No. 5

MacRobertson-Miller Airlines Pty., Viscount 720C, VH-RMQ accident near Port Hedland, Western Australia, on 31 December 1968. Report, dated September 1969, released by the Department of Civil Aviation, Australia

1.- Investigation

1.1 History of the flight

Flight 1750 was a scheduled domestic flight from Perth to Port Hedland in the State of Western Australia. Whilst taxiing for take-off on runway 02 at Perth Airport, the crew received and acknowledged an air traffic clearance communicated by Perth Tower. Of the alternative clearances offered, the pilot-in-command elected to proceed via the 030^{o} radial of the Perth Very High Frequency Omni-Range (VOR), to Ballidu, whilst climbing to FL 170. Take-off was normal and the crew reported the departure time as 0836 hours Western Standard Time.

At 0839 hours the pilot-in-command reported that he was climbing at an indicated airspeed of 155 kt, instead of the 175 kt proposed in the flight plan, because of turbulence which he first encountered at 1 500 ft. During this climb the co-pilot also advised Perth that the aircraft would continue its climb beyond the proposed FL 170 and cruise at FL 190. Apart from these minor changes to the flight plan the aircraft continued normally along the intended route with position reports being transmitted as scheduled to Perth Flight Service Centre, Meekatharra Flight Service Unit and Port Hedland Flight Service Centre. At 1114 hours the aircraft advised Port Hedland that it was abeam Wittenoom Gorge at FL 190 and that its estimated time of arrival at Port Hedland was 1142 hours.

At 1120 hours the flight advised that it would be commencing its descent from FL 190 in three minutes and at 1134 hours it reported that it was 30 miles by Distance Measuring Equipment south of Port Hedland and had left 7 000 ft on descent. The flight service officer at Port Hedland acknowledged this message and transmitted the surface wind and temperature conditions and the altimeter setting for landing at Port Hedland. When this communication was not acknowledged further calls were made but no further communication from the aircraft was heard or recorded.

At about the time that the aircraft failed to respond to the radio communication, two persons, each in different positions, saw the aircraft descending rapidly and steeply although these observations were made from distances of 4½ and 6½ miles respectively. Neither of these eyewitnesses was able to observe any impact with the ground because of intervening high terrain. At 1212 hours a Cessna 337 aircraft left Port Hedland to search along the route which the aircraft had been expected to follow and, eleven minutes later, the pilot of the search aircraft saw the burning wreckage of the Viscount aircraft, close to the intended route. Approximately one hour later a ground party from Port Hedland reached the scene of the accident. The location of the wreckage was later determined to be 28.1 miles on a bearing of 184^{o} true from Port Hedland Airport.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	22	
Non-fatal			
None			

1.3 Damage to the aircraft

The aircraft was destroyed by severe impact forces and the major portion was also affected by an intense post-impact fire.

1.4 Other damage

The aircraft struck the ground in open spinifex-grassed country. There was no damage to property.

1.5 Crew information

The pilot-in-command, aged 47, was first issued with a first class airline transport pilot's licence on 14 November 1947. He became pilot-in-command on Viscount 747 aircraft on 8 July 1968 and his licence was endorsed for Viscount 720C aircraft on 19 September 1968. He also possessed a valid first class instrument rating and a radio telephone operator's licence. On 16 October 1968 he successfully underwent a medical examination for renewal of his pilot licence and no evidence that he was in other than good health at the time of the accident was found. He passed his proficiency checks on Viscount on 26 and 29 October 1968 and on both occasions the examining check captain assessed his performance as sound. He had flown a total of 19 129 hours of which 17 877 hours had been flown in command, including 367 hours on Viscount aircraft.

The co-pilot, aged 31, was first issued with a second class airline transport pilot's licence on 20 August 1965. He served as a co-pilot on DC-3 and Fokker F-27 aircraft until 1 October 1968 when he became co-pilot on Viscount 720C aircraft. On 5 December 1968 he successfully underwent a medical examination for renewal of his pilot licence and no evidence that he was in other than good health at the time of the accident was found. He passed his last proficiency check on Viscount on 23 November 1968 and the examining check pilot recorded that all exercises were carried out to a good standard. He had flown a total of 2 660 hours of which 620 hours had been flown in command, and 143 hours as co-pilot on Viscount aircraft.

Both hostesses had satisfactorily completed their emergency and flight training for Viscount type aircraft.

1.6 Aircraft information

The aircraft had a valid certificate of airworthiness.

1.8 Aids to navigation

At the time of the accident, the aircraft was operating in visual meteorological conditions, its radio compass was tuned to the Port Hedland non-directional radio beacon and its distance measuring equipment was interrogating the Port Hedland DME responder beacon. During the whole of the period within which the aircraft could have been flying by reference to these facilities, they were operating normally.

1.9 Communications

During the flight all communications between the flight and ground stations were made on VHF and were normal.

An examination of the tape recordings and flight progress strips relating to the movement of the subject aircraft on this day revealed no abnormality in the conduct of the flight up to the time at which the accident occurred. It is apparent that all of the services provided to the aircraft by the ground stations were provided in accordance with established procedures.

1.10 Aerodrome and ground facilities

Aerodrome and ground facilities were not factors in this accident.

1.11 Flight recorders

(a) Flight data recorder

The aircraft was equipped with a United Control Corporation Type F-542B flight data recorder, recording the aircraft's pressure altitude, indicated airspeed, heading and vertical acceleration against a time base. The recorder was mounted in the rear fuselage, under-floor area of the aircraft and, although subjected to impact damage which distorted the outer case, the recorder was not affected by fire. When the recording tape was removed for examination it was found that the impact damage had induced some distortion of the tape and it was torn diagonally across the engravings of aircraft altitude; however, a satisfactory read-out was obtained.

A graphical representation of the read-out for the last 100 seconds of flight prior to ground impact is given at Figure 5-1. Since there is an altitude trace down to ground level in the area of the accident it is apparent that the recorder continued to operate right up to the point of ground impact. It may also be seen from the altitude trace that prior to reaching 7 000 ft in its descent towards Port Hedland, the aircraft lost height normally at an average rate of approximately 1 070 ft/min. When a height of 7 000 ft was reached, however, gross variations occurred in the aircraft's vertical acceleration, heading and indicated airspeed whilst the rate of descent increased to an average of 14 000 ft/min which was maintained until the aircraft reached ground level.

During the read-out of the indicated airspeed record it was noticed that the speeds recorded were significantly higher than those prescribed for the operation of Viscount aircraft. A careful examination of other evidence indicated that, at some time, probably during the last overhaul or installation of the recorder, the airspeed stylus was inadvertently displaced 0.015 inches. Due to this displacement, the record of indicated airspeed was approximately 12 kt higher than the actual airspeed of the aircraft as displayed on the cockpit instruments whilst the aircraft was operating in the cruise and

The aircraft had been properly maintained in accordance with a maintenance system approved by the Director General of Civil Aviation. All components of the aircraft were operating within their approved limits and, at the time of its departure from Perth on the morning of 31 December 1968 there were no known defects in the aircraft. It had flown a total of 31 746 hours and had made a total of 25 336 landings, including 7 188 hours and 6 420 landings since the last overhaul.

The aircraft's maximum permissible gross weight for take-off was 62 000 lb and the load sheet prepared for this flight indicated that the take-off weight would be 58 791 lb. The aircraft's maximum permissible gross weight for landing was 57 500 lb and the load sheet indicated that the landing weight would be 50 691 lb. The investigation revealed that the gross weight of the aircraft at take-off was in fact 58 841 lb and its estimated landing weight 50 741 lb.

The centre of gravity of the aircraft at the time of the take-off from Perth was estimated to be at 20.8 per cent standard mean chord and at the time of the accident at 19 per cent standard mean chord, i.e. well within safe limits during the whole of the flight.

The fuel being used was aviation kerosene.

The Viscount fuselage is an aluminium alloy stressed skin structure with frames and stringers. The inner and outer wing construction consists of a single main spar, leading and trailing edge members and a stressed skin. The main spar is an 'I' section composed of upper and lower tapering 'T' section booms and a stiffened plate web. The booms are machined from a stretched and precipitated extrusion of aluminium alloy to specification DTD 363A or DTD 5074. This single main spar is designed to carry 90 per cent of the over-all wing bending moment and shear force.

