BAC One Eleven 510ED, G-AVMH

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Aircraft Type and Registration:	BAC One Eleven 510ED, G-AVMH
No & Type of Engines:	2 Rolls-Royce Spey 512-14E engines
Year of Manufacture:	1968
Date & Time (UTC):	19 May 1996 at 1532 hrs
Location:	100 nm Southeast of Dublin
Type of Flight:	Public Transport (positioning)
Persons on Board:	Crew - 5 - Passengers - None
Injuries:	Crew - None - Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Not relevant
Commander's Age:	Not relevant
Commander's Flying Experience:	Not relevant
Information Source:	AAIB Field Investigation; Information supplied by the Irish Department of Transport, Energy and Communications, the Operator, and the Operator's Maintenance Contractor

The aircraft had been undergoing a major service following itsacquisition from another operator. Upon completion of the maintenancework, the aircraft was positioned from its home base, Hurn, toStansted in preparation for its introduction into service. Thispositioning flight was also programmed to include checks of theflying controls manual reversion system, and general handlingchecks.

During climbout from Hurn, the No 1 air system temperature rosethrough 210° C and thereafter continued to rise until itwas registering maximum on the temperature gauge (approximately300°C). A strong *hot paint* smell also became apparent. No air conditioning system failure captions illuminated. TheNo 1 air system was isolated, and the temperature started to fall;when the system was reset, however, the temperature rose againand the No 1 system was therefore shut down for the remainderof the flight.

The crew climbed the aircraft to approximately flight level (FL)190 above cloud, and the manual reversion and handling checkswere completed satisfactorily. They then called the company'smaintenance base to request instructions regarding the air systemoverheat, and were asked to continue to Stansted where an associatemaintenance organisation could carry out a change

of the No 1system air temperature control valve (TCV), which is located inthe air supply to the air conditioning pack, just downstream fromthe engine off-take.

Upon arrival at Stansted, it was found that the maintenance organisationdid not have the correct TCV in stock. They nevertheless carriedout checks in an effort to confirm the source of the problem. No fault could be found, and the aircraft was returned to serviceas originally planned. After boarding the passengers, the crewrequested clearance to carry out power checks at the end of therunway prior to take off, with a view to checking for any recurrenceof the air system overheat. During these checks, the No 1 airsystem temperature again increased above normal and the aircraftwas therefore taxied back to the stand where the passengers weredisembarked for transfer onto alternative flights. The aircraftwas then positioned back to Hurn using the No 2 air system only,with no further problems becoming apparent. At Hurn, the No 1system TCV was changed and maintenance personnel satisfied themselvesthat the cause of the overheat had been cured. (A defect investigationof the TCV subsequently revealed that one of the actuator motorbearings within the unit had partially seized, a fault likelyto cause intermittent operation of the actuator).

After the TCV had been changed, the aircraft was re-scheduledto position to Connaught (Knock) Airport, with a cabin crew, totake up the scheduled service which it had originally been plannedto operate from Stansted. The take-off from Hurn was normal,but during climbout the No 1 cabin attendant came forward to reporta *hot* smell in the rear cabin, which by that time was alsobecoming evident on the flight deck. The flight crew were busyat this time, but they did check the air system temperature indicationsand noted that they were normal. Shortly afterwards, the firstofficer went back into the cabin where he noted a slight hazein the cabin atmosphere. However there was still no indicationof any air system over-temperature at this stage, and it was concludedthat the problem was most probably caused by the dissipation ofresidues in the air system, originating from the previous overheat. However, later in the flight, approximately 100nm Southeast ofDublin, one of the cabin crew came onto the flight deck and reportedthat the other cabin crew members were feeling unwell, and wereusing oxygen. She had not been so badly affected, but had beenworking in the galley whereas the others were in the cabin.. The commander decided to divert into Dublin, partly on safetygrounds and partly because of the engineering support availablethere. The aircraft was descended below 10,000 feet and depressurised,and the ram air valve opened.

Approximately 10 minutes afterwards, at approximately 210 kt andat an altitude of between 3,000 feet and 5,000 feet, the cabincrew came forward and reported a very strong smell of fuel inthe rear cabin. The landing approach was continued, and the aircrafttouched down without further problems. Once on the ground, thedirect vision windows and main cabin door were opened at the firstavailable opportunity in order to ventilate the interior.

Subsequent investigation at Dublin by the company's maintenancecontractor, overseen by an Aeronautical Officer from the IrishDepartment of Transport, Energy and Communications, identifieda steady dripping of fuel from a coupling in the main low pressurefeed pipe to the No 2 engine, at a point where it passed throughthe right main landing gear bay. This coupling was in an inaccessibleposition adjacent to the landing gear attachment to the structure,and had not been subject to any disturbance during the maintenancework which had recently been carried out on the aircraft. Upondismantling the coupling (an *Avery* type, commonly foundon aircraft of this vintage), the large rubber sleeve which formsthe seal between the two pipe sections was found to have deteriorated;after replacement of this seal, the joint no longer leaked. Afew beads of fuel were also noted on the attachment bolts of thecentre tank transfer pump. This leak was cured by replacementof the flange seal.

Functional checks of the air system failed to reveal any tendencyto overheat, but when the TCV contact breaker was pulled to simulatea TCV failure, thereby inducing an over-temperature conditionin the No 1 air system, the over-temperature thermostat failedto operate. Further investigation revealed that this fault wascaused by an intermittent contact in the connection between thewiring and the plug pins at the thermostat connector.

