

Lockheed L1011 Tristar, TF-ABT

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Aircraft Type and Registration: Lockheed L1011 Tristar, TF-ABT

No & Type of Engines: 3 Rolls Royce RB 211-22B

Year of Manufacture: 1982

Date & Time (UTC): 30 September 1998 at 1305 hrs

Location: South of London Gatwick Airport

Type of Flight: Public Transport

Persons on Board: Crew - 14 - Passengers - 289

Injuries: Crew - None - Passengers - None

Nature of Damage: Loss of left Environmental Control System (ECS) bay door, structural damage to door aperture, failure of ducting to No 1 ECS, substantial damage to No 1 engine and nacelle

Commander's Licence: FAA ATP with Icelandic Validation

Commander's Age: 56 years

Commander's Flying Experience: 14,500 hours (if which 2,000 were on type)

Last 90 days - 200 hours

Last 28 days - 85 hours

Information Source: AAIB Field Investigation

History of the flight

The aircraft was wet leased to the airline whose paint scheme adorned the exterior. It was operating a charter flight service and took off from Gatwick's Runway 26L at 1258 hrs bound for Venice. The take off was carried out with reduced thrust and, following the normal procedures, No 2 air conditioning pack was ON for take off. Numbers 1 and 3 air conditioning packs were selected ON at gear retraction and 600 feet agl respectively. On climbing through 1,000 feet the crew were given an easterly radar vector and cleared to climb.

Soon after passing through approximately FL 80 at 250 KIAS with the commander handling there was a loud bang accompanied by a yaw to the left and a nose-down trim change. All three flight deck crew members were immediately aware that an engine had failed and the vibration warning for No 1 engine illuminated. The commander diagnosed severe damage to the No 1 engine and

ordered the first officer and flight engineer to shut it down. They carried out the immediate action drills of closing the thrust lever, selecting the engine fuel/ignition switch to OFF and pulling the engine fire handle. The flight engineer then reached for the emergency checklist and began reading the remainder of the procedure. The first pertinent item was to select a hydraulic power transfer unit (PTU) to ON. As he looked up at the hydraulic system panel he noticed a warning light had illuminated on the adjacent engine bleed control panel. The warning was the 'AREA A OVERHEAT' light. The flight engineer selected the No 1 pack (ie the No 1 unit of the ECS) to OFF whereupon the light extinguished. He and the first officer then continued with the remainder of the engine shutdown drill. On completion of the drill the airframe vibration had diminished but the engine was still making an unusual rattling noise, and it continued to do so throughout the remainder of the flight.

The commander decided to jettison fuel and return to Gatwick. He declared an emergency and approximately 15,000 lb of fuel was jettisoned at FL 120 before the aircraft was radar vectored for a two-engined ILS approach and landing on Runway 26L. The approach and landing were without further incident and the aircraft landed at 1323 hrs with the emergency services at local standby. The aircraft was inspected by the fire service who reported that a panel near the nose landing gear was missing. The aircraft was taxied to a suitable stand where the passengers were disembarked in the normal manner via the jetway.

Flight recorders

The Cockpit Voice Recorder had a 30 minute duration and had continued to run erasing the recording of the flight. Data from the Flight Data Recorder showed that the No 1 Engine Pressure Ratio fell from 1.5 to 1.0 in not more than 4 seconds whilst the aircraft was climbing through FL 95 at 265 kt.

Examination of the aircraft

On examination of the aircraft, the hinged left side door to the ECS bay was found to be missing, leaving evidence that it had torn from its hinges at the same time as the latching shoot bolts had been forced past their striker plates, apparently by internal pressure on the door.

Examination of the remainder of the aircraft confirmed that the ECS bay door had then been ingested by the No 1 engine, causing severe damage to the fan blades whilst being sliced into fragments. Considerable damage to the interior of the bypass duct had also occurred, largely as a result of small fragments of door debris being projected radially into the duct lining both forward and aft of the plane of the fan. Two such debris fragments had passed completely through the inner and outer walls of the bypass duct without, however, striking other parts of the aircraft.

