No: 3/91 **Ref: EW/C1185** **Category: 1a**

Aircraft Type and Registration:	Lockheed L1011-500 Tristar, C-GAGI
No & Type of Engines:	3 Rolls Royce RB211-524 Turbofan Engines
Year of Manufacture:	1981
Date and Time (UTC):	11 December 1990 at 0630 hrs
Location:	South of Manchester at Flight Level 370
Type of Flight:	Scheduled passenger
Persons on Board:	Crew - 10 Passengers - 104
Injuries:	Crew - Nil Passengers - Nil
Nature of Damage:	Rupture of gore panel in rear pressure bulkhead
Commander's Licence:	Canadian Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Total Flying Experience:	13,047 hours (of which 350 hours were on type)
Information Source:	AAIB Inspector's Investigation

History of the flight

The aircraft was operating schedule Air Canada 866 from Montreal Mirabel to London Heathrow. Shortly after passing Manchester at flight level (FL) 370 the aircraft suffered a rapid loss of cabin pressurisation and a few seconds later the cabin altitude warning horn sounded. The crew donned oxygen masks and the first officer obtained clearance to descend. The commander began a maximum rate descent whilst the second officer completed the checklist for an emergency descent and confirmed the automatic deployment of the passenger oxygen masks. Having advised ATC that the aircraft had a pressurisation problem, the first officer then declared an emergency and was given unrestricted clearance for both altitude and heading. He then switched on the 'Fasten Seat Belts' sign and broadcast on the cabin address system an instruction to the passengers to put on oxygen masks immediately, repeating these words twice.

In the passenger cabin, two flight attendants near the rear of the aircraft heard a dull 'boom' and a sound of rushing air from the left-hand rear toilet. Some 30 to 40 seconds later the flight attendants saw the passenger oxygen masks deploy. All then took their seats and donned masks in accordance with their

standard operating instructions.

The commander meantime had established the aircraft in descent at maximum operating speed (M_{MO}/V_{MO}), descending to FL180 in a little over 3 minutes. He continued down to FL100 at a slightly reduced rate of descent, reaching this level some 5 minutes 20 seconds after cabin pressurisation was lost. During the descent, cabin altitude rose rapidly from 6,300 feet to a peak of 20,500 feet before falling again quickly to 10,000 feet. Cabin altitude was above 20,000 for 56 seconds and above 18,000 for 2 minutes 20 seconds.

When the aircraft was level at FL100 the commander used the cabin address to call the in-charge flight attendant to the cockpit, who advised him that the passengers were in a satisfactory condition. On hearing this call on the cabin address, the flight attendants left their seats and continued their normal duties. They found that during the emergency 3 passengers had experienced severe headache and earache. A few others complained of dizziness.