Cabin air system

Air is supplied to the cabin by a pair of independent air conditioningpacks, fed by P3 air from their respective engines. Before enteringthe fuselage ducting which supplies air to the conditioning packsand other services, the high temperature P3 air from each engineis pre-conditioned by a pressure reducing valve and a heat exchanger,the latter cooled by P2 air which is modulated by a temperaturecontrol valve to maintain the P3 outlet temperature to approximately210°C. (It was this TCV which was replaced at Hurn, followingthe original overheat en-route to Stansted.) The air ductingimmediately downstream of this heat exchanger incorporates a temperaturetransducer which drives a duct temperature gauge on the flightdeck, and an overheat thermostat designed to illuminate a warningcaption on the flight deck and to close down the system automaticallyshould the temperature exceed 270°C. (It was this overheatthermostat which was found, after the second incident, to havean intermittent plug pin contact.)

The No1 and No2 conditioning packs are essentially similar, independent,units located in the air conditioning bay in the lower fuselagebeneath the wing centre section, on the left and right side respectively. Each comprises a conventional heat exchanger system and air-cyclecold air unit, together with associated control and ancillaryequipment. Each heat exchanger matrix is located toward the downstreamend of a large divergent/convergent duct, just upstream of theconvergent section which discharges to atmosphere via a set ofoutlet louvres in the belly, positioned just ahead of the mainlanding gear bays.

The primary supply of cooling air to the each main heat exchangeris taken from individual ram air intakes in the belly of the aircraft. At speeds below 165 kt, when the ram air supply may be insufficientand also on the ground, heat exchanger cooling air is suppliedby an electrically driven ground cooling fan which takes air fromthe air conditioning bay (effectively the lower fuselage cavity)and feeds it to both the No 1 and No 2 heat exchangers via a largebifurcated duct. On the ground, a set of louvre panels in thelower fuselage are opened automatically by an electro-pneumaticactuator signalled via the 'weight-on-wheels' switches, providingan additional supply of external air into the conditioning bayto service the needs of the ground cooling fan. A flap valvein the intake section of each heat exchanger duct moves underthe influence of the incoming air, to close-off the redundantinlet path.

Should both air-conditioning systems fail, or be shut down, aram air valve may be opened which connects the cabin main airdistribution system to a take-off tapping in the divergent sectionthe No 2 heat exchanger duct, providing a limited supply of fresh(external) air to the cabin. The ram air system is intended foruse only when the aircraft is unpressurised and the aircraft altitudeis below 10,000 feet.

Cause of the fumes in the cabin

The fact that there were no over-temperature indications accompanyingthe second *fumes in the cabin* incident suggests that thesefumes were almost certainly residues from the earlier overheat,as the crew concluded. However, it was unclear as to why theydid not appear at an earlier stage, and it

is a cause for concernthat although these appeared merely residues, they were neverthelesscapable of making the cabin crew unwell.

It did not prove possible to identify positively the route bywhich the fuel vapours entered the cabin. However, it is of notethat the smell of fuel first appeared shortly after the aircrafthad descended and depressurised, and the ram air valve opened,ie about 10 minutes later by the crew's recollection, when theywere between 3000 feet and 5000 feet altitude and at about 210kt. When the ground cooling fan activated, which normally occursat speeds below about 165 kt, this could have resulted in fuelvapours from the leaking fuel supply pipe in the landing gearbay being drawn through the air conditioning bay, into the fanintake, and thence into the No 2 conditioning pack heat exchangerduct from where they could have found their way into the cabinsupply via the ram air valve. The crew recollection was thatthe airspeed was about 210 kt when the fumes first occurred, iebefore the fan should have activated. However, it is possiblethat some fumes nevertheless found their way into the heat exchangerduct before the fan activated, by migrating through inlet trunkof the fan due to small pressure differentials between the variousparts of the system, possibly influenced by aircraft configurationand attitude. Alternatively, they may have first appeared a littlelater than the crew recalled, after the fan had activated. Whicheverwas the case, the ram air ventilation system appears to have beenthe route by which the fumes reached the cabin.

Overheat protection

During the original overheat incident en-route to Stansted, thetemperature was noted as being approximately 300°C. To achievethese conditions, it would have been necessary for two separatefaults to have occurred:-

a TCV malfunction causing the duct temperature to rise to abnormallevels, **and**

a failure of the over-temperature thermostat, preventing thesystem from detecting the overheat and automatically shuttingdown the No 1 air system as soon as the temperature exceeded 270°C.

Because the thermostat fault was intermittent, it is possiblethat the overheat protection fault had cleared itself temporarilyby the time the aircraft had returned to Hurn for the TCV change.

The aircraft was originally equipped with two separate over-temperaturesensors, a *bulb* type sensor and a thermostat. It is understoodthat the bulb type was found to be unreliable in service and operatorswere subsequently given the option of disabling it; the reliabilityof the thermostat unit alone being considered sufficient to ensureadequate protection. G-AVMH was one of those aircraft (the majority)so modified. The remaining duct over-temperature thermostat isnot covered by the press-to-test facility on the flight deck,nor is it subject to frequent inspections. However, it is subjectto a functional check carried out during the annual air systeminspection.

The lack of regular functional testing, and of a press-to-testfacility, introduces a risk of a dormant fault occurring in theoverheat detection system, with an attendant risk of a seriousoverheat. However, in practice a *hot* smell would almostcertainly accompany any significant overheat, and would serveto alert the crew to a duct overheat, as it did on this occasion. The duct temperature gauges should then allow the faulty systemto be identified and shut down manually.