1.7 Meteorological information

A weather forecast for the route to be followed by the aircraft was prepared by Perth Airport Meteorological Office and handed to the pilot-in-command before he completed his flight plan. This forecast indicated that the weather conditions throughout the flight would be fine and the only significant feature was the expected presence of moderate turbulence below 5 - 6 000 ft. A post-flight analysis of the en-route weather carried out by the Perth Office of the Bureau of Meteorology indicated that the weather along the route was generally as forecast with the exception that the wind profile above Perth Airport showed marked shear in the lower levels and this produced turbulence up to 8 000 ft which may have been severe in the layer immediately above 5 000 ft.

The report made by the pilot-in-command whilst the aircraft was climbing after take-off indicated that the turbulence encountered by the aircraft was at least of moderate intensity in patches and this assessment was confirmed by a reading of the vertical acceleration trace on the aircraft's flight data recorder. This trace showed that moderate turbulence was encountered in the layer from 2 000 ft to 7 000 ft during the climb, but there was no significant turbulence recorded during the remainder of the flight.

The weather in the area of the accident at the time it occurred was fine, there was no low cloud, the visibility was slightly restricted by haze and the surface wind was 5 to 8 kt from approximately 340°. The Port Hedland QNH altimeter setting was 1 006 mb.

descent modes. The presentation of indicated airspeed at Figure 5-1 therefore shows the read-out of the actual record as a broken line and the corrected airspeeds as a solid line.

The recorded aircraft headings were appropriate to the route being flown and showed normal navigation corrections up to the point at which the aircraft reached 7 000 ft on its descent. Thereafter, gross and rapid changes of heading were recorded which could only be consistent with a complete loss of control.

The trace of the aircraft's vertical acceleration showed that, in the first eight minutes of the aircraft's climb after take-off from Perth, turbulence was encountered and acceleration excursions ranging from 0.44 g positive to 0.45 g negative were recorded. There were no further significant recordings of vertical acceleration during this flight until the aircraft reached 7 000 ft on its descent into Port Hedland. Beyond this point and until the aircraft struck the ground, very large excursions in vertical acceleration, ranging from 2.95 g positive to 2.85 g negative, were recorded.

(b) Cockpit voice recorder

The aircraft was also equipped with a United Control Corporation V-412 cockpit voice recorder. The recorder was mounted in the rear fuselage, under-floor area adjacent to the flight data recorder. It was ejected from its mounting during the aircraft's impact with the ground and suffered substantial heat damage to the outer case in the subsequent ground fire. When the tape magazine was removed from the recorder, it was found that the fire protection material between the outer case and the magazine had protected the tape from serious heat damage but it was severely crushed and torn as a result of impact damage.

Despite the damaged condition of the tape an almost complete read-out was obtained of those channels recording radio communications and the cabin announcement system. On the other hand, great difficulty was encountered in interpreting the record of cockpit conversation, because of damage to the tape and the very high ambient noise level present in the cockpit area.

It was apparent that the cockpit voice recorder continued to operate until the aircraft struck the ground. That part of the cockpit conversation which could be deciphered in the period prior to the aircraft reaching 7 000 ft in the descent, indicated that the operation of the aircraft was completely normal and that the flight crew received no warning of the event which obviously induced a complete loss of control on reaching 7 000 ft. Between this point and the completion of the recording at ground impact, there was no record of any cockpit conversation but, at 7 000 ft, there was a distinct change in the frequency and volume of background noise in the cockpit and this continued until the ground impact occurred. The ambient noise recorded in this period seems to be consistent with that which might be produced by an aircraft moving at high speed and out of control.

The evidence obtained from both the flight data and cockpit voice recorders indicated clearly that the aircraft's operation was normal during the whole of this flight until it reached a height of 7 000 ft on its descent into Port Hedland. At 1134 hours and 1 second the co-pilot commenced his report to Port Hedland that the aircraft was 30 miles south of the aerodrome and had left 7 000 ft on its descent. Approximately 4 seconds after that message had been completed, or at 1134 hours and 12 seconds, there was obviously a catastrophic event affecting the aircraft and inducing a complete loss of control. At 1134 hours and 38 seconds the aircraft struck the ground and all recordings were terminated.

1.12 Wreckage

The principal impact of the aircraft occurred 1.2 miles west of the planned flight path to Port Hedland and at a point 28.1 miles on a bearing of 184° true from the Port Hedland Airport. The terrain at this point is approximately 250 ft AMSL. The principal impact occurred on hard rocky level ground covered with spinifex grass and a few stunted trees. Although the major portion of the wreckage was found there, many other components, including some major items, were found throughout an area extending in a southwesterly direction from the principal impact point, for a distance of some 7 750 ft and over a width of 2 500 ft.

The most significant feature of the wreckage distribution was the fact that the whole of the starboard wing outboard of the inner or No. 3 engine and including the No. 4 engine, its propeller and supporting nacelle structure were found close together, but separated from the point of principal impact by some 3 000 ft. None of these components had been affected by fire and, although the No. 4 engine, the nacelle structure and the inboard portion of the wing had been severely damaged by ground impact, there was relatively little damage to the outer wing section. The tail section and rear fuselage of the aircraft was also found at a point some 1 600 ft south of the main wreckage. It was quite apparent from the distribution of wreckage that the aircraft structure had failed in flight.

All of the fuselage encompassing the cabin and cockpit areas, together with the port wing, the inboard section of the starboard wing and the undercarriage units, were found in the main impact area. Nearly all of these components had been severely affected by a fire which raged through this area after the impact. Although there was smoke staining and paint blistering on some external surfaces, including those of the tail section, which apparently resulted from a flash fuel fire at the time of wing separation in the air, there was no evidence that any in-flight fire occurred in the aircraft prior to the structural failure.

Examination of the tail section and rear fuselage showed that all failures had been produced by overload and there was no evidence at any point of prior defect. The starboard tail plane and elevator, which were separately located, had failed in flight as a result of being struck by sections of the separating wing structure. Similarly, all of the engine nacelle failures were produced by overload and no evidence of any prior defect was found.

Detailed examination revealed that fatigue cracking and primary failure of the starboard inner wing main spar lower boom occurred at Station 143 which almost coincides with the outboard edge of No. 3 engine nacelle. The fatigue cracking and subsequent failure at Station 143 had occurred through the rear bushed hole of a group of five in the boom at this point to permit attachment of the No. 3 engine nacelle outboard lower tube attachment fitting which is bolted to the lower boom. These holes are 7/16 inch in diameter and contain steel bushes which accommodate five of the seven 5/16 inch diameter bolts attaching the nacelle tube fitting to the wing structure. They are normally hidden from view by the lower wing skin and other components.

No evidence of any prior defect was found other than that which occurred at Station 143 in the main spar lower boom.

The Fracture Surface and Hole at Station 143

Metallurgical examination of the fracture surfaces of the boom at Station 143 confirmed that a fatigue crack, extending over some 85 per cent of the cross-sectional area of the spar lower boom, existed at the time of failure. It also revealed that fatigue cracking had initiated at a number of points in the bore of the hole and that these initiations were not associated directly with corrosion, fretting or metallurgical defects.

The retirement life for the main spar lower boom had been determined by the manufacturer and the primary certificating authority, the Air Registration Board of the United Kingdom, as 11 400 flights. Nevertheless, the boom failed after only 8 090 flights since new and every effort was made to discover any condition of design, construction, maintenance or operation which might have induced this unexpected and early failure. A close visual examination of the hole in the boom at Station 143, from which the fatigue crack propagated, revealed that significant differences existed between the surface features in the bore of this hole and those apparent in other bushed holes of the boom. An examination of the manufacturer's drawings and process specifications showed that the steel bushes are designed to be inserted with an interference fit in the aluminium alloy boom of between 0.0015 and 0.0029 inches in diameter. The bushes are required to be cadmium plated and the hole surfaces anodised before insertion of the bush; a chromate anti-corrosion compound to specification DTD 369 is applied when the bushes are inserted. The bushes are normally inserted in the boom from the lower surface until they are flush with that surface, and the length of each bush is arranged so that, at any point in the tapering spar boom, the bush will be slightly shorter than the hole. The amount of interference between the bush and boom is taken up by elastic deformation of the bush and of the surrounding material. The bushes prevent fretting between the bolts and the boom whilst the insertion with an interference fit is designed to improve fatigue resistance properties of the boom by introducing local compression stresses into the surface of the boom material.