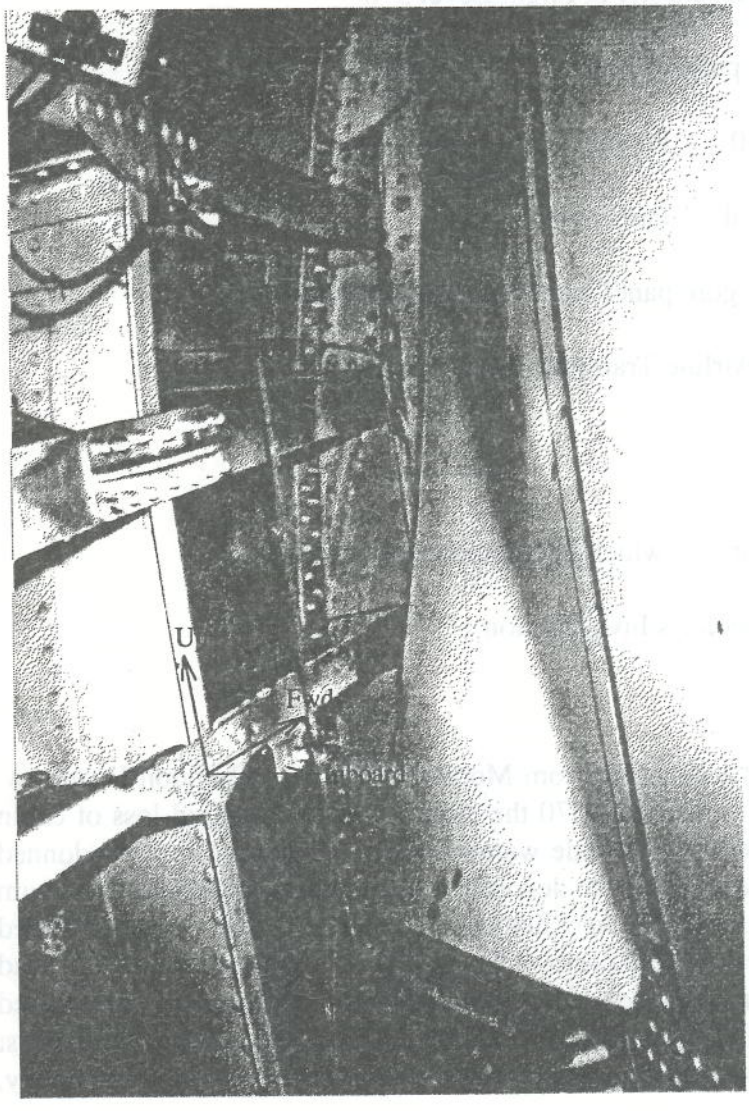


Fig 1
Bulkead rupture
(View looking forward onto rear face of bulkead, adjacent to fuselage side)

The aircraft made a normal landing at London Heathrow at 0658 hrs.

After landing, an inspection of the aft toilet compartments revealed that one of the decorative wall panels had been pushed back towards the rear pressure bulkhead, causing the corners of the panel to split. Fibreglass insulation material was hanging from access panel grills on the fuselage skin beneath the tailplane centre section, and additional insulation could be seen distributed around the interior of the rear fuselage aft of the rear pressure bulkhead. An inspection of the aft side of the rear pressure bulkhead revealed that it had ruptured near the outer edge of the 8-9 o'clock gore panel, allowing a rectangular element approximately 2ft high by 1ft wide to flap outwards, as shown in fig 1.

Rear pressure bulkhead construction.
The rear pressure bulkhead was a thin shell structure comprising a series of 0.040" thick gore panels lap-jointed to form a pressure membrane, with additional doublers and anti-tear straps, producing a bulkhead of spherical pro

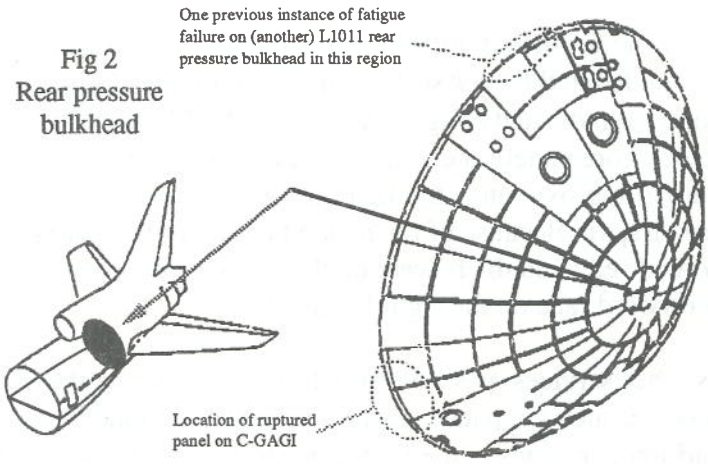


Fig 2
Rear pressure bulkhead

file as shown in fig 2.

Constructional details are shown in fig 3. The gore panels were lap jointed alternately on the forward and aft sides of the nominal membrane surface, producing a handed form of construction. A series of radial and circumferential anti-tear straps, bonded in a typical *waffle* pattern to the aft face of the bulkhead, subdivided each of the gore panels into ten elements of approximately rectangular shape.

