

Concorde Type 1 V102, G-BOAC

AAIB Bulletin No: 6/2004	Ref: EW/C2003/06/03	Category: 1.1
INCIDENT		
Aircraft Type and Registration:	Concorde Type 1 V102, G-BOAC	
No & Type of Engines:	4 Rolls-Royce Olympus 593 turbojets	
Year of Manufacture:	1975	
Date & Time (UTC):	13 June 2003, time unknown	
Location:	Transatlantic cruise	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 9	Passengers - 98
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Fire damage in under wing area	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	55 years	
Commander's Flying Experience:	17,000 hours (of which 2,200 were on type)	
	Last 90 days - 60 hours	
	Last 28 days - 20 hours	
Information Source:	AAIB Field Investigation	

Synopsis

On 21 June 2003, during the routine maintenance investigation of a reported defect, a short circuit condition was detected on the Fuel Quantity Indication wiring for fuel tank No 7. Damage was found to an associated wire bundle which had been caused by a localised fire within the area enclosed by the wing/fuselage fairing area aft of the main landing gear (zone 198) below fuel tank No 3. Fuel seepage from this tank, in the area of the chafed wire, had collected in a box section fairing support member and had been ignited, resulting in a short duration, low intensity fire. The ignition source for the fire was identified as a chafed wire for the main tank No 3 fuel pump, which carries 115V AC power, arcing against the aluminium fairing. It was possible that the chafing of this wire had been precipitated during maintenance activity two years prior to the incident when this wiring had been disturbed. The fire probably occurred during a flight from LHR to JFK on 13 June 2003, although no indications were apparent to the flight crew at that time. Modifications have since been introduced to prevent the build up of fuel in the box section fairing support structure.

History of Flight

On 21 June 2003, the aircraft was to fly from London Heathrow (LHR) to New York (JFK) airport. Prior to the flight the failure flag for the No 7 fuel tank gauge had been in view, indicating that the gauge was unserviceable, and it was indicating 1,500 kg. However, the fuel tank, which holds 7,480 kg, was full. The gauge was interchanged with that for the No 5 fuel tank, but the defect remained. The fuel quantity packs were then interchanged, but the defect persisted. A description of the fault was entered into the aircraft's Technical Log and the aircraft departed with the No 7 tank gauge unserviceable, in accordance with the minimum equipment list (MEL). Approximately one hour after takeoff, the failure flag disappeared and the fuel gauge appeared to work correctly for the remainder of the flight.

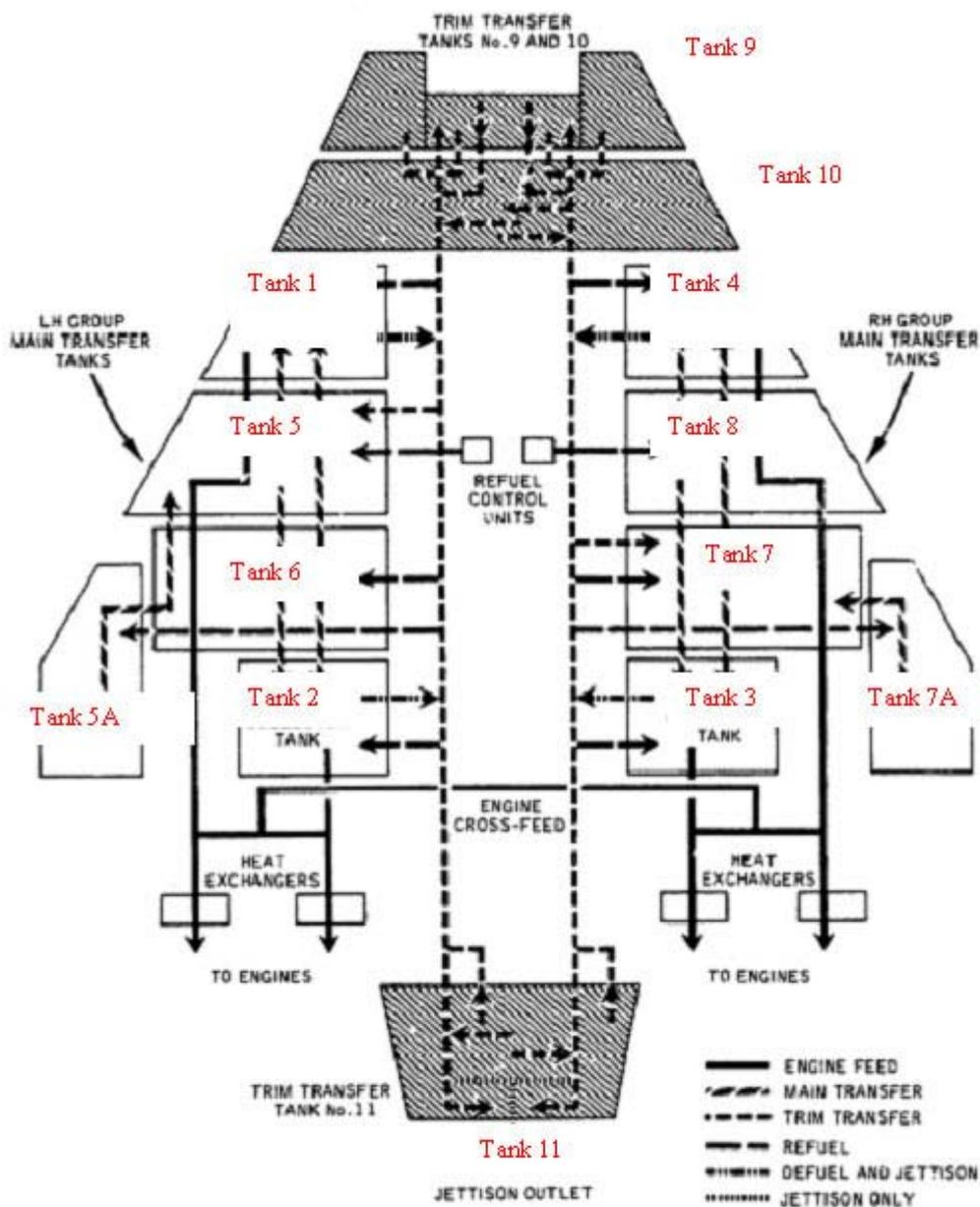
Prior to refuelling for the return flight, the contents of the No 7 fuel tank were physically checked and confirmed as being correct. After refuelling, with the No 7 tank full, the gauge again indicated a total of 1,500 kg but on this occasion there was no failure flag in view. There was now, however, a failure flag displayed on the No 5 tank fuel gauge. Once more, the No 5 and No 7 fuel gauges and fuel quantity packs were interchanged, but the defects remained. (Under the conditions of the MEL the aircraft was not permitted to depart with two fuel gauges unserviceable.) The centre of gravity (CG) computer also displayed a failure warning flag, although the indications appeared to be correct. Whilst the engineering analysis continued, the failure warning flags for the No 5 fuel tank gauge and the CG computer cleared and so the aircraft once again departed under the conditions of the MEL.