The observed differences between that part of the hole at Station 143 which had been occupied by the bush and other similar holes examined in the same boom were as follows:

(a) No anodised material was evident on the wall of the hole.

(b) No anti-corrosion compound was evident on the wall of the hole.

(c) The hole surface had a bright burnish over-laying some circumferential grooves.

(d) There were heavy score marks on the surface of the hole parallel to its axis.

(e) Metal had been broached from the walls of the hole such that its mean diameter was in excess of the maximum allowable diameter by 0.008 inches at the lower end and 0.006 inches at the upper end.

(f) A circular lip of metal had been formed around the circumference of the hole at a position corresponding with the upper or chamfered end of the bush.

(g) A plastic flow of metal had taken place in the direction of bush insertion and this was evident over all that portion of the hole occupied by the bush. The signs of this deformation were evident to a depth of 0.0043 inches beneath the surface.

Not only were these differences noticed but it was also apparent that the diameter of that portion of the hole which had not been occupied by the bush was in accordance with the manufacturing specification. Both anodised material and anti-corrosion compound were evident in the circumferential metal lip and in that portion of the hole not occupied by the bush and it could be seen that the bush had been inserted from the lower face of the boom, which is the direction adopted by the manufacturer.

The Bush at Station 143

Close examination of the steel bush from the Station 143 hole, which had been recovered still on the bolt in the fitting which normally attaches the No. 3 nacelle outboard lower tube to the wing structure was then carried out.

In comparing the dimensions of that bush with those prescribed by the manufacturer in Drawing No. 70103/3345 Issue B III for production of these bushes, a number of differences were noticed as follows:

(a) The external chamfer angle was 40^{o} to the longitudinal axis of the bush and not 15^{o} as specified.

(b) Although not called for in the manufacturer's drawing, chamfers existed at both ends of the bore of the bush. In addition, a metallographic examination showed distinct signs on both of these chamfers that, at least in part, they had been produced by the impact of some form of conical tool rather than by a machining process.

(c) At the externally-chamfered end of the bush, and for a distance of approximately 0.055 inches along the parallel part of its length, the bush had been flared to a mean external diameter of 0.4437 inches which is 0.0038 inches greater than the maximum specified. The initiation of the flare was quite sharply defined.

(d) The mean external diameter at the mid-length of the bush was 0.0005 inches less than the minimum specified in the manufacturer's drawing. The mean external diameter at the other end was 0.0023 inches greater than the maximum specified but, in respect of this dimension, there was a pronounced ovality of the bush at this end, probably arising from abnormal loadings occurring at the time of wing separation which could have produced some or all of this increase in mean diameter.

In addition to these dimensional discrepancies the grinding and tool marks on the bush were examined and, although in machining mark pitch they were somewhat different from a number of other bushes recovered from the same boom, they were substantially similar in this respect to at least two other bushes from the same boom. They were also similar in this respect to a production bush examined at the manufacturer's premises. In addition, it was noticed that the cadmium plating on the surface of the bush was of uneven thickness and, in places, had come away from the surface, indicating that adhesion was poor. This condition was not evident on other bushes examined.

When the internal surface of the bush was examined it was noticed that, on one side of the bore and commencing at the lower end as installed in the aircraft, there were relatively coarse machining marks which had removed the cadmium plating and 0.006 inches of bush material. These marks were consistent with the bush having been counter-drilled from its lower end, subsequent to manufacture. Similar signs of post-manufacture counter-drilling were found in bores of two other bushes in the group of five located at and about Station 143. In these bushes the amount of material removed was 0.006 and 0.015 inches.

In considering the reasons why this counter-drilling may have been necessary, a close examination was made of the engine nacelle attachment fitting which is joined to the spar boom at Station 143. The fitting was one which was supplied by the manufacturer to the previous operator of the aircraft for the purpose of carrying out a spar boom change in this aircraft in 1958. The fitting was supplied without boom attachment holes and the hole drilling would have been carried out in workshops of that operator. By the time the second boom change became due in 1964 the manufacturer had amended the procedures to permit the re-use of the engine attachment fitting removed from the aircraft. Thus, the procedure in 1964 involved a re-installation of the fitting originally drilled and installed by the previous operator in 1958. A dimensional check of this fitting was carried out during the investigation and it was found that the hole spacing would have been incompatible with any new spar boom to the extent that not all of the five bolts could have been entered into the bushed holes through the nacelle attachment fitting. In this situation it is conceivable that some attempt might have been made to improve the alignment of some of the holes by passing a 5/16 inch drill through the fitting into the bushed hole from below.

Other boom holes in VH-RMQ

Apart from some small sections which were badly affected by fire, all of the other bushed holes in the flanges of the starboard inner wing lower spar boom of the subject aircraft, as well as those in the starboard outer wing and port inner wing lower booms, were broken open and examined for any signs of fatigue cracking. The lower boom in the starboard outer wing had completed 13 449 of the 19 000 flights specified as its retirement life. The port inner wing lower boom was installed at the same time as that in the starboard inner wing and had completed 8 090 flights. Almost 300 bushed holes of 3/8 inch and 7/16 inch diameter were examined with the following results:

(a) At Station 34 and 88.5 in the port inner boom fatigue cracks were found which commenced in the bores of bushed holes. The maximum depth of crack in each hole was 0.010 inches and 0.008 inches respectively.

(b) In the starboard outer boom at Station 274.6 a fatigue crack was found which had initiated from a corner of a bushed hole and had grown to a maximum depth of 0.015 inches.

These fatigue cracks were, in each case, associated with typical anodised holes with anti-corrosion compound present. There was no sign of any other significant defect or of broaching of metal in any of the holes examined.

The lower boom of the main spar centre-section contained a number of unbushed holes for attachment of the centre-section spar webs. These holes were broken open and examined but no evidence of fatigue cracking was found. This boom had completed 19 417 of the 20 500 flights specified as its retirement life.

The main spars in both tailplanes and the main spar in the fin of VH-RMQ were also examined for any signs of fatigue cracking. These components had been with the aircraft since new and had completed 25 336 of the 30 000 flights specified as their retirement lives. The web attachment holes in the inboard 50 inches of the upper boom in each tailplane and in the lower 70 inches of both booms in the fin were broken open and examined but no cracks were found.

1.13 Fire

The smoke staining and paint blistering on some sections of the aircraft, and the evidence of one eyewitness that there was a puff of black smoke visible in the air indicated that some of the fuel, which would have been released from the fuel tanks at the time of wing separation, burned in the air, momentarily. There was no evidence that any fire had occurred prior to wing separation or that any other form of fire had occurred prior to ground impact. The major portion of wreckage found in the area of principal impact had been severely affected by fire which undoubtedly commenced at impact. The wreckage of No. 2 engine was affected in a minor way by a grass fire which burnt through the area where it was located at some time after it struck the ground. A small fire broke out post impact in the vicinity of No. 3 engine as a result of the spillage of fuel from a broken filter case but this fire did not spread and did not significantly affect the wreckage of the engine. None of the other items of wreckage was affected by fire.

A Department of Civil Aviation fire fighting vehicle left Port Hedland Airport at 1230 hours, seven minutes after the wreckage of the subject aircraft was first sighted from the air. After covering the intervening 46 road miles the vehicle arrived at the accident scene at 1330 hours, or almost two hours after impact, to find that most of the fire damage had already been done.

1.14 Survival aspects

The evidence points to the probability that, with the possible exception of the two hostesses, the occupants of the aircraft were seated with seat belts fastened at the time of the wing failure. The severity of the ground impact, however, eliminated any possibility of a person surviving this accident. The pathological evidence indicated that none of the occupants of the aircraft was exposed to the effects of smoke, fire, flame, fuel mist or explosion before the ground impact.

