8 shows fatigue in the stringer and Fig 9 associated fatigue cracks in the skin.

Stringer 6 (rolled BS L72 sheet)

The fracture on this stringer, which was by bending and compression, was two rivet hole spacings back from the main separation line which suggests that it was, like a number of the other stringers, a secondary crash damage fracture. There were, however, fatigue cracks in the skin at a rivet hole on this stringer attachment line at the equivalent position to that at stringer 5, ie the pick-up point on the lower boom. Thus it appears very likely that stringer 6 contained a similar fatigue crack to 5, and that a short end piece of this stringer, 2 rivet spacings long, had broken away in bending and compression in the final crash.

Stringer 7 (BS L65 extrusion)

This terminated at the 3½ inch cut-out and was, therefore, not involved in the main fracture.

Stringer 8, 9, 10 and 11 (BS L65 extrusions)

These had all failed in bending and compression at points well back from the main separation line as can be seen in Fig 2. Again, it is possible that they had failed by fatigue, and these ends had been broken off in the crash.

Stringer 12

The stringer and the associated reinforcing straps and skin failures are shown in Fig 10. There was clear evidence of fatigue from some of the bolt holes of the two doubler straps and skin and rubbing of the slant fractures up to the boundary marked in Fig 11. The fatigue origins in the straps are shown in greater detail in Fig 12. This boundary marks the furthest forward extent of fatigue evidence.

2.3 Note regarding Stringer 5 and Associated Skin Attachment

It was observed that the anodic coating in the vicinity of the hole in Stringer 5 from whence fatigue cracks had emanated was itself stress cracked in a somewhat peculiar manner. This is illustrated in Figs 13 and 14 which show the two faces of the stringer and the cracks are illustrated schematically in Fig 15. It should be emphasised that the surroundings of this particular hole had not been distorted by the crash and in fact the pattern of anodic cracking was present on both faces which suggested a direct tensile load. As previously indicated, there had been two fatigue cracks growing diametrically from the hole, and yet the cracks in the coating (which are known to form at general yielding of the alloy) were densely distributed right up to the hole and the edges of the fatigue cracks. At some distance back from the hole the cracks diminished in number but again became more intensely distributed in the region of general yield, ie before final break of the stringer. The latter observation is to be expected but the presence of stress cracks up to the edge of the fatigue crack can only be explained by the fact that this hole must have been stressed to general yield before the fatigue cracks had formed. As no life estimation based on striation counting can be made for these cracks it can only be stated that this overload had happened on some previous occasion.

2.4 Reinforcing Plate at 3½ inch Cut-Out (Stringer 7 Position) and Associated Skin (BS L72)

It was on this reinforcing or doubler plate that the most clearly developed fatigue features were observed. As elsewhere there was considerable evidence of fretting and by referring to Figs 4, 5, 16, 17, 18 and 19 the assembly of the plate and related skin can be seen, together with the directions of crack growth that have been determined. It is clear that the main fatigue area originated at the hole B, in Fig 2 working aft towards rivet hole A and meeting small fatigue cracks from this hole thence to the cut-out. The main growth from hole A was found to enter hole C where it reinitiated and finally broke through to the edge of the plate at D. The crack front curvature that can be seen in Figs 16 and 17 gave a somewhat confused picture of growth direction but on closer inspection this was resolved when it was found that, the crack in the neighbouring skin had been growing aft at this point while that in the plate was growing forward. The skin fracture directions have been shown in Fig 19. The plate aft of the cut-out had been cut in Argentina to extract test pieces and about a 20mm length of the fracture was missing. However, there appeared to be a fatigue origin at the face that mated with the skin somewhere near arrow A in Fig 4 and a length of fatigue crack growth to points B and C where it then turned smoothly to slant fracture. Figs 20 and 21 show microscopic fracture striations from which crack growth direction could be determined.

2.5 Failed Dagger Bracket (BS L73 Forging)

This failure is indicated in Fig 2 on the rib 134 line and is shown in Fig 22. A fatigue crack had practically separated one side of the lug which was then followed by bending and compression failure. The origin is indicated at A.

