No. 13

Straits Air Freight Express Ltd., Bristol 170, ZK-AYH, accident at Christchurch, New Zealand, on 21 November 1957. Civil Aircraft Accident Report No. 25/3/884, released by Accidents Investigation Branch, Air Department, New Zealand.

(Subsequent to the receipt of the report on which this summary is based, the investigating authority forwarded comments made on the report by the manufacturer and the operator of the aircraft concerned. The investigating authority did not, however, consider that these comments justified alteration to the conclusions reached in the report.)

Circumstances

The flight was a routine cargo flight from Woodbourne to Timaru via Paraparaumu. After take-off the aircraft was climbed to 2 500 ft on instruments and a period of asymmetric instrument flying followed during which the starboard propeller was feathered and rate half turns were made in both directions. The starboard propeller was unfeathered and when the minimum operating temperatures had been reached, normal power was applied. Two minutes later a sudden and severe vibration was felt throughout the aircraft. Feathering of the port engine was delayed until nearer the North Island coastline, and no further vibration was felt on the remainder of the flight to Paraparaumu.

The aircraft was then loaded and one crew member was off-loaded prior to take-off on the second segment of the flight to Timaru. At 1127 hours the flight called Harewood Tower giving its position as 6 miles north of the Waimakariri River mouth at 3 000 ft contact. It was subsequently cleared to maintain 3 000 ft to the Harewood Range Station. It then advised that it would descend VFR from the Range Station and proceed VFR to Timaru and was subsequently cleared for this procedure by Harewood Tower. At 1133 hours, at an approximate height of 2 000 ft, the aircraft was seen to suffer structural failure in the air. The starboard outer wing folded upwards and backwards and then separated. The remainder of the aircraft performed a series of violent manoeuvres while diving towards the ground at a mean angle of 35°, shedding a number of major components before finally striking the ground 1 000 yards beyond the point of wing separation. The 2 crew and 2 passengers aboard were killed, and the aircraft was destroyed.

The Weather

Strong northwesterly wind conditions, accompanied by severe turbulence, prevailed on the east coast of the South Island, on the day of the accident. Weather observations made within 1 500 yards of the accident scene two minutes after the accident were:

Cloud 5/8 CuSc base 3 500 ft,
visibility 25 NM
Surface wind 200°T, 5 knots

The surface wind fluctuated and changed direction from 280°T through 200°T to 100°T between 1115 and 1145 hours. No observations of local turbulence were recorded but several pilots reported severe turbulence in the area. Simultaneously with the structural failure of AYH, a witness immediately beneath the aircraft noticed the passage of a whirlwind of sufficient force to raise two single bed mattresses, which were airing on the lawn, to a height of 15 ft from the ground.

The anemometer wind trace recorded at Harewood Airport indicates a 180° wind shift associated with gusts up to 33 knots at the time of the accident.

History of the Aircraft

The aircraft, ZK-AYH, was manufactured by the Bristol Aircraft Company Ltd. in England, in April 1951, and was flown to New Zealand in May 1951. The Certificate of Airworthiness was valid until 4 May 1958. The aircraft had flown 7 898 hours of a 10 400 hour life since new, and 1 011 hours since last complete overhaul.

The aircraft had been maintained in accordance with the approved maintenance schedule; special instructions had been fulfilled, and all mandatory modifications had been incorporated. During its life AYH had made 12 964 landings and had operated at an average of 80% of the total permissible all-up weight. It is estimated that 33% of ground/air transitions were carried out from rough aerodrome grass surfaces.

In 1954, after 3 018 hours and 4 843 landings, cracks were discovered in the starboard outer wing spar. These were repaired in accordance with an approved scheme by cutting out the cracked section of the spar web and the installation of a rivetted patch. Simultaneously Bristol Modification 1169, Extended Link Fittings, and 1192 - Redesigned Bottom Boom and Skin Angle, were incorporated.