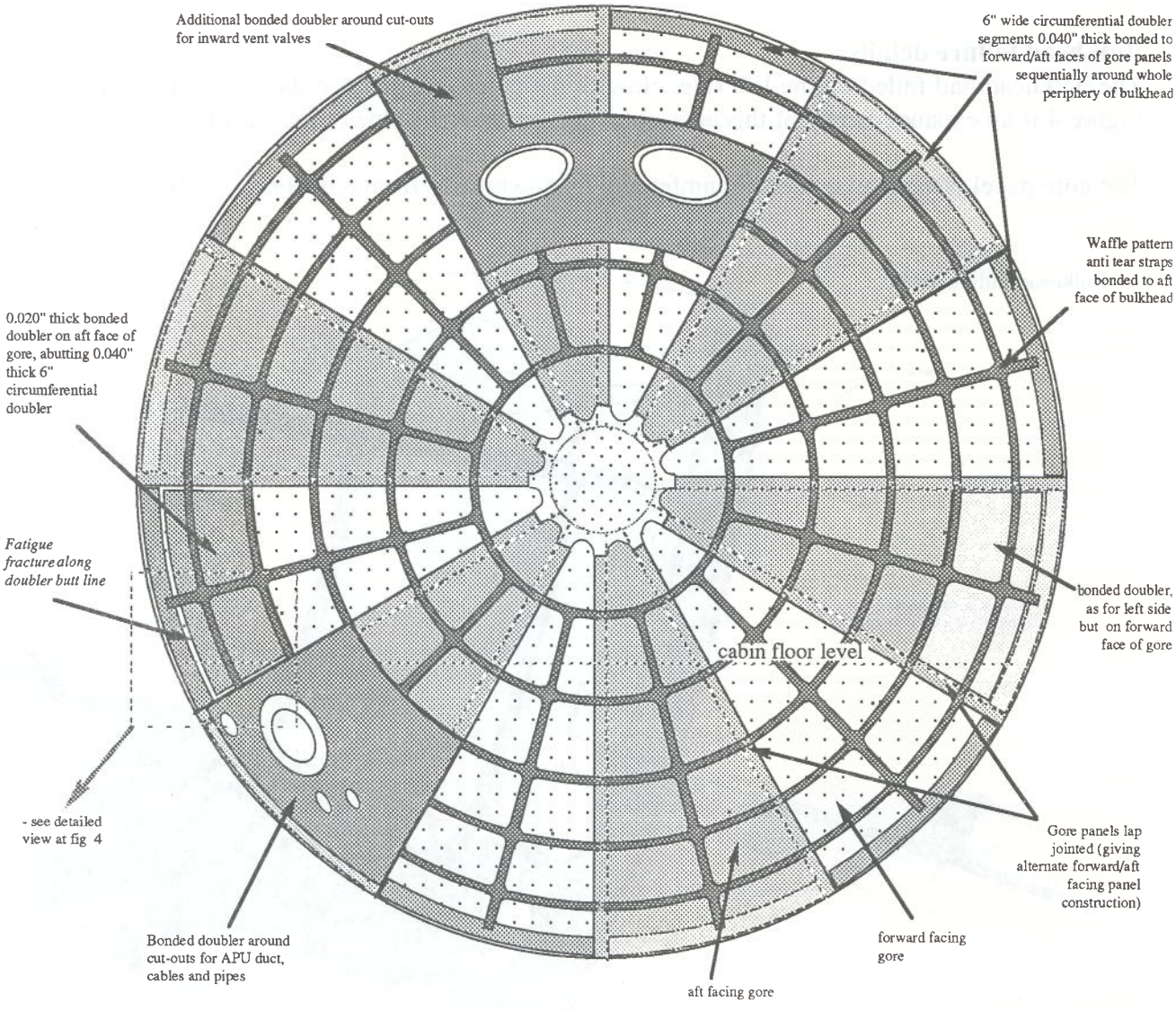


Fig 3
Constructional details of Lockheed L101-500 series rear pressure bulkhead
(view looking forward)