3. TENSILE TESTS ON SKIN MATERIAL (BS L72)

The results of these tests are shown in Table I. The material properties were within the specification limits. It is worth commenting that the yield strength was only slightly above the specification minimum, and, as might be expected at this strength level, the material had high ductility.

4. SUBSEQUENT OBSERVATIONS

Since the preparation of this report additional wreckage has been made available for examination. The only new evidence that has been revealed by this further examination, and is of interest in the present context, is that fatigue cracks were found to be present in the skin at the inboard end attachment hole of the forward reinforcement strap at Stringer 12. A second examination of the equivalent hole in the skin relating to the rearward reinforcement strap shows that the failure at this location also had fatigue origins. The positions of these cracks are shown in Fig 2. Although these particular cracks had not contributed to the main break it is possible that there were similar cracks at the opposite (inboard) ends of these straps which would have been in the vicinity of what is suspected to be the path of the forward moving separation.

CONCLUSIONS

1. It is concluded that fatigue cracks had originated first in the general vicinity of the $3\frac{1}{2}$ inch cut-out, with rivet hole B being the most likely origin. They had grown fore and aft from this hole in both the skin and the reinforcing plate.

2. A skin failure must also have originated somewhere forward of the reinforcing plate in one of the absent pieces because there was rearward growth towards hole C and out of hole C rearwards towards hole B.

3. There had been fatigue cracks at various holes in both skin and at least one stringer in the rear panel adjacent to the cut-out but the main line of this part of the fracture was straight and slanted. This could have been rapid fatigue or even bursts of tension but its impacted and fretted nature indicated that it had existed for some time prior to the final break-up.

4. Fatigue origins have been observed in stringers 3 and 5 and in two of the reinforcing straps at the stringer 12 position.

5. It can be concluded that the total crack length at the time when final fast separation occurred was approximately 36 inches, ie completely across the two central panels.

6. Stringer 5 had been subjected to a load that had caused general yielding around the rivet hole at its attachment to the lower engine rib boom at some time prior to the formation of the fatigue cracks from this hole.

7. There were no other holes of those available for examination that showed this feature.

8. The material was satisfactory.

9. It is considered that fretting had played a considerable part in initiating the various fatigue cracks but there was no evidence that corrosion had influenced the general situation.'

In view of the results of the metallurgical tests (Nos.1 and 2), we consulted expert Ing. Kuguel and Ingeniero Aeronáutico Ventura, a specialist in structures at the University of La Plata.

In his final report (see file), Ing. Kuguel emphasised that the tests effected and results obtained are purely metallurgic and that they must be supplemented with consideration of the aeronautical causes and effects which might have led to the damage.

Ing. Ventura (see file) agreed in general with the foregoing assessment and thinks that one must consider the dynamic stresses that could have arisen through a modification of the torsional and flexural rigidity accompanying the changes in structural continuity in the area of the cracks.

In line with this, tests are being continued by HSA and the RAE (on the ground and in flight) with strain recorders to determine the levels of strength of the critical areas.

On these aspects, the manufacturer has advanced the following at this time:

1. 'that they have investigated the stresses of a dynamic nature and have concluded that even a crack of approximately 37 inches (98 cm) would not cause critical torsional or flexural dynamic effects'.

2. 'that these tests have indicated that no events of the ground loading were omitted that might have contributed to better knowledge of fatigue behaviour in service conditions, for example landing and take-off on unpaved or rough strips, cross-wind landings, sharp turns during taxying, etc. In-flight measurements also have good correlation with the predicted stresses both in level flight manoeuvres and in symmetrical pitching manoeuvres'.

1.17 Additional information

1. Earlier accident

In view of the possibility of some parts of the aircraft having undergone stress above the elastic limit, we collated and analysed the work-sheets compiled on the major repair after the heavy landing, made on the aircraft between 22 August and 27 October 1966. At that time, the aircraft had flown 9,913:55 hrs overall.

The repair work was carried out by British personnel (1 Team leader, 1 Inspector and 6 mechanics) sent by the manufacturer. From reading of the work-sheets (see file), no indication arises of the matter now under investigation.