The Wreckage

The complete wreckage trail extended over a distance of 1 200 yards on a mean track of 235°T. The distribution of components clearly indicated two distinct phases in the sequence of break-up. Over the first 250 yards the wreckage was directly associated with the separation of the starboard outer wing. A gap of 560 yards in the trail indicated that the second phase of break-up was as a result of the severe loading imposed on the structure by violent involuntary manoeuvres after the separation of the starboard outer wing.

It was evident from inspection of the wreckage that the starboard outer wing broke away from the aircraft in flight. It was also clear that the cause of the structural failure was metal fatigue in the lower boom of the starboard outer wing front spar. This fatigue originated in the outermost 1/4" bolt hole drilled in the boom by the Operator during the incorporation of Bristol Modification 1169, which called for the installation of an extended joint fitting outer wing to centre section. This modification moved the point of stress concentration in the boom to a new location and, as a result, prolonged the life of the aircraft to 10 400 hours. The modification was incorporated on 21 January 1954, after the aircraft had flown 3 018 hours and the failure occurred at 7 898 hours. Although the complete boom had expended 3 018 hours of its fatigue life, it can logically be assumed that the boom was incorrupt at the point where the 1/4" hole was drilled. Thus, the initiation and propagation to failure of the fatigue crack took place at some time during the accumulation of 4 880 flying hours, over a period of 3 years and 10 months.

The aircraft had made a total of 12 964 landings and of these 4 843 had occurred before the incorporation of Modification 1169. Therefore, the initiation and development to boom failure occurred during the accumulation of 4 880 flying hours or 8 121 landings. This represents failure at 66% of the 7 400 hours extended life guaranteed (granted) to the aircraft after incorporation of Modification 1169 at 3 018 hours.

A fatigue crack of less magnitude was discovered in an identical location in the port front lower boom. The presence of this fatigue crack in the port boom indicated that the failure of the starboard boom was not an isolated occurrence; on the contrary, it was an indication of the average life to failure of a Bristol freighter modified to ZK-AYH's state engaged in this kind of operating conditions.

No evidence could be found in the history of AYH of any unusual occurrence which could have precipitated the early onset of fatigue.

Sequence of Failure Starboard Outer Wing

The sequence of events was set in train some considerable time before the accident, when a fatigue crack originated in the last bolt hole of the starboard lower boom joint and gradually propagated over 25% of the effective section of the boom. Additionally, a vertical crack occurred in the shear strap. Simultaneously, fretting with associated cracking, was taking place near the outer end of the joint, in the spar web, doubler, skin angle, and shims. Fretting and elongation in the bolt holes also took place during this development stage.

It was considered that the crack in the shear strap transferred extra tensile loads on to the front lower spar boom. It should be noted, however, that the boom was designed to take all longitudinal tensile loads, while the shear strap carried only shear loads in the wing structure.

Fracture, as a result of encountering a severe gust, occurred in the starboard front lower boom under axial tensile loading at the section weakened by fatigue cracking.

The starboard outer wing then folded upward and backward, resulting in failure of the starboard front upper boom at the outermost bolt hole of the wing joint fitting. Simultaneously, horizontal fractures occurred at the upper and lower ends of the spar web doubler and shear straps, with bolt hole shearing at the upper end of the strap.

As the outer wing was carried backward in the airstream the rear spar booms remained attached to the centre section, resulting in a portion of the upper boom and the lower boom being filletted from the wing.

The filletting of the rear booms facilitated the breaking away of a portion of the wing aft of the rear spar. In carrying away, this portion of the wing pulled out the inboard and outboard aileron hinges, the centre aileron hinge bolt and actuating rod being sheared by the force of the airstream, thus allowing the aileron to fall clear of the wing.

Subsequently, the ingress of the airstream into the wing tore off the inboard wing tank lid and the petrol tank was thrown from the wing.

The disintegration of the remainder of the aircraft occurred as it performed a series of violent manoeuvres as it dived to the ground.