Around the outer circumference of the bulkhead, adjacent to its attachment to the fuselage proper, were a series of 6" wide by 0.040" thick doublers bonded to the *back* surface of each gore panel, mirroring the constructional form of the gore panels proper, as indicated in fig 3. Additional doublers 0.020" thick were bonded to the 8-9 o'clock and 3-4 o'clock gore panels at cabin floor level, abutting the 6" wide circumferential doubler, and extending inboard to approximately the 1/3 radius position (ie over the two outermost grid panels formed by the anti-tear straps). Because of the handed nature of the gore panel lap-joints, these doublers and the adjacent 6" wide edge doublers were on the aft face of the gore panel on the left hand side of the aircraft, and the forward face on the right hand side.

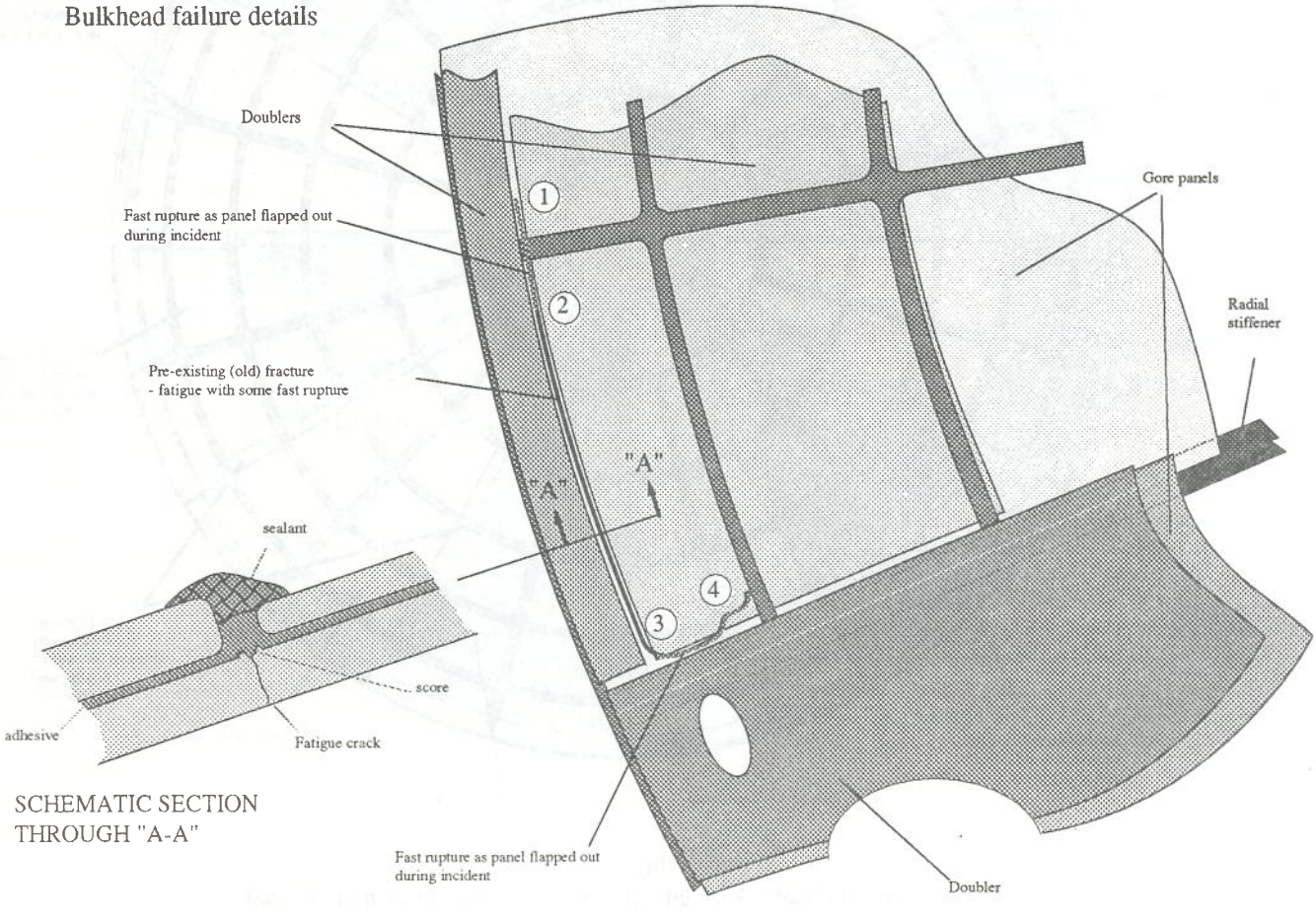
A large diameter APU air duct, and various other services, passed through the bulkhead in the outer segment of the 7-8 o'clock gore panel. In this area the gore panel was reinforced by a bonded doubler and the anti-tear straps were omitted. The mid-upper regions of the 11 o'clock to 1 o'clock gore panels contained the inward vent valves. These areas were also reinforced by doublers, again without anti-tear straps.