1.15 Tests and research

Bush insertion experiments

A large range of experiments was carried out, both in the United Kingdom and in Australia, with bushes having different diameters, surface finishes, entry chamfer angles and flared shapes in combination with boom holes having different diameters and surface treatments in an attempt to reproduce the conditions found in the hole at Station 143. Many of these experiments were unsuccessful because all of the conditions found in the Station 143 hole of VH-RMQ were not accurately reproduced or the experimental situation introduced some new factor which had obviously not occurred in VH-RMQ.

The best replica of the VH-RMQ bush characteristics was obtained by inserting a nominal size, 40 degree, chamfered, cadmium-plated bush into an anodised hole of normal production specifications. Insertion of the bush was continued until 0.040 inches of the parallel portion at the chamfered end protruded beyond the hole in the aluminium alloy test piece. Whilst still in the hole, and using a 65 degree included angle conical tool, the bush was flared until its largest diameter was 0.4464 inches (i.e. 0.002 inches in excess of the largest diameter found at the flared end of the VH-RMQ bush). The flared bush was then pushed out of the hole in the same direction as it had been inserted.

Two experiments were then carried out using bushes produced this way. In the first experiment the bush was re-inserted, using anti-corrosion compound, in the same direction and into the same hole from which it had been extracted after flaring. In the second experiment the flared bush was inserted into a new standard anodised hole again using anti-corrosion compound. Both experiments reproduced closely the conditions of hole and bush found at Station 143 in VH-RMQ. The diameter of the bush after insertion in each case was approximately the same as that of the VH-RMQ bush (i.e. the flared end of the bush had been crushed by approximately 0.002 inches during the insertion process). In both cases there was a uniform broaching of the anodised material in the holes and approximately the same amount of metal was rolled up to form a lip ahead of the bushes. In both of these experiments there was also a uniform plastic flow of surface material in the holes to approximately the same depth as was found in the VH-RMQ hole. It was noticed, however, that the first of these two experiments produced a closer resemblance of the condition found in the bore of the VH-RMQ hole, (i.e. the condition of the hole was not simulated exactly unless the anodic film had first been damaged by prior bushing). These two experiments carried out in Australia were later repeated in the United Kingdom using the manufacturer's hydraulic bush insertion tool. These later tests produced similar conclusions to those carried out in Australia.

Flared bush fatigue tests

Since the characteristics of the flared bush and of the hole at Station 143 in VH-RMQ had been precisely defined and a means of accurately and consistently reproducing these conditions had been discovered and, since it was thought likely that these conditions were associated with the premature fatigue cracking which had occurred at this location, it was apparent that tests could and should be carried out to determine, quantitatively, the effect of the insertion of a flared bush on the fatigue endurance of the spar boom. The manufacturer of the aircraft, the British Aircraft Corporation at Weybridge in the United Kingdom, already had considerable experience in the conduct of fatigue tests relevant to Viscount spar booms and possessed fatigue testing equipment having a suitable capacity which was not available within Australia. Accordingly, the manufacturer agreed to carry out an extensive programme of fatigue tests which would compare the fatigue endurance of test specimens made from DTD 363 material, having normally bushed holes, with that of similar specimens incorporating flared bushes such as were found in VH-RMQ.

Thirteen specimens were tested and each was machined from new DTD 5074 boom extrusions, this being the current material specification equivalent to the now-superseded DTD 363 specification. The first five specimens were manufactured with four 3/8 inch diameter holes fitted with standard parallel bushes, since holes of this dimension are used widely throughout the boom and are representative of earlier fatigue specimens. The next six specimens each incorporated four 7/16 inch diameter holes in two of which were fitted standard parallel bushes, the other two containing flared bushes such as were found at Station 143 in VH-RMQ. The final two test specimens each contained four 7/16 inch diameter holes fitted with standard parallel bushes.

Each test comprised a series of programmes, each programme consisting of a ground-air-ground cycle ranging from 4 700 psi-compression to the 1 g mean stress of 13 500 psi-tension, followed by seven cycles of alternating stress of ± 6 300 psi about the 1 g mean. In respect of test specimens Nos. 5, 6 and 8 the fatigue test was stopped before final failure occurred and the specimens were broken by static overload in order to provide residual strength data.

The main tests results are summarized hereunder:

Specimen number	Programmes to Failure	Failing Load (tons)	Fatigue Cracking		Residual Strength (Percentage Ult.)	Estimated Start of Measurable Propagation	
			Area (in.^{2})	Percentage of Total Area		Number of Programmes	Percentage of Total Programmes
1	51,043	36.8	1.865	45.0	23.3		
2	15,850	36.8	0.285	6.89	23.3		
3	17,227	36.8	0.560	13.5	23.3		
4	34,669	36.8	1.050	25.35	23.3		
5	76,296	103.5	0.090	2.06	65.6	66,000	
6	15,377	75.5	0.450	11.1	49.2	9,500	
7	19,357	36.8	0.768	18.9	24.0	12,000	62
8	31,285	48.0	2.722	67.0	31.2	25,000	
9	19,496	36.8	0.915	22.6	24.0	13,000	67
10	24,800	36.8	1.135	28.0	24.0	18,000	72
11	32,643	36.8	1.675	41.5	24.0	24,000	74
12	39,356	36.8	0.890	22.0	24.0	25,000	64
13	85,000 Unbroken						

Notes

- Some doubt existed as to the validity of the results obtained in respect of specimens Nos. 2 and 3. Post-test examination of these specimens showed that the bottom wedge grip pattern could have resulted in asymmetric loading in the test section of the specimen. Accordingly, the results from these two tests were included in the graphical presentation of crack propagation rates.

- The "Residual Strength" values are based on net area and an ultimate tensile strength of 38 tons/in^2 obtained from the material specification.

- In test specimens Nos. 6 to 11 inclusive the primary cracking initiated from a hole containing a flared bush.

On completion of these tests the British Aircraft Corporation concluded that "the results of this series of tests showed that the installation of a 'belled' bush in the Viscount spar boom in lieu of a parallel bush had a significantly adverse effect on the fatigue life of this spar. The reduction of life could well be of the order of 50 per cent". This conclusion was based upon a comparison of log mean endurance values of the specimen groups.

The manufacturer's report provided, in a number of cases, fatigue crack micro-progression rates in terms of the number of programmes per 0.001 inches progression at known crack lengths. These were integrated and replotted with a common origin in Figure 5-2 and provided a comparative estimate of crack propagation rates between holes with flared bushes and holes with normal bushes. Although there was a degree of estimation in this graph, particularly in respect of the determination of time of actual crack initiation, the results showed under the test conditions used that, up to a crack length of approximately 0.25 inches, the crack propagation rate for a specimen with flared bushes approached twice that of a specimen with normal bushes. It was also estimated from extrapolation of the crack propagation data that, in each case considered, the crack started to propagate measurably at about two-thirds of the life to failure under the test cycle loading. The crack propagation rates were obtained using electron microscope fractographs of the fracture surface in the VH-RMQ boom over a distance one to six millimeters from the crack origin. At similar crack lengths the relative crack propagation rates showed good agreement with the crack propagation rate curve for flared bush specimens.

An attempt was also made to relate the crack propagation data obtained from the specimen tests to actual aircraft flights. An approximate relationship between test programmes and flights was obtained by making use of the known flights to failure of VH-RMQ. Test specimen No. 9 was chosen for this purpose because it was close to the mean endurance of flared bush specimens and its crack origin and direction of primary crack propagation provided the closest representation of the cracking which occurred in VH-RMQ. The factor obtained in this manner was 2.44 programmes per flight and the crack propagation curves derived on this basis are shown at Figure 5-3.

1.16 Other information

Viscount Wing Spar Development

The structural testing of the Viscount wing extended over more than ten years prior to the VH-RMQ accident and comprised a wide range of static and fatigue tests both on complete wings and on boom specimens. The first fatigue test took place in 1953 on a wing which was representative of the first 36 production aircraft in the 700 series in which all the holes in the inner wing main spar lower boom were unbushed. The fatigue test programme applied to the wing consisted of a single load level equivalent to a positive and negative 10 ft/sec gust alternating about a mean load corresponding to 1 g steady flight. This level of load was estimated to produce the maximum fatigue damage in the wing. The aim of the test was to determine the crack and failure locations in the wing, together with the applicable number of cycles of alternating stress.