2. Major maintenance before the accident

In the light of the size of the fatigue cracks, we inquired inter alia into the major maintenance, in charge of Aerolíneas Argentinas, in the period before the accident.

At the request of the Investigation Board, the airline submitted an exhaustive report (see file) on the work effected during maintenance under its charge.

Aerolíneas Argentinas performed a J-21 1,200-hour inspection (cumulative 25,200hrs) on the aircraft in the accident between 31 March and 23 June 1975. At this time, cards No.0182 and 0183 were filled in (see file), under the maintenance schedule in force. No unusual points were noted.

The inspections given in the '748 Maintenance Schedule (Recommended)' which were carried out on the accident aircraft and on the other aircraft were:

CHECK A (Primary Inspection), recommended by the manufacturer to be carried out before 96 hours, was carried out at 60 hours for AA aircraft and at 50 hours for YPF aircraft.

PERIOD 1 (Basic Inspection), recommended to be carried out at not later than 500 hours or 90 days, was carried out at 600 hours for AA and YPF.

PERIOD 4 (Follow-up Inspection), referring exclusively to item 2.2 the HSA recommendation was 4 x 500 = 2,000 hours and not exceeding 2 years. The AA maintenance programme stipulated that it should be carried out every 1,200 hours.

This maintenance programme was approved by the airworthiness authority for AA on 14 December 1973 (Doc. 701978 DGIH) and for YPF on 31 January 1974 (Doc. 706727 DFH). On this basis, AA issued Procedure Bulletin No. 21 Rev.C (see file) on 19 February 1974. Inspections carried out prior to this were at the following hours and dates:

J - 21 Cumulative total	25,246		12 June 1975
J - 20 Cumulative total	24,660	(-586 hours)	30 April 1974
J - 19 Cumulative total	24,237	(-423 hours)	12 September 1973

In short, the flying time for the primary (50 hours) and basic (600 hours) inspections were strictly complied with. The only thing not taken into account was the calendar periods recommended by the manufacturer. It must be made clear that this limit was taken into account in relation to the corrosion aspects.

It is appropriate here to go into some detail on the specific maintenance recommendations for the areas showing fatigue cracks. We can state these as follows:

1. *Manufacturer's recommendations:*

Basically there were two items of inspection relating directly to the zone in question:

Item No. 1.1. Period 1 (500 hours) Code A.B.C. involving visual checks for cracks without using chemical detectors or electrical apparatus. An additional requirement was to: 'check particularly for cracks in the skin radiating from the reinforcing plate in the area of the landing gear and along the engine ribs. In aircraft with unprotected skins, check for surface corrosion'.

This Recommendation is in the Maintenance Schedule on Page F of AL 116 of 12 July 1974.

The above inspection was transferred from the period 1 inspection (500 hours) to Check A (before 96 hrs) but adding 'check for OBVIOUS DAMAGE......' according to AL 127 of 30 January 1976, but notice of this was sent from London on 9 April 1976 and reached the Maintenance Department in Ezeiza (Buenos Aires) on 28 April 1976. The accident occurred on 14 April 1976.

Item 2.2. Period 4 (2,000 hrs or not more than 2 years), Code A.B.C. An additional requirement was to 'check for evidence of fuel leaks ...... check for cracks in the reinforcing plates of the access panel and at the holes in the skin'.

2. *Operator's procedures:*

Long before the manufacturer's recommendation of 27 December 1968, AA had included item 1.1 in the primary inspection (Check A) which was carried out at 60 hrs for AA and at 50 hrs for YPF. This work was indicated at item 17 (main landing gear and nose gear, paragraph a) 'check structural pick-up points, frames, fittings at the undercarriage attachment points and fittings at the actuator cylinder attachment points for evidence of damage'.

It was also mentioned at item 18 (wings, nacelles, fuselage and tail unit), section a): 'outer wing skin for damage and evidence of fluid losses, pay particular attention to the lower wing section at rib 'O' and de-icing boots for damage and sticking'.