Bulkhead failure details

The bulkhead had failed on the left side, close to the outer periphery of the 8-9 o'clock gore panel. Figure 4 is an expanded view of this area, showing the general shape of the fracture path.

The gore panel fracture extended circumferentially downwards from position "1", along the joint line

Fig 4
Bulkhead failure details



between the 6" wide 0.040" thick doubler and the adjacent 0.020" thick bonded doubler panel, to the bottom of the panel at position "3". It then turned inboard and ran along the radial stiffener frame as far as the next circumferential anti-tear strap at position "4", before turning upwards, along the circumferential strap, for a short distance.

Detailed fracture examination

Following examination and photography in-situ, the material containing the failed region was excised from the bulkhead, leaving the fractures intact, and taken to the Royal Aerospace Establishment metallurgical laboratory at Farnborough for examination.

Evidence of dirt on the fracture faces suggested that approximately 18" of the circumferential fracture had existed for some time prior to the final rupture. This pre-existing, or *old*, fracture is shown as the solid black line in fig 4, extending from position "2" to position "3". The radial fracture (grey fracture line from "3" to "4") and the uppermost 6" of the circumferential fracture (grey fracture line from "2" up to "1") appeared to be fast rupture immediately preceding, or contemporary with, the *blow-out* event.

Within the central region of the *old* fracture was an area of fatigue, approximately 7" in length, which comprised a series of fatigue *thumbnails* growing from the aft face of the gore panel, ie from the interface between the gore panel and the bonded doublers - along the doubler butt join line. Three of these thumbnails (approximately 1" across) had broken through to the front face of the gore panel; the remaining thumbnails extended only partially through the thickness.

Extending approximately 2.5" beyond each end of this central *thumbnail fatigue* region, were areas of fast fatigue fracture.

The remaining, outermost, regions of the *old* fracture apparently resulted from one or more bursts of fast rupture, which had occurred at some time in the past.

Fatigue crack initiation

Microscopic examination of the fatigue fracture region revealed clear evidence of a score line on the aft face of the gore panel between the doublers, as shown diagrammatically at section "A-A" in fig 4. The score extended over the whole of the fatigue fracture region and slightly beyond, a total distance of approximately 15". Adhesive, of a type visually similar to that used to bond the doublers to the gore panel, could be seen filling the score channel in many areas.

Microscopic examination of sections cut from the fracture/score line area indicated that the score was produced by some form of tool which had been drawn along the edge of the 6" doubler, producing the score channel itself and also throwing up material at the sides of the score channel. The score cross-section is clearly evident in the micrograph reproduced in fig 5, one of three sections taken through the fatigue fracture region.

The sections indicated a score depth of the order of 0.004" to 0.010", and 0.012" to 0.016" wide.

The maintenance and repair documentation for the aircraft did not record any remedial work on the bulkhead during its period in service; however, the paint/adhesive/sealant layers suggested that the score was produced during manufacture.