The experience gained in these early tests led to a number of modifications of the spar boom installation, not the least of which was the decision to reduce fretting between the skin attachment bolt and the holes in the spar boom by the insertion of steel bushes in each bolt hole. The adoption of an interference fit for these bushes also had the advantage of further improving the fatigue resistance of the boom.

In order to gauge the effect of bushing these boom holes a test programme was commenced in 1954 involving 81 test specimens containing bushed and unbushed holes of two different diameters and various grouping arrangements. Each test specimen in material, shape and gross cross-sectional area was representative of the lower boom flange at Station 131 which was a fatigue-critical area. These tests were carried out over a wide range of mean and alternating stresses and the results showed that bushing the specimens had increased their fatigue lives by an amount of between 2.1 and 10.7 times that of the unbushed specimens according to the stress level. An improved lower boom was then designed incorporating interference-fit, steel bushes for all bolt holes in the flange and reducing the number of holes in each skin attachment group. Some minor dimensional changes were made but no change in material was called for. This new boom was introduced by Modification D.562 raised in 1954.

The next step in development of the Viscount wing was to assess, by means of a full-scale wing fatigue test, the performance of the improved lower boom manufactured to the Modification D.562 standard. In this test a similar single-level load programme was applied as in the previous full-scale wing tests and, finally, a fatigue fracture of the lower boom at Station 131 occurred after 518 787 cycles of load. It was found that this failure initiated at a point of fretting between the wing skin and the spar boom and signs of similar fretting were also found at various other points along the boom. No damage of any kind was found at the bolt holes and it was apparent that the introduction of interference-fit, steel bushes, together with the other improvements incorporated, had almost doubled the fatigue life of the test wing.

In order to eliminate the fretting occurring between the spar boom and wing skin a strip of linen-based plastic material called "Formapex" was inserted between the boom and the lower skin. A further full-scale wing fatigue test was carried out in which the value of this precaution in improving the fatigue life of the boom was clearly demonstrated. Modification D.956 which was promulgated in 1955 introduced the Formapex strip to production wings and to replacement booms. The booms fitted to VH-RMQ incorporated the steel bushes to Modification D.562 and the Formapex anti-fretting strips to Modification D.956.

Determination of Wing Safe Life

The retirement life applicable to the inner wing spar lower booms installed in VH-RMQ at the time of this accident was 11 400 flights. This life was proposed by the manufacturer, approved by the Air Registration Board in the United Kingdom and agreed to by the Australian Department of Civil Aviation in 1960. This figure was promulgated in the manufacturer's Viscount Overhaul Manual and adopted in the engineering documents of Ansett-ANA having direct relevance to the aircraft VH-RMQ.

The procedure used by the manufacturer in estimating the safe life of the boom was to establish, using special instruments installed in a large number of airline aircraft, the spectrum of loads experienced by the spar boom in flight and then calculate the resulting airborne fatigue damage rate. The damage caused by the ground-air-ground cycle was determined and added to the airborne damage giving the total damage per flight. This information, in conjunction with the results of the fatigue tests, enabled the mean lives to failure to be calculated for the required range of operational environments and spar boom modification status. Airworthiness standards require that, in establishing a safe retirement life for a component such as a main spar boom, agreed factors must be applied to the estimated mean life to failure to allow for such contingencies as variations in material quality, production process, climatic environment, flight condition and for the degree of estimation involved in the determination of the mean and variance of a set of test results. In the case of the Viscount inner wing lower boom a factor of 5 was used in calculating the airborne damage and a factor of 3.5 in calculating the more accurately definable ground-air-ground damage. The recommended retirement life, obtained by combining the factored airborne and ground-air-ground damage rates was expressed in flights rather than hours because the ground-air-ground cycle contributes over half of the total damage and the majority of the airborne damage occurs during climb and descent. In the case of

Australian Viscount Type 720 aircraft, the flight spectrum used was derived from Strain Range Counter records obtained from some 14 000 Viscount flights carried out in Australia prior to 1961.

Viscount Booms in Service

Subsequent to the modification of Viscount lower booms in 1954, by the introduction of steel bushes to the wing skin attachment bolt holes, the manufacturer undertook a programme of examining retired booms by breaking open bushed holes and inspecting for fatigue cracking. Detailed examinations of this sort were carried out on 47 inner wing spar lower booms and on a number of centre-section and outer wing lower booms. Although no cracks were found, the majority of inner wing booms examined had only completed approximately 6 000 flights, this being the approved retirement life for the spar boom at this stage in its development.

At the time of this accident a total of 252 booms of DTD 363 material had been retired, of which 64 had exceeded 8 000 flights and 27 had achieved 11 400 flights. One hundred and forty booms of this type were still in service and no doubt a proportion of these had already exceeded 8 000 flights. Prior to this accident there was no case of a wing spar fatigue failure in a Viscount aircraft or of discovered fatigue cracking in a boom modified by the insertion of steel bushes.

As a consequence of this accident the British Aircraft Corporation, with the approval of the Air Registration Board in the United Kingdom, reduced the retirement life of all DTD 363 inner wing lower booms to 7 000 flights. This gave rise to a need for immediate boom changes in a large number of Viscount aircraft operating in many countries. The replaced booms were obtained and examined by the manufacturer by breaking open the bushed holes at four critical stations in each boom. Within three months of the accident 421 holes in 19 booms had been examined and 37 holes with small fatigue cracks were discovered in 16 of these booms. The depth of these cracks varied from 0.054 inches to less than 0.001 inches and the larger cracks are plotted in the graph of crack propagation rates at Figure 5-3. The number of flights achieved by the booms examined ranged from 7 282 flights to 12 897 flights.

2.- Analysis and Conclusions

2.1 Analysis

The flight data record indicates that the aircraft was competently navigated and flown within the prescribed safe limits. There is no record of any voluntary manoeuvre or other event affecting the aircraft during this flight which could have contributed to the accident. The cockpit voice record also indicates that the aircraft was properly flown by the flight crew and that there was nothing in the performance of the aircraft which provided any warning of an impending disaster.

The evidence that VH-RMQ experienced a structural failure in flight in which the whole of the starboard wing outboard of No. 3 engine separated from the remainder of the aircraft is irrefutable. The distribution of items of wreckage on the ground, the evidence given by eyewitnesses and the flight data record of the aircraft behaviour, all support this conclusion. The evidence derived from the two flight recorders also points to the probability that this event occurred at 12 seconds past 1134 hours. There was no evidence that this wing failure was induced by any preceding unusual manoeuvre of the aircraft or by any collision with another object. The wreckage examination established that the primary failure in the wing occurred at Station 143 in the lower boom of the main spar which is the principal load bearing component of the wing whilst the aircraft is in flight. The separation of the wing would have been almost instantaneous, following failure of the main spar lower boom and the aircraft would have immediately commenced violent and uncontrollable movements. It is apparent that these movements were violent enough to cause the remaining three engines, as well as the rear fuselage and tail section, to separate from the main structure in flight. It is clear from examinations conducted that the final failure of the boom at Station 143 was preceded by fatigue cracking at this point such that some 85 per cent of the cross-sectional area of the boom was affected. The signs of progressive failure under cyclic loads were unmistakable, even to the naked eye, and the residual strength of the boom in its final state would have been such that it may well have failed under steady 1 g flight loads.

At least four small fatigue cracks initiated within the bore on the rear surface of the bolt hole at Station 143 and they propagated towards the trailing edge of the boom. These several small cracks joined together and the propagation continued as a single fatigue crack. At some later time, multiple cracking also commenced on the forward surface of the hole and again these joined to form a single crack propagating towards the leading edge of the boom. Not enough is known about the propagation rates of these fatigue cracks, particularly in their earliest stages, to do more than estimate that the cracking probably commenced to propagate measurably when VH-RMQ had completed some 5 000 flights after installation of this boom.

