No: 7/91 **Ref: EW/C91/1/4** **Category: 1a**

Aircraft Type and Registration:	BAC One Eleven 510ED, G-AVMS
No & Type of Engines:	2 Rolls-Royce Spey 512-14 turbofan engines
Year of Manufacture:	1968
Date & Time (UTC):	19 January 1991 at 1126 hrs
Location:	10 nm south west of Manchester International Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 6 Passengers - 71
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fracture of HP bleed air duct leading from No. 1 engine and extensive overheat damage in No. 1 stub wing and rear fuselage
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	11,705 hours (of which 6,638 were on type)
Information Source:	AAIB Field Investigation

History of the flight

G-AVMS was to operate a scheduled flight from Manchester to Geneva. All checks prior to departure were completed satisfactorily, including a check of the failure warning system for the bleed air ducts in the stub wings. The take-off from runway 24, using the reduced thrust technique, was uneventful and the aircraft then climbed in accordance with the noise abatement procedure. On completion of the noise abatement procedure at 4000 feet, the throttles were advanced to set climb power. As climb power was reached, the crew heard a thump which they thought came from the rear of the aircraft. There were no handling problems with the aircraft, no flight deck warnings and all engine indications were normal except that the P7 on No. 1 engine had fallen from the climb value of approximately 90% to 55-60%.

In the rear of the passenger cabin, the cabin staff heard a muffled thump followed by the sound of rushing air coming from the area of the No.1 engine. A steward entered the left toilet, which is located adjacent to No. 1 engine, but at this stage there was no evidence of the source of the noise.

On the flight deck, the crew proceeded to confirm that there was a problem with No. 1 engine. During this process, the No. 1 throttle was advanced and retarded but there was no response from the engine. During this check, the throttle lever felt very slack and vibration could be felt. The commander was now convinced that there was a serious malfunction of the No. 1 engine and carried out the appropriate shut-down drill 85 seconds after the thump. He then declared an emergency and initiated a return to Manchester.

Subsequent to the engine shut-down, the cabin staff noticed that the smoke detector light for the left toilet was flashing. On investigation it was found that the toilet was filling with grey smoke. A long burst from a BCF fire extinguisher was discharged into the toilet compartment and the door closed. After a short time, the toilet was again checked and by this time the smoke had reduced considerably. Further extinguishant was discharged into the toilet compartment and after a further short period the smoke had greatly diminished. A member of the cabin staff then entered the toilet and removed all possible panelling and trim, while discharging further extinguishant behind the remaining panelling. At no time was there any sign of fire. Regular checks of the toilet compartment were subsequently made but there were no further signs of smoke.

The return to Manchester and subsequent landing were uneventful and having checked with the emergency services that there was no sign of fire, the commander disembarked his passengers at the terminal.

Flight Recorders

The Flight Data Recorder (FDR) fitted was a Davall 25 hour digital recycling wire recorder with a Plessey 726 recording format, which recorded 10 analogue parameters and 19 discrete parameters. Engine P7 pressure was recorded on the FDR: this showed a loss in engine power on No. 1 engine as power was increased during climb-out at an altitude of 4060 feet and the engine was shut down 85 seconds later.

The Cockpit Voice Recorder (CVR) was a Fairchild A100 with a 30 minute recycling tape and a satisfactory readout was obtained. The recording began before take-off and the record of the flight was preserved after landing.

HP Duct failure

When the aircraft was examined it became apparent that there had been a failure of the HP ducting within the stub wing: this ducting carries P3 bleed air from the last stage of the HP compressor to the

primary heat exchanger at the aft end of the stub wing. The actual fracture (see figure) was around the entire circumference of the duct at the downstream flange of the HP shut-off valve (isolation valve) and this separation had allowed HP bleed air to escape into the stub wing between the No. 1 engine and the fuselage. The resulting pressure increase had caused one of the stub wing lower surface panels partially to detach. There had been a considerable transfer of heat before the No. 1 engine was shut down and this had damaged portions of the electrical systems which pass through the stub wing. The adjacent fuselage skin had also sustained thermal damage and the plastic covering of the cabin insulation was charred.

The fracture of the shut-off valve was examined in detail. On this valve, an end flange fitting is used to clamp the shut-off valve assembly to the next length of duct and the skirt of this flange fitting is nickel-brazed within the duct. The metallurgical examination indicated that the fracture was by a fatigue mechanism propagating through the nickel braze material and then through the flange fitting itself, culminating in a rapid overload failure through the small amount of remaining wall material. The pattern of the fatigue was similar around the entire circumference of the duct, indicating that the fatigue mechanism had resulted from in-service cyclic stresses.

Further examination of the valve body and flange fitting did not show any evidence of material fault, incorrect manufacture or assembly which could have contributed to the fatigue mechanism. In addition, neither the manufacturer nor the operator had any record of a previous duct failure with this type of valve. However, a programme has been initiated by the operator and the valve manufacturer to ensure that any of these valve bodies removed from aircraft are submitted to NDT inspections for crack detection by the valve manufacturer. In addition, the operator has removed a sample of 10 serviceable high-time shut-off valves for these inspections.