Assessment of Safe Lives of Aircraft Component Parts

The safe lives of the front spar lower booms of the Bristol freighter aircraft used by Straits Air Freight Express were progressively increased between June 1953 and September 1956 from 1 700 hours to 13 400 hours. In the case of ZK-AYH the increase was to 10 400 hours. These increases were recommended by the Bristol Aircraft Company, approved by the United Kingdom Air Registration Board and accepted by the New Zealand Civil Aviation Administration. The revised lives were considered justified as the result of laboratory fatigue tests and the incorporation of modifications to the wing joints.

It was evident that the data, from which the increase in lives was calculated, was not representative of actual fatigue damage sustained under operating conditions. As a result, a grave error was made in the assessment of the safe life of the front spar lower boom. While it is true that Straits Air Freight aircraft operate under particularly severe conditions, the number of fatigue cracks in the booms of aircraft operating in other theatres, and the radical change in lifeing policy since this accident, would indicate that the error in lifeing was general and not confined to its application to the aircraft operated by Straits Air Freight Express.

The accident raises the question of New Zealand's acceptance and assumption of responsibility for safe lives recommended and approved by an overseas source. Because the necessary facilities and information for assessing safe lives are not available locally it has become the practice to accept overseas figures, after certain local data has been supplied to the lifeing authority. As it requires virtually the same information to reject or modify a safe life as to make the original assessment, it follows that New Zealand aeronautical engineers, charged with responsibility in the matter, should be given opportunity to keep fully abreast of the latest research into fatigue and associated problems. The fact that the New Zealand Airworthiness Division accepts responsibility for lifeing figures evolved overseas, without having the necessary information to assess such figures, makes it essential that present policy should be reviewed by the Civil Aviation Administration.

As far as the future operation of Bristol freighters is concerned, the complete failure of the ZK-AYH boom in 4 880 hours or 8 121 landings has provided the Civil Aviation Administration with a criterion on which to modify overseas safe life figures. In consequence a local condition factor of .773 has been calculated. In addition a series of probe inspections of the three outermost bolt holes of all centre section and outer wing lower boom fittings has been instituted, commencing at 3 700 flying hours.

Operational Techniques

The discovery of fatigue cracks in aircraft operating in other theatres indicates that the fatigue failure of the aircraft was not essentially associated with the particularly severe flying conditions encountered by Straits Air Freight aircraft. It is opportune, however, to consider what steps could be taken to minimize the detrimental effect on fatigue life of incessant crossings of Cook Strait at low altitude in turbulent conditions.

The topographical features of the northern portion of the South Island and the southern portion of the North Island induce extremely unstable conditions in the winds channelling through the Strait. The track of Straits Air Freight aircraft across the Strait is approximately at right angles to the prevailing winds, and the short length of stage makes it inevitable that aircraft will spend the major part of flight times at the most damaging altitudes from the gust point of view. In consequence, the aircraft are subject to a high incidence of pitching, rolling and severe asymmetric gusts. As conditions are materially influenced by adjoining land masses, it seems logical to assume that some turbulence could be avoided by adjusting routes and heights to suit the varying wind conditions. A number of theories to achieve this end exist among pilots, but it would appear that no organized effort has been made to analyze and test the validity of the various claims. Alteration of routes involving increase in flight time might appear to involve economic penalty. The contrary might well, however, be the case, as a reduction in the exposure to turbulence may reduce the present high level of maintenance and repair requirements of aircraft. Furthermore, as lifeing is directly related to the frequency of gusts, a reduction in exposure could well result in an increase in total life.

Analysis of the captain's flight plan of ZK-AYH revealed that he maintained the normal operating air speed of 140 mph between Paraparaumu and Harewood. The flight was undertaken in northwesterly wind conditions along the east coast of the South Island, which inevitably result in severe turbulence. New Zealand pilots become so used to these conditions that they pay little attention to the extreme turbulence. It is noteworthy, that a United States Navy pilot flying over the same route at the time, and not familiar with New Zealand conditions, considered it expedient to materially reduce his air speed.