Quite apart from the physical difficulties involved in inspecting the boom at Station 143 it was clear that this crack could not have progressed to the point of being externally visible when the boom was last inspected in the Ansett-ANA workshops in May, 1968, after having completed 7 169 flights since the boom was installed. Visual inspections of such components as this wing spar boom can only be carried out in conjunction with a major disassembly of the wing structure and thus the continued serviceability of the boom depends primarily upon the proper prescription of a safe retirement life. Prior to this accident the possibility of fatigue cracking in this boom within its safe life had not arisen and hence the need for any inspection of this component had not been contemplated. Even if such inspections had been thought necessary the use of radiographic or ultrasonic techniques would not have been capable of detecting the onset of this fatigue cracking in view of the complexity of the structure involved and the inherent limitations of these methods.

In the context of operations in many countries by hundreds of Viscount aircraft without there being any suggestion of wing spar boom fatigue cracking in service, this case of fatigue failure at about 70 per cent of the specified retirement life was difficult to understand. It was established beyond reasonable doubt that the unusual conditions of the Station 143 hole arose from the insertion of a flared bush, which had probably been inserted in the boom after a normal bush had been removed. The examination of the bush also established the probability that it was manufactured in the United Kingdom, but, having regard to the nature of the deformation, it was apparent that the flaring did not occur in the normal machining and grinding processes involved in its manufacture. The flaring of the bush at its chamfered end took place whilst the bush was externally restrained and the flaring was carried out by blows imparted by a tool having an included angle of some 65 degrees being applied to the bore of the bush. It was also apparent that this or a similar tool was applied to the bore of the same bush at its unchamfered end. The other unusual feature of this bush was the evidence of post-manufacture drilling in the bore, progressing from its lower end. Similar evidence was found in the bores of two other bushes from holes closely adjacent to Station 143.

Considerable but unsuccessful efforts were made to discover when, why and by whom the Station 143 bush was flared and inserted in this spar boom.

Enquiries were also made in connexion with the post-manufacture drilling in the bores of the three bushes at and close to Station 143. The nacelle support tube fitting must accommodate the five bolts which pass through the bushed holes in the spar boom at and about Station 143. This fitting was examined and the spacing of the holes was sufficiently different from the spacing consistently established in new spar booms to indicate that some difficulty must have been encountered, during the spar boom change in 1964, when it became necessary to secure the fitting to the wing structure by passing the five bolts through it, through the doublers and wing skin and through the lower boom of the spar. The misalignment of the holes was such that the 5/16 inch bolts could not have been passed through all of these components unless some action was taken to improve the alignment. One of the possible remedies for such a situation would be to pass a 5/16 inch drill through the holes from beneath the fitting so as to remove some of the material in those bushes which were preventing the passage of the bolts. Although it is probable that this difficulty was encountered in 1964 and led to the drilling marks in the bores of these three bushes, the identity of the person carrying out this action could not be established and the leading hand, in charge of the boom change project, was unable to recollect that this difficulty had even arisen.

The insertion of the flared bush at Station 143 obviously produced features of the hole, such as removal of the anodised layer and scoring of the walls of the hole, which might have reduced the fatigue resistance of the material in this area. More importantly, the broaching of metal from the hole effectively removed the interference fit between the bush and the boom which the manufacturer had sought and relied upon as a means of improving fatigue resistance in this area. On the other hand the insertion of this bush had produced some features which conceivably could have improved the fatigue resistance of the material, these being the burnishing of the hole surface and the production of a metal flow in the surface material. The extensive programme of fatigue testing carried out by the British Aircraft Corporation between February and July of 1969 on behalf of the Australian investigation was designed primarily to evaluate the net effect of the particular features of the hole at Station 143 upon the fatigue endurance of the boom. The Aircraft Laboratories Report No. AL/MAT/3054 published by the British Aircraft Corporation described the detail of these tests and their results. After their completion the manufacturer concluded that the installation of a "belled" or flared bush in the boom in lieu of a parallel bush has a significantly adverse effect upon the fatigue life of the spar and the reduction of its fatigue endurance could well have been of the order of 50 per cent. It was also apparent that the flared bush induced earlier crack initiation and more rapid crack propagation. The illustration at Figure 5-2 is based on the information derived from these tests and demonstrates the higher crack propagation rate in booms contained in flared bush.

The knowledge that the insertion of a flared bush in a boom could be expected to reduce its fatigue endurance by approximately 50 per cent was certainly a significant finding but, on its own, it did not provide a complete explanation for the failure of the VH-RMQ boom at 8 090 flights, or some 70 per cent of its specified retirement life. Considering the fact that determination of the retirement life involved an estimation of mean life to failure based upon the results of earlier fatigue tests and the division of this figure by a factor of approximately 5 to produce the specified safe life, it was not immediately apparent that the reduction of fatigue endurance by 50 per cent should necessarily have caused this boom to fail before 11 400 flights had been achieved. The possibility that the VH-RMQ boom was an extreme case in the normal scatter about the mean life to failure; or that the flight load environment was abnormally severe; or that some other defect was present in the aircraft; or that the mean life to failure determined on the basis of the earlier fatigue tests was incorrect, all had to be explored.

The investigation did not discover any other defect in VH-RMQ which might have reduced the fatigue endurance of the boom. Furthermore, calculations have shown that, although the flight load environment which the aircraft experienced during its Western Australian operations was more severe than that which applied to earlier Viscount operations in the eastern states of Australia and was used in the establishment of the boom retirement life, the period of the Western Australian operation was not long enough to have significantly affected the fatigue endurance of the boom.

Whilst the investigation of this accident was in progress, the manufacturer undertook an extensive programme of inspecting retired booms for evidence of fatigue cracking. The precautionary reduction in the retirement life for inner wing lower booms to 7 000 flights soon had the effect of making available a number of retired booms whose lives ranged between 7 000 and 13 000 flights. These booms, from aircraft which had operated in Europe or Canada, were returned to the manufacturer and inspections for fatigue cracks were made at four critical stations in the boom, including Station 143. A significantly large number of fatigue cracks was found and, although for the most part they were quite small, some 90 per cent having a maximum crack depth of less than 0.010 inches, some larger cracks up to 0.054 inches in depth were also found and the manufacturer, in conjunction with the Air Registration Board, decided to confirm the new safe life of these booms at 7 000 flights. It is also of interest that none of the holes inspected in this programme was irregular or contained a flared bush such as had been discovered in VH-RMQ.

Figure 5-3 depicts crack propagation rates in terms of flights both for the VH-RMQ boom and for other booms in which cracking has been discovered. On the basis of the known failure of the VH-RMQ boom at 8 090 flights, a crack propagation rate curve has been drawn, derived from the crack propagation results for the flared bush specimens. It may be seen that the crack probably commenced to propagate measurably when about 5 000 flights had been completed. Figure 5-3 also depicts the larger cracks discovered in the programme of boom inspection. The crack propagation rate for normally bushed specimens derived from the tests has been applied to the largest of these cracks, which had a maximum depth of 0.054 inches and was found at Station 26 in a boom retired after completing 8 194 flights. It may be seen that this curve also fits very closely a number of smaller cracks discovered in booms which had completed approximately 7 500 flights. It is apparent that these booms, which had normal bushes, would have suffered a significant reduction in strength before reaching a life of 11 400 flights. It could also be said that, if the evidence that is now available had been available when the boom retirement lives were established, the number of flights to retirement would have been set at a lower figure.

There can be no doubt that insertion of a flared bush in the VH-RMQ boom brought about a substantial reduction in its fatigue endurance and made a significant contribution to this accident. It is also apparent that a number of other DTD 363 booms which were in service at the same time would have failed before achieving their retirement lives if they had contained a bush flared as in VH-RMQ. It was noted, however, that the airworthiness requirements relating to the specification of retirement lives for "safe-life" items of this type are not intended to allow for unpredictable gross defects of this nature. Nevertheless, it is now apparent that the insertion of the flared bush in the VH-RMQ boom and the small margin of safety which actually existed in the specified retirement life, was the combination of factors which constitute the cause of this accident.

2.2 Conclusions

(a) Findings

At approximately 1134 hours Western Standard Time on the 31 December 1968, Viscount 720C aircraft VH-RMQ, registered in the name of Ansett-ANA and operated by MacRobertson-Miller Airlines Pty. Ltd., experienced a structural failure in flight and struck the ground at a point 28.1 miles on a true bearing of 184° from Port Hedland Airport in Western Australia, Australia.