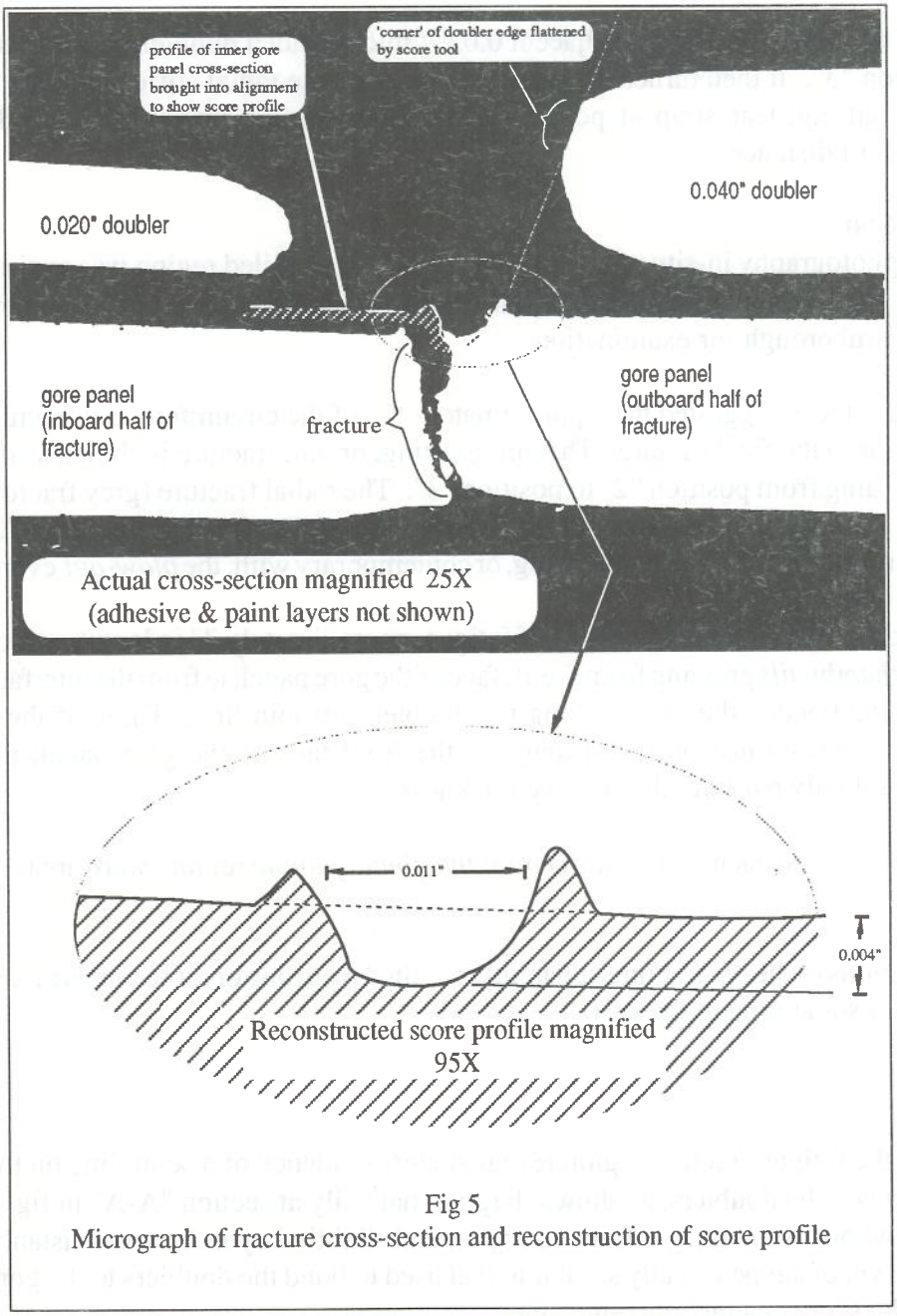


Fig 5
Micrograph of fracture cross-section and reconstruction of score profile

No evidence of corrosion or other potential fatigue initiating feature was found.