The wording used is not aligned precisely with that used by the manufacturer although in any case this item was not mandatory up to the time of the accident. Later, with effect from 30.1.1976, the manufacturer issued the change to 96-hours and this change arrived after the accident. Nonetheless, the inspection procedures adopted by AA did cover the zone in question.

Item 2.2 was included by AA on cards No. 0109, 0110, 0182 and 0183, which were worked through progressively at each 1,200-hr interval. However, these areas were also inspected at each basic inspection (every 600 hours,equivalent to the manufacturer's Period 1 inspection every 500 hours) at items 25, 33, 38 and 46. We show below, copies of cards 182, 109, item 25a and 33a and -b left-hand side:

1. *Card No.(8)0182 (zone 52 - port main gear and housing)*

WING STRUCTURE

Internal structure of housing, including: strengtheners, fixing pins and support structure of the landing gear and actuating cylinder.

JOB 'A' 'B' 'C'

Detailed 'A' 'B' 'C' inspection of the structure, hinges and latches of the nacelle front fairing.

Check that the space between the jet pipe cover strip assembly and the engine mounting lower strut (forward and right of 'Y' plate) is not less than 0.025 inches.

2. *Card No.(8) 0109 (zone 51 - port wing from rib O to tip)*

WING STRUCTURE

External structure of wing including the lower fairing of the wing-root at rib 'O'.

JOB 'A' 'B' 'C'

Comply with Inspection Bulletin 490.

Check for evidence of leaks in the area of the fuel tank.

Check skin in area of reinforcing plates of landing gear and ribs in the area of the engine nacelle for cracks.

3. *Item 25a*

Check on wing (including lower fairing of wing-root at rib 'O'):

(a) External structure for condition (special attention to area of reinforcing plates of landing gear and JOIN WITH NACELLE of engine), loss of fluid, comply with Inspection Bulletin 490 and cleaning of water drains.

4. *Item 33a*

Check gear housing (including the nacelle):

(a) Internal structure (including fixing strengtheners of landing gear and actuating cylinder) for condition and that the space between the jet pipe cover strip assembly and the lower strut of the engine mounting (forward and right of 'Y' plate) is not less than 0.025inches ....

(b) External structure for condition ....

3. *Minor maintenance before the accident*

As owner of the aircraft, YPF possessed an organisation approved by the competent authorities, under No. 122 (Category B) to effect maintenance on the Avro aircraft at Cutral-Có (Neuquén Province).

YPF carried out the primary inspections (50 hrs) following the basic inspections which Aerolineas Argentinas did. Approval of this Plan is referred to in the foregoing paragraph.

The maintenance work carried out by YPF following the basic inspection by AA is shown below.

Type of Inspection	*Total hrs*	*Date*
Basic (600 hours)	25,246	12.6.75
Primary (50 hours)	25,296	15.7.75
Primary (")	25,346	19.8.75
Work Order 012662		21.8.75 (AA)
Primary (50-hour)	25,396	17.9.75
" "	25,446	11.10.75
" "	25,498	11.11.75
" "	25,549	3.12.75
Work Order 012788		20.12.75 (AA)
Primary (50-hour)	25,596	29.12.75
Work Order 012817		15.1.76 (AA)
Primary (50-hour)	25,656	16.2.76
" "	25,701	9.3.76
" "	25,746	7.4.76

The record of all work done was verified as to existence, accuracy, completion of work and signature of inspectors. In the file is included the latest work-sheet for the 50-hour inspection done on 7 April 1976 on the aircraft in the accident. This has been duly checked and shows no unusual features.

4. *Features found on similar aircraft*

As a result of the accident, and following the subsequent Bulletins issued by the manufacturer, similar aircraft were inspected and cracks of various lengths and size were found; this was after different kinds of work had been done on them since, on some of them, the cracks were not detected. The aircraft on which cracks have been found up till now are LV-HHC, HHF and IEE.

It should be noted that on LV-IEE (overall 26,810 hrs) and on LV-HHF (overall 25,844 hrs), cracks of some size were found. On IEE approximately 25cm and on HHF one 70cm long was found. This aircraft had been out of service since June 1975 and had 207 flying hours since its last 600-hr basic inspection.