At the time of the accident the aircraft was engaged on a regular public transport service from Perth to Port Hedland, designated as Flight 1750 and authorized by an airline licence issued to the Operator.

In addition to the crew of four, there were 22 passengers on board the aircraft. The remains of all 26 persons on board the aircraft were recovered in the area of the accident and post-mortem examinations revealed that all had died as a result of impact forces.

The aircraft, together with its contents of freight, mail and baggage, was destroyed by impact forces and subsequent fire but the damage to other property was negligible.

The aircraft had a valid certificate of airworthiness and had been properly maintained in accordance with a system approved by the Director-General of Civil Aviation. All components of the aircraft were operating within their approved lives or overhaul periods and, at the time of its departure from Perth on the flight which culminated in this accident, there were no known defects in the aircraft.

The aircraft was loaded within permissible limits and there was no evidence that any element of the load contributed to the accident.

The pilot-in-command was the holder of a valid first class airline transport pilot licence endorsed for Viscount 720C type aircraft and he had a valid first class instrument rating. The evidence indicated he was properly qualified and competent to undertake the responsibilities of pilot-in-command of this aircraft and there is no evidence to suggest that he was not medically fit to do so.

The co-pilot was the holder of a valid second class airline transport pilot licence endorsed for Viscount 720C type aircraft and he had a valid second class instrument rating. The evidence indicated he was properly qualified and competent to undertake the responsibilities of co-pilot on this flight and there is no evidence to suggest that he was not medically fit to do so.

The pilot-in-command was adequately informed on the expected weather conditions prior to commencing the flight and it was conducted in fine, visual meteorological conditions. In the area of the accident there was no element of weather which might have contributed to it.

All the airways and airport facilities pertinent to the flight were functioning correctly and the information and advice given to the flight by the Air Traffic Control and Flight Service Units were in accordance with approved procedures.

VH-RMQ took off at Perth Airport at 0836 hours and climbed to Flight Level 190 for the planned 189 minutes of flight to Port Hedland. The evidence from the flight data record and, in the last 30 minutes of flight, from the cockpit voice record indicated that the aircraft reached Flight Level 190 at 0925 hours and continued at this level with the automatic pilot engaged until 1123 hours, at which time the aircraft commenced its descent for the landing at Port Hedland Airport. At 1134 hours the first officer informed the Port Hedland Flight Service Centre that the aircraft was 30 miles south of Port Hedland Airport and had reached 7 000 ft in its descent. The evidence indicated that no irregularity in the operation of the aircraft presented itself to the flight crew during this stage of the flight and it had been conducted in accordance with procedures prescribed in the Operations Manual.

At 1134 hours and 33 seconds VH-RMQ failed to acknowledge landing information passed by the Port Hedland Flight Service Centre and it is apparent from the flight data and cockpit voice records that control of the aircraft was suddenly and unexpectedly lost 21 seconds prior to that time.

Consideration of the wreckage distribution and the evidence offered by components of the wreckage itself indicated that the starboard wing of the aircraft, outboard of Station 143 and including the No. 4 engine installation, separated from the aircraft in flight and the cockpit voice record shows that this occurred at 1134 hours and 12 seconds without any prior warning being perceived by the flight crew. Immediately following this failure some components of the starboard wing struck the starboard tailplane and elevator causing the outboard portions of these two components to fail and the tail section and rear fuselage to separate from the aircraft. At the same time fuel released into the air from the ruptured fuel tanks burned momentarily and affected, superficially, some external surfaces of the aircraft.

The gyrations of the aircraft subsequent to the wing failure were violent enough to cause the other three engine installations to separate in flight. The remainder of the aircraft, comprising the cabin, cockpit, port wing and the inboard portion of the starboard wing, struck the ground at 1134 hours and 38 seconds.

The starboard inner wing failed in upward bending at Station 143, where the strength of the lower boom of the main spar had been substantially reduced by fatigue cracking extending over some 85 per cent of its cross-sectional area. It is probable that, at the time of the failure, flight loads close to 1g steady flight loads were being applied to the wing.

The fatigue cracking at Station 143, which preceded the final failure of the lower boom, commenced at a number of points within the length of a bushed hole in the flange of the lower boom. This hole was designed to accommodate the rear bolt of a group of seven attaching the No. 3 engine nacelle lower outboard tube attachment fitting to the wing structure. The fatigue cracking commenced to propagate measurably towards the trailing edge of the flange when the boom had completed approximately 5 000 flights subsequent to its installation. At a later time, further fatigue cracking had initiated and propagated towards the leading edge of the boom and the final failure occurred after the cracking had progressed over most of the boom cross-sectional area and when the aircraft had completed 8 090 flights since the boom had been installed. At the time of this accident the safe life specified for the inner wing spar lower boom was 11 400 flights.

The 7/16 inch hole in the boom flange at Station 143 contained a steel bush intended to be an interference fit so as to improve fatigue resistance around the hole. The bush was also intended to prevent fretting between the boom and the 5/16 inch bolt attaching the nacelle fitting to the boom. The bush at Station 143 in the VH-RMQ boom had been deformed before final insertion and, in its found condition, the mean diameter at its leading or chamfered end was 0.0038 inches greater than the maximum specified.

Insertion of the bush at Station 143, which probably took place after a normal bush had been inserted and removed, caused metal to be broached from the hole over almost its entire length. This broaching action removed the anodised surface and the anti-corrosion compound and virtually eliminated the designed interference between bush and boom. The evidence indicated that the bush was flared at its leading or chamfered end by the application of a conical tool to the bore of the bush at this end. There is also some evidence that a similar tool was applied to the bore of the bush at its other end.

It has not been possible to establish why, when, or by whom this bush was flared and inserted in the boom. This action must have taken place at least four years prior to the accident and the investigation was unable to develop even a satisfactory hypothesis as to the reason for such actions or the circumstances in which it could be carried out without being recollected by the persons responsible or recorded in engineering records.

Three of the bushes associated with the attachment of the No. 3 engine nacelle fitting to the lower boom, including that at Station 143, had material drilled from their bores subsequent to manufacture. It is probable that this action took place whilst the lower boom was being installed in VH-RMQ in 1964 and arose from the fact that an imperfect placing of the holes in the nacelle attachment fitting resulted in misalignment between these holes and those in the spar boom. The investigation has been unable to determine who undertook this drilling or to conclude whether or not it had any relation to the flaring of the bush at Station 143.

The spar boom is a "safe-life" item and as such is not subject to in-service inspections for fatigue cracking nor can such inspections be carried out without major disassembly of the structure. Although an inspection of the visible portions of the spar was carried out by Ansett-ANA, 922 flights prior to this accident as part of the routine maintenance of the aircraft, it is apparent that it would not have been possible to detect the fatigue cracking at Station 143 during this inspection.

Fatigue tests carried out by the manufacturer on representative boom sections show that a reduction of approximately 50 per cent in mean life to failure of the boom can be expected as a result of inserting a flared bush of the type found at Station 143 in VH-RMQ.

Examinations and tests, carried out as a result of this accident, suggest that the original fatigue life substantiation was less conservative than had previously been believed. Nevertheless, the method of substantiation conformed with accepted engineering practice at the time the aircraft type was being developed and the subsequent service experience of Viscount aircraft throughout the world supported its adequacy. Up to the time of the accident no evidence was available to suggest that the approved retirement lives were anything other than conservative.

The retirement life for DTD 363 booms was specified prior to this accident as a greater number of flights than probably would have been specified if the evidence that has become available since the accident had been available at that time.

The real safety margins in the boom fatigue lives, specified at the time of this accident, were not necessarily sufficient to ensure that a boom would achieve the nominated retirement life when a defect such as was introduced to VH-RMQ was present. The airworthiness requirements relating to the specification of retirement lives are not intended to allow for a defect of this nature.

The extent of fatigue cracking in booms retired and examined subsequent to this accident indicates that a number of these booms would have suffered a significant reduction in strength before reaching a life of 11 400 flights. All of these booms and a number of others found to contain cracks would probably have failed before reaching their specified retirement lives if they had contained a bush flared as in VH-RMQ.