Vibration on Preceding Flight

With regard to the sudden vibration which was experienced on the first segment of the flight, the examination of the wreckage provided no logical answer. The absence of pounding on the surface faces of the primary fracture in the front spar lower boom rules out the possibility that the vibration was associated with fracture of the boom. The vibration could be reconciled with a crack in one of the shear plates, although the cracks appeared to be of long standing. It can only be stated that it is probable that the vibration was associated with the sudden relief of stress, evidence of which was destroyed by fire.

Workmanship

A report of the Dominion Laboratory, Department of Scientific and Industrial Research, on the examination of parts of the crashed aircraft, made reference to the ovality in the bolt holes in the port and starboard wing joint fittings and the failure of the bolts in many cases to meet the required Class B fit tolerance. It was pointed out that these departures from required standards applied to work carried out by both the manufacturers during construction, and to the operator during the subsequent incorporation of Modification 1169. In regard to the misdrilling of the shear plates, also referred to in the above-mentioned report, this took place during the incorporation of Modification 1192 on 21 January 1954 and represents a very serious defect in workmanship and inspection by the operator. Neither the departures from the required standard in the wing assembly joint nor the specific defects in workmanship on the shear plates caused the structural failure. Such defects together with the influences of fretting, anodizing and surface recrystallation could, however, contribute towards the variability shown in the life of the Bristol freighter wing joints.

Freight

The payload represented on the waybills recovered from the wreckage came to a figure of 11 823 lb, as opposed to the weight of 11 058 lb recorded on the load sheets presented to the pilot before take-off. If the waybills represented a true record, the aircraft would have left the ground at a weight in excess of that represented to the pilot, of which 550 lb would have been overload.

Investigation revealed that the waybills recovered from the aircraft did not, in fact, represent the load aboard the aircraft. The discrepancy was associated with the direct delivery of two cows to the airport - it was realized that the weight of the animals was considerably less than that recorded on the waybill. The loading certificate was, therefore, amended but the waybills were not, nor were they withdrawn from the aircraft. Thus the actual load being carried was 10 614 lb plus the weight of two passengers and a tarpaulin which made a total weight of 11 014 lb. The difference between this figure and the 11 058 lb appearing on the load sheet is accounted for by the inadvertent omission from the aircraft of a package weighing 44 lb.

As no facility exists in the Straits Air Freight Express cargon loading system for the weighing of loaded cargons, an inherent possibility exists of a clerical or weighing error causing the overload or unbalance of an aircraft. The only accurate method of ensuring that the aircraft is not overloaded would be for the loaded cargons to traverse a weighbridge en route to the aircraft. It is considered that, in long term planning, provision should be made to provide this facility. On the subject flight, however, it was concluded that the gross weight of the aircraft and the position of the centre of gravity were within the prescribed limits.

Probable Cause

The accident was caused by inflight structural fatigue failure of the starboard front lower spar boom.

The circumstances which made the accident possible were created by the assessment of a life which was materially in excess of the safe life.

The error in life assessment stemmed from the fact that simulated operational conditions from which the lifeing data was evolved were not truly representative of actual operating conditions.

Recommendations

It was recommended:

1. that the failure of ZK-AYH at 4 880 hours and/or 8 121 landings be used as a basis for amending the current maker's assessment of safe lives;
2. that as an interim measure Straits Air Freight Express should evolve and lay down operational techniques to minimize exposure to gusts on the Cook Strait crossing;
3. that the Civil Aviation Administration examine the desirability of sponsoring a full scale gust research project covering the Cook Strait area;
4. that the Civil Aviation Administration review the existing lifeing policy with special regard to the question of responsibility for the acceptance of overseas lifeing figures;
5. that provision be made to facilitate the weighing of loaded cargons at some stage in transit from the railhead to the aircraft. That, meantime, frequent snap checks be undertaken and recorded by the Civil Aviation Administration representatives.