Examination of the area inside the door aperture of the ECS bay revealed that a pneumatic duct had failed close to the bulkhead which separates the bay from the forward freight hold.

Layout of relevant bays and structure

The section of ECS bay accessible through the relevant hinged door of the L1011 aircraft is within an unpressurised underfloor volume also occupied by the nose-leg housing. The volume within the left side doorway is bounded to the rear by the pressure carrying bulkhead forming the boundary of the forward freight hold and above by the pressure bearing cabin floor. The remaining boundaries are non-pressure carrying.

The inboard boundary is the diaphragm forming the left wall of the nose-leg housing and the forward boundary is a bulkhead enclosing a further unpressurised volume which contains other components of the No 1 ECS system. Of the three ECS systems, only No 1 is accessible from the left hand side whilst Nos 2 and 3 are positioned to the right of the nosewheel trunking and are accessible via a corresponding hinged door on the right hand side.

The ECS door in question is mounted at its upper edge by three hinges. It is latched by 5 shoot-bolts. One of these is positioned mid-way along the lower edge of the door whilst two are positioned on each vertical edge member of the door. The shoot bolts are operated by a single rotary handle on the outside of the door which is pushed inwards to stow flush in a recess once the door is correctly closed. The door is double skinned, the inner skin being perforated with a number of flanged lightening holes which also permit air to act on a small hinged blow-out door in the outer skin of the main door. The blow-out door opens to relieve any internal bay pressure above 1.5 psi. (The forward sections of the ECS zone on either side of the nose-leg housing can be accessed from outside the aircraft via large removable panels secured by multiple fasteners).

Layout of ducting

The duct in question supplies engine bleed air from the main bleed manifold (situated in the lower fuselage, just forward of the wing) to the heat exchanger and the air-cycle machine of the No 1 system, both of the latter being situated in the forward unpressurized ECS zone, forward of the unpressurized bulkhead described above. The ducting routes from its ECS flow control valve (one positioned on each of the three ECS systems, adjacent to the manifold, controlling flow from the manifold into the relevant system) beneath the floors of the lower-deck galley and the forward freight-hold before passing through the pressure bulkhead into the rear of the ECS bay. Thereafter it passes longitudinally across the bottom of the bay and exits through the unpressurised forward bulkhead to the heat exchanger.

A dual loop overheat sensor, with both elements adjacent to the duct, extends along the whole of the No 1 ECS system ducting from its flow control valve to the heat exchanger. This length is defined as Zone A. Functioning of the detection system causes the Zone A overheat warning to illuminate on the flight-engineer's panel.

Most of the ducting, including the failed section, is manufactured from commercially pure titanium. The ducting is in varying lengths, with suitably shaped ends, enabling them to be joined by a V-band clamp system. Compensators, in the form of short bellows type sections, are incorporated at intervals to allow thermal expansion to take place without creating significant longitudinal stresses.

The total length of the duct section in which the failure occurred is approximately 10 inches and it is connected at its forward end to a longer section of generally similar ducting, having a compensator close to the joint. At its rear end it is connected aft of the pressure bulkhead to an air cleaner unit positioned beneath the floor at the forward end of the freight hold. The failed duct section incorporates a welded circular mounting collar enabling it to be located in position by being secured inside a close-fitting cylindrical member, itself forming part of the bulkhead structure. (Figure 1)

The duct failure

The duct fracture face was situated along one edge of the weld joining the main cylindrical duct section to the mounting collar. Figures 2 and 3 show the forward and rear halves, respectively, of

the failed duct, whilst the plane of the fracture face is indicated in Figure 1. Examination revealed that the fracture face was positioned almost entirely in one plane, at right-angles to the duct axis. Fatigue damage was evident and although it was difficult to establish the exact amount, it is estimated that it accounted for approximately 80% of the wall thickness over approximately half the duct circumference.

Other smaller areas of fatigue were evident over the remaining circumference. All fatigue areas had their origins on the outer surface of the duct. The amount of fatigue identified was judged to be sufficient to account for failure of this section of the duct at a typical working pressure. Hardness tests on the material of the duct section revealed that the weld area was some 40 to 50 Vickers Micro-Hardness (HV) harder than the parent material. The weld geometry of the junction between the collar and the cylindrical section of the duct was such that an unfused area extended into the weld region, probably creating local stress concentration.