(b) Cause or
Probable cause(s)

The cause of this accident was that the fatigue endurance of the starboard inner main spar lower boom was substantially reduced by the insertion of a flared bush at Station 143 when the margin of safety associated with the retirement life specified for such booms did not ensure that this boom would achieve its retirement life in the presence of such a defect.

ICAO Ref: AIG/058/68

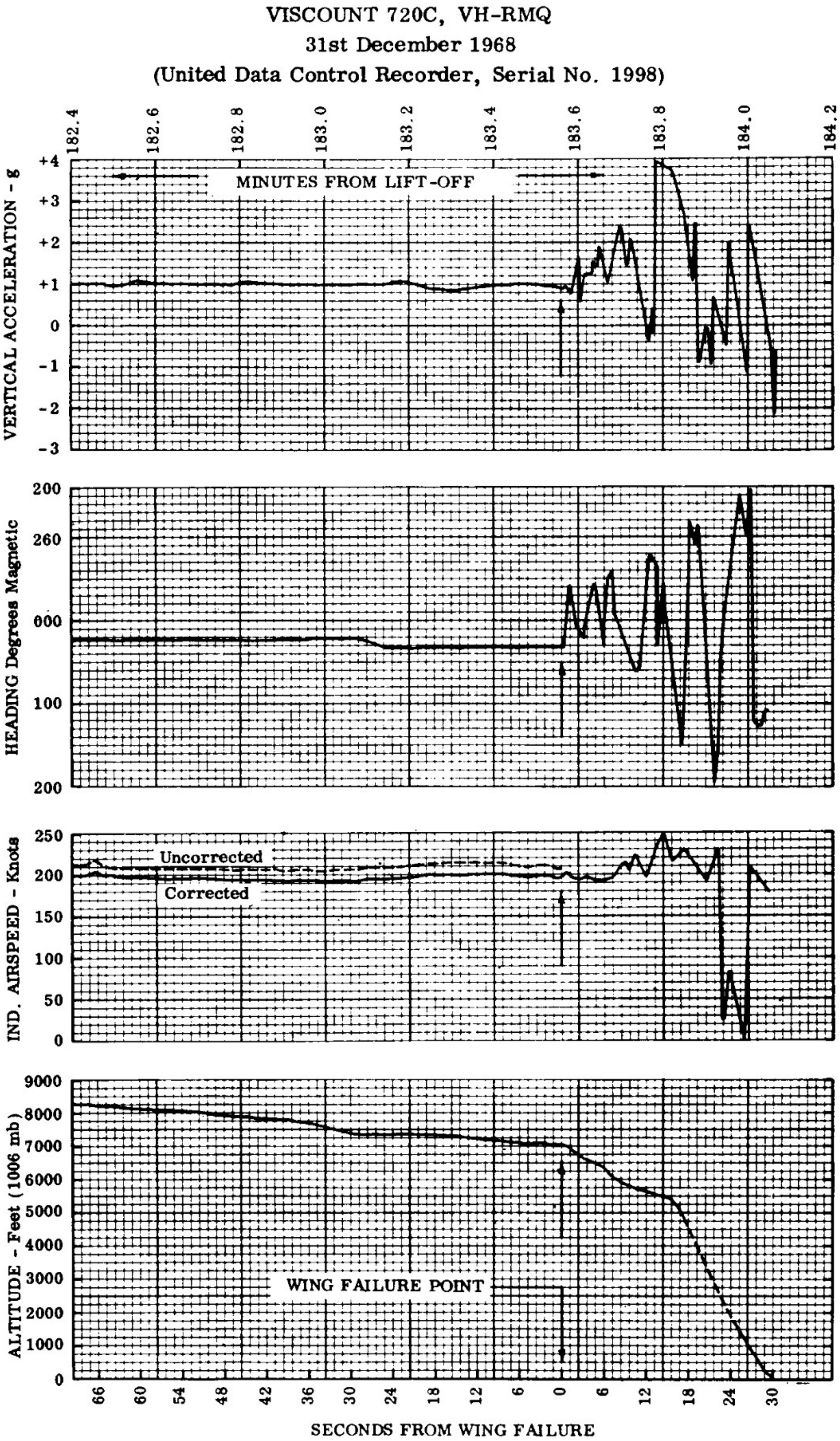

Figure 5-1. Graph of Flight Data Recorder Readings

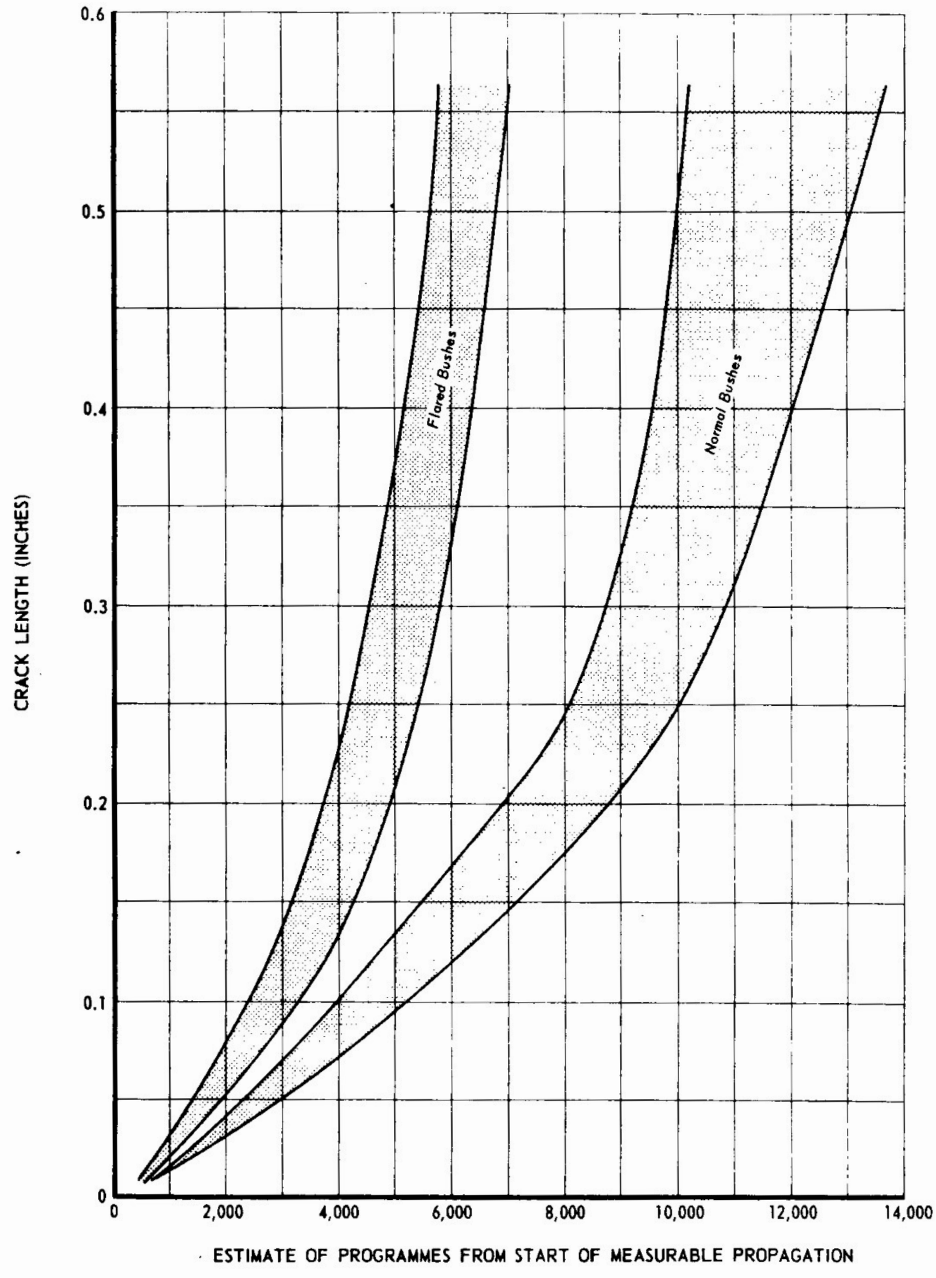

Figure 5-2. Comparison of Crack Propagation Rates - Flared and Normal Bushes