Warning system

To protect the structure and systems within the stub wing from the effects of the high temperature bleed air, which would be released in the event of a duct failure, the aircraft design incorporates a system of 14 thermostats in the stub wing area, arranged in pairs. In the event of overheating, activation of 2 of these thermostats would, amongst other things, automatically:

(1) remove electrical power from the shut-off valve (isolation valve) causing it to close by bleed air pressure and

(2) illuminate the SYSTEM FAIL light on the Air System panel on the flight deck.

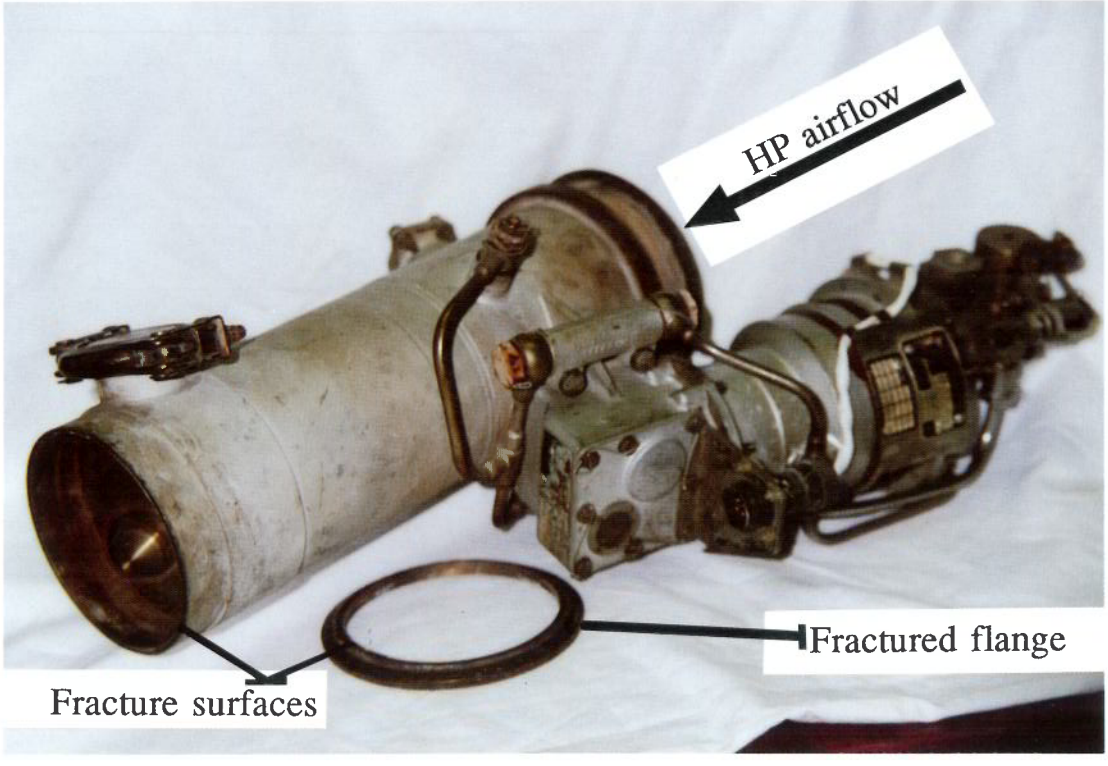
The serviceability of the overheat protection system is proved by a DUCT FAIL TEST button which, in the case of the operator of G-AVMS, would be checked by the flight crew before the first flight of each day. Pressing this button would illuminate the SYSTEM FAIL light, if the protection system were serviceable.

From the recollection of the flight crew, there had been no abnormalities when the SYSTEM FAIL light was tested before the flight but the degree of heat damage strongly supported the CVR/FDR evidence that the system had continued to release high temperature HP bleed air into the stub wing for the 85 seconds between the failure of the duct and the flight crew shutting down the No. 1 engine. It was apparent therefore that, had the system operated correctly, the shut-off valve would have closed and the SYSTEM FAIL light would have illuminated. The engineering and CVR evidence indicated that neither of these had occurred.

After the aircraft had been repaired, a systems check of the warning system showed that the Duct Fail Warning electrical relay had failed, being 'open circuit' in its relaxed (ie de-energized) state. The relay was removed and a simple cleaning of the relay contacts restored electrical continuity.

A fleet check of the operator's remaining One-Eleven aircraft produced a further 11 identical failures of this Duct Fail Warning relay. From a study of the design of this system it became apparent that, although the original design ensured that all the electrical relays were checked by pressing the DUCT FAIL TEST button, the introduction of an optional Service Bulletin, 36-PM 4684, had inadvertently removed the operation of the Duct Fail Warning relay from this test. The operator had applied this Service Bulletin to G-AVMS and the other -510 aircraft in its fleet at that time.

The aircraft manufacturer has subsequently issued a 'campaign wire' to operators, dealing with this problem by requiring a systems check of the duct failure warning system. This notice has been classified as mandatory by the UK Civil Aviation Authority. The manufacturer has also produced a modification to the stub wing overheat protection circuit, to ensure that correct functioning of the Duct Fail Warning relay is verified by pre-flight operation of the DUCT FAIL TEST button.



No. 1 HP shut-off valve - G-AVMS