The work required according to the bulletins issued for detection of the cracks was as follows (carried out in part or in full):

- removal of the gear-door operating mechanism.
- removal of the gear actuator.
- removal of the paint from the whole area for inspection.
- jacking the wing according to the fuel present.
- radiograph inspection around stringer 12.
- inspection by magnifying-glass, penetrating dye and/or eddy current.
- opening of six inspection doors in nacelles to obtain access to clean and inspect.

According to a 'General and Technical Notice' issued by the manufacturer in June 1976 (see file) concerning 94 aircraft, 18 were found to have small cracks varying from 1/8 to 2½ inches long in the area of the reinforcement. It reported also that an operator who had initially notified no cracks had found them after removing the paint in that area.

5. It should be mentioned also that in 1969, HSA published 'Technical Paper 8' on structural aspects of the Avro 748, in which one paragraph reads 'The tests showed that, during simulated flight of 100,000 hrs, any crack which might have developed was easily detected. Even if they were left unrepaired for 2000 flying hours, the cracks did not reduce the residual strength below the target figure of 120% of the highest anticipated service loads'.

On 5 July 1977, further information was received from the aircraft manufacturer regarding the following:

1. that the estimated residual strength of the wing of aircraft HHB immediately before the accident could have been any of the following:

   (a) with stringers 4-11 inclusive failed - wing strength 1.3g;

   (b) with stringers 4-10 inclusive failed - wing strength 1.53g;

   (c) with stringers 4-9 inclusive failed - wing strength 1.88g;

The manufacturer considers that the most probable cases would be (a) or (b) and they therefore suggest 1.4g as the most likely figure.

2. that examination of the sample of fracture obtained from aircraft HHF and sent to the UK was not complete but made it possible to forecast, in their opinion, that the crack had been present for a very long time, that is, years rather than months. Further, they have found that 'fretting' is present only on one side of the fracture. They therefore conclude that the fretting took place after the crack was propagated, that is that it occurred as a result of the crack and is consequently not a contributory factor. The manufacturer therefore suggests that something similar probably occurred on HHB, but of course the inner side of the fracture was not recovered.

2. Analysis

2.1 From the evidence on hand to date and from discussion among those taking part, we accept as correct the hypothesis that in the moments preceding the accident there took place firstly detachment of the starboard wing (Annex III), followed by separation of the starboard tailplane, without there having been an impact at any other position.

2.2 From the separation of the starboard door of the forward landing-gear leg, which must have occurred moments before the aircraft crashed into the ground, taking account of the nature and disposition of the breaks in the hinges, it is assumed that the landing gear was operated, either deliberately or accidentally, to put it down.

2.3 It should be pointed out that the location shown in the plan at Annex II for the door must be considered questionable, for it was found subsequently, by non-Accident Board staff. Board personnel, immediately after the accident, made an extensive search and did not find it. It is presumed therefore, that the door was found in the neighbourhood of the aircraft's impact.

2.4 Referring to the separation of the wing: this was produced by structural weakening, starting from fatigue cracks. But it remains to be established whether the weakening was so severe that collapse occurred in undisturbed flight or whether there was an assisting factor which precipitated separation. In this matter, the following hypotheses may be made:

1. The cracks encountered, plus any that may have existed in the missing parts, were of such size that when they made rapid progress in the moments preceding the accident, leading to separation of the wing, with the results known;

2. In the zone where the cracks were, there occurred progressive variation of structural continuity. This caused modification of torsional and flexural rigidity of the wing. This could have started at a time when dynamic stresses in the flight created special conditions such as vibration, resonance or flexing (etc) and this, alone or together with a recovery manoeuvre by the pilot, precipitated separation of the wing.

In any case, and regardless of the circumstances which precipitated the collapse of the wing, the principal cause must be based on the extent and severity of the fatigue cracks found and those others which must be presumed to have existed.

2.5 Concerning the origin of the fatigue cracks, we may also put forward two theories. The first would be that they were caused by earlier stress which induced permanent deformation (such as heavy landings, the wing's own aerodynamic stress, etc).