The manufacturing date on the data plate of the failed component was 10/9/81, some 5 months before the initial delivery date of the aircraft. At the time of the incident the aircraft had completed some 37,000 hours of operation. Information supplied by the manufacturer indicates that there is no previous history of failures at this particular location. The component is, however, not present on all examples of the L1011; those not equipped with the air cleaner have a different duct arrangement at this location.

Discussion

Failure of the duct clearly caused the ECS bay to become pressurised. The door is understood to be capable of carrying a pressure differential of approximately 2 psi. Although a blow out door provides pressure relief at approximately 1.5 psi differential, this is believed to have been designed to accommodate leakage from joints rather than complete duct failure. The normal operating duct pressure is in the region of 20 psi and the flow rate available with all 3 engines supplying the main manifold is considerable. It is likely to have been such that even with the blow-out door open, the available area of its aperture was insufficient to prevent the internal pressure from rising above the 2 psi necessary to fail the main ECS door attachments, once the duct had fractured.

Although welding of commercially pure titanium normally results in a slight local hardness increase, a well executed weld should only produce an increase in the range 10 to 25 HV. The weld at the duct fracture location exhibited a much greater hardness increase (45 HV) and would therefore be expected to have had reduced ductility, impairing the fatigue characteristics of the duct.

A difference greater than 30 HV compared with the parent material with an associated loss of ductility can indicate that gas contamination has occurred, leading to weld embrittlement. Gas contamination and embrittlement occurs when the weld pool is not sufficiently shielded from atmospheric gases such as oxygen, nitrogen and hydrogen. The blue/purple tint to the weld area adjacent to the fracture is evidence of elevated temperature oxidation; the fact that this feature is only visible in the weld region strongly suggests that it occurred during the weld operation rather than in subsequent service. The geometry produced by the lack of fusion between components at the edge of the weld probably resulted in local stress concentrations, thereby encouraging fatigue growth at that location, although there is no evidence to suggest that similar geometry would not have been present on correctly welded components.

The positions of the fatigue origins, on the outside of the main pressure carrying cylindrical section, within the circumference of the mounting collar, are not, however, consistent with the expected

effects of the theoretical pressure or thermal cycles (ie the maximum stresses generated by the above loadings would be expected on the inner rather than the outer surfaces at this location).

Mounting loads do not pass through the fractured area since the mounting collar attaches the rear part of the failed component to the aircraft structure at a point on the duct aft of the failure plane (Figure 1). Tensile and bending loads acting on the fracture face should have been limited by the presence of the compensator positioned slightly forward of the joint between the failed duct section and the longer section connected to its forward face. It is not therefore immediately obvious which element of the duty cycle created the fatigue stresses leading to the cracking.

The material of the ducting has been widely used in this type of application in a number of common aircraft types. There is a history of failures of pneumatic ducting in the regions of welds on more than one aircraft type, so, although the exact mechanism of crack development is not clear in this case, any inadequacy in weld quality could confidently be expected to reduce the life of such a component.

The manufacturing date on the data plate of the failed component, preceding as it does the aircraft delivery date by some 5 months, strongly suggests that this was the original component. In this case it would have completed 37,000 hours of operation. This figure is below the fleet average for a type whose earliest examples have been in service for approximately 25 years. It must be assumed that a significant number of ducts of this design are in service having completed substantially more flight cycles than this failed component.

Emergency procedures

The aircraft is normally operated with the isolation valves, situated in the main manifold, in the open position. Once failure of any ECS ducting occurs, airflow will continue through the failed duct, as long as at least one engine continues to supply bleed air to the manifold. The position of the failure on TF-ABT allowed the leaking air to activate the adjacent heat detector causing the relevant warning (zone A overheat) to operate on the flight engineer's panel. His action in selecting No 1 pack 'off' closed the No 1 ECS flow control valve, successfully shutting off the bleed air to the failed duct.