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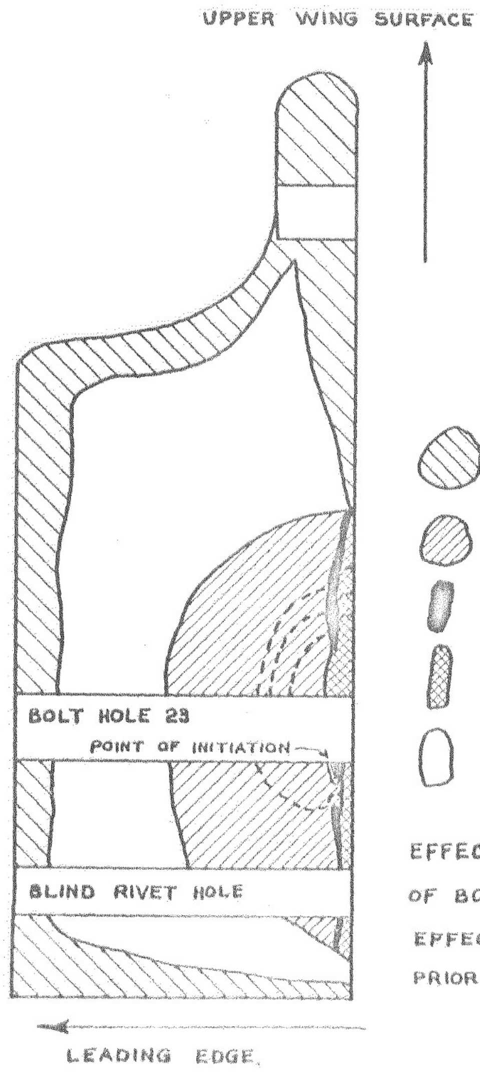
ICAO Ref: AR/551

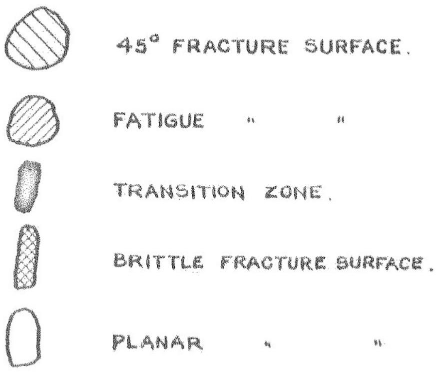
Scheduled
En route
Airframe -Air

FIGURE 5

ZK-AYH

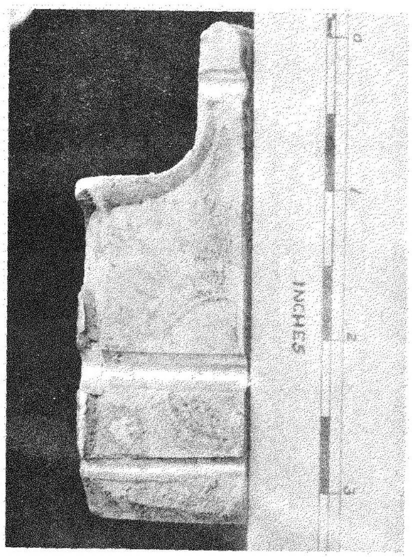
STARBOARD FRONT LOWER BOOM.





EFFECTIVE CROSS-SECTIONAL AREA OF BOOM AT THIS POINT — 2·8 sq. INS.

EFFECTIVE CROSS-SECTIONAL AREA PRIOR TO FINAL FRACTURE — 2·1 sq. INS.



VIEW OF FRACTURE SURFACE SHOWING FATIGUE CRACK

FIGURE 6

THESE ILLUSTRATIONS WERE CONTAINED IN THE REPORT OF THE DOMINION LABORATORY, DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH, N. Z., WHICH WAS ATTACHED TO THE ACCIDENT REPORT

FIGURE 7

STARBOARD OUTER WING