2.6 And the other hypothesis is that, bearing in mind that, under continued strain, fatigue cracks grow in a direction perpendicular to the force applied (see 'Mechanical Failures of metals in service' NBS Circular 550 of the National Bureau of Standards - USA), we must suppose that the fatigue cracks found had their origin solely in normal aerodynamic stress of the wing.

2.7 The possibility that wind shear, turbulence, etc., affected the cracks has not been mentioned, because there is no evidence or suspicion concerning the subject, as explained in 1.7 above, although the aircraft manufacturer considers that this aspect should not be completely discounted.

2.8 Consideration should be given to the manufacturer's opinion that the cracks could have been present for years, taking into account the 'fretting' encountered. Available evidence makes it possible to state that the cracks did not exist over a long period or, if they were present, they were not such that they could be detected by eye (and obviously) with the existing maintenance instructions. Therefore such cracks progressed rapidly, in less than a year, until they became critical. Some of the existing evidence is:

1. HHB, the accident aircraft, flew 513 hours in less than 10 months.

2. HHF had flown 207 hours since the last 600-hour inspection (20 Feb 75) up to the time it was removed from flying on 6 April 75 - it flew 207 hours in 3½ months and had a 70cm crack.

3. IEE, which flew 480 hours from the 600-hour inspection (17 Jan 75) until it was taken off flying on 31 October 1975 (9½ months), had a 25cm crack-

all this occurred although the inspections had been carried out in accordance with the manufacturer's instructions.

2.9 Likewise, as is shown on pages 15-18, the accident aircraft was given all inspections as recommended by the manufacturer.

2.10 Following from this – and discounting materials failure, for it was found generally within the specification – the primary initial factor must be attributed to the geometry of the parts involved. This is known to all aeronautical manufacturers and is countered by a reliability programme.

2.11 In the case of the accident aircraft, the manufacturer had issued a maintenance programme which required inspections for cracks in the area concerned. However, a study of the organisations which carried out major and minor maintenance and the scrupulous manner in which they carried out the services required (see records in the file) leaves no doubt that the maintenance work was executed correctly. The fact that, notwithstanding this, the cracks in the accident aircraft were not detected, plus the difficulty which other operators had in detecting the cracks when sought on aircraft of the type, after the appropriate warning had been issued, suggests that only a more precise manufacturer's instruction regarding inspection of the area under suspicion might have led to detection of the cracks before they became critical.

3. Conclusions

3.1 From all this, it may be concluded that the accident was the result of detachment of the starboard wing in normal flight, through structural fatigue failure of the wing in the area between stringers 3 and 12 and in the area of the engine outer rib (Annex V).

3.2 Within the area indicated, one may identify among the origins of the fatigue the reinforcing plate, and especially, the holes in it for rivets (see Annex IV).

3.3 The cause of these fatigue cracks, since the material of which they were made was satisfactory, must be attributed to stress concentration in the area concerned due to the geometry of the design, these cracks becoming critical sooner than had been estimated. The cracks remained undetected and became critical because the manufacturer's inspection programme for the area concerned was insufficiently precise and made it possible for the operator not to detect and correct them in time.

4. Safety Recommendations

1 Inspection and repair of the areas affected have already been covered by the manufacturer through service bulletins approved by the United Kingdom Civil Aviation Authority.

2 It seems proper that encouragement should be given to continuation of the studies currently being pursued by Hawker Siddeley Aviation and the Royal Aircraft Establishment at Farnborough with the purpose of identifying on those aircraft concerned the origin of fatigue cracks and the appropriate reliability schedule.

3 It is recommended to users of transport aircraft similar to those in the accident, with an overall flying time exceeding 15,000 hours, that they should adopt forthwith inspection procedures based on the procedures specified in HSA Service Bulletin No.57/34.

12 July 1977

C J Bondio

Investigator in Charge

NOTE: It is proper to stress the co-operation and dedication of the Accidents Investigation Branch and the Royal Aircraft Establishment of the United Kingdom who, with their invaluable efforts and studies, made a fundamental contribution to clarification of the causes of this accident.

We make mention also of the very valuable technical collaboration and support of the INTI.

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