Estimated period of crack growth

The fracture was examined in detail by metallurgists at the Royal Aerospace Establishment, using both high power optical and scanning electron microscopes. Calculations of crack growth rates using fatigue striation counts showed that the growth rate varied, with slow growth being evident within the fatigue thumbnails and more rapid growth in the regions where the thumbnails merged together. At the maximum rate of growth observed, the number of pressure cycles required to drive a crack from the base of the score through to the back face of the gore panel was estimated to be of the order of 1500 load cycles, ie 1500 flights. C-GAGI had accumulated a total of 8308 flights up to the time of the incident.

Previous instance of rear pressure bulkhead rupture on Lockheed L1011 aircraft.

Only one prior instance of rear pressure bulkhead rupture on L1011 aircraft is recorded, in which a slightly smaller "D" shaped rupture was produced adjacent to the 6" wide edge doubler at the top of the bulkhead, in the area indicated in fig 2.

The incident, which involved a foreign registered aircraft, occurred whilst in the climb and passing 28,000 ft. Cabin altitude peaked at 18,000 ft.

Detailed laboratory reports on the failure are not available, but the manufacturer has indicated that a

circumferential fatigue fracture of the gore panel was found along the line of the 6" edge doubler, initiating from corrosion pits on the outer side of the gore - in the corner adjacent to the doubler. As the crack progressed, it was turned inboard by an anti-tear strap. The rupture then continued inboard before being turned again by the next anti tear strap, thereafter running back circumferentially to form a "D" shaped flap which flexed upwards until it came into contact with the engine intake duct.

No evidence was found of scores or other mechanical defects, apart from the corrosion.

In response to the incident, FAA Airworthiness Directive 90-03-11 (89-NM-279-AD) and Service Bulletin SB-093-53-258 were issued, requiring inspections of the affected area.

Potential hazards resulting from scores

Light scores, similar to that on C-GAGI, are known to have produced potentially catastrophic rupture of pressure hulls on other aircraft types.

On the basis of investigations carried out by the US National Transportation Safety Board (NTSB), it was concluded that the critical nature of this type of slight surface damage was not fully understood by many personnel engaged in the repair and maintenance of aircraft structures. Prompted by this concern, a recommendation was made to the FAA on August 9 1989, highlighting two examples where such scores had led to pressure hull rupture, and recommending that the FAA should issue a maintenance bulletin drawing attention to the hazards associated with surface defects.

Although the score found on C-GAGI appears to have been produced during original manufacture rather than during repair, the NTSB recommendation is entirely appropriate to this incident, and is reproduced below.

> "The National Transportation Safety Board recommends that the Federal Aviation Administration:
> Issue a Maintenance Bulletin to all manufacturers, airlines, air carrier maintenance organisations, and aviation maintenance training schools which:
>
> - Informs them about the circumstances of (these two) incidents.
>
> - Requests that they issue appropriate informational material to the personnel who perform work on aircraft structure, whether certificated or non-certificated mechanics, about the serious consequences of minor practices on pressurized fuselage skin panels; and
>
> - Outlines the proper techniques and tools for marking materials to prevent the possibility of creating fatigue initiation from minor scratches.
> (Class II, Priority Action) (A-89-79)
>
> Direct all Principal Maintenance Inspectors to review the maintenance practices of the operators under their jurisdiction to determine that the certificated and non-certificated maintenance personnel are utilizing proper tools and repair techniques when marking structure for repair or painting. (Class II, Priority Action) (A-89-80)"

Recommendations

Following a preliminary examination of the failure on C-GAGI, the AAIB made preliminary safety recommendations to the UK and US airworthiness authorities on 21 December 1990, dealing with:

1) the inspection of L1011 rear pressure bulkheads for cracks,

2) aft fuselage body venting capability.

The Chief Inspector of Air Accidents has ordered a formal investigation into this accident.