When in the supersonic cruise phase of flight, the No 7 fuel tank gauge began to indicate correctly. However, all other fuel tank gauges, except those for tanks 4, 5A, 9, 10 and 11, displayed failure flags intermittently for the remainder of the flight. At no time did any of the gauges fail. The failure flag for the CG computer also re-appeared but the CG reading corresponded closely with the calculated value. The failure flags for the No 2 and No 3 fuel tank gauges remained in view for most of the flight, although the indications on these gauges were considered by the crew to be accurate. During the flight the crew had contacted the operator's engineering control to advise them of the multiple fuel gauges failure flags. After flight, when the engines were shut down all of the failure flags disappeared from view and the flight engineer fully debriefed the ground engineering staff.

Fuel system

On Concorde, the fuel system has three functions; to supply fuel to the engines, to control the position of the aircraft CG and to act as a heat sink to absorb kinetic heating from the structure and to dissipate heat generated by the air-conditioning and hydraulic systems. Fuel is stored in thirteen integral tanks, as shown in Figure 1.

Figure 1: Fuel Tank locations



Tank numbers shown in red

These are arranged in three groups; the left main transfer group, the right main transfer group and the trim transfer group. The left and right main transfer groups store fuel in the wings and sections of the centre fuselage, and both groups are comprised of three main tanks which supply two collector tanks per group, from which the engines are fed. The collector tanks on the right main transfer group are tank Nos 3 and 4, which feed engines Nos 3 and 4 respectively. The main fuel transfer system transfers fuel from the main transfer tanks to the collector tanks at a rate sufficiently high to ensure that the collector tanks are always maintained in a near full condition. Fuel is transferred from each tank by electrically driven pumps, which can be manually controlled, to match an automatic sequence of mechanically operated transfer valves which are governed by float sensors in the tanks receiving the fuel.

A fuel quantity indication (FQI) system shows the level of individual and total tank contents. The system is also used to provide an indication of the aircraft's CG. Tank Nos 5, 6, 7, 8, 9, 10 and 11 have magnetic fuel level indicators installed to provide an underwing method of manually checking the contents of these tanks. These indicators are intended to be used when a fuel quantity gauge has failed, or when the fuel quantity probes are suspected of giving incorrect signals. Gauge failure is indicated by the display of a warning flag.

Each collector tank is equipped with main and standby 115V AC electric motor driven pumps. The electrical loads of the fuel system are supplied from the aircraft's electrical power system via circuit breakers on the distribution busbars. The main AC and DC circuit breakers are located above the equipment racks on both sides of the flight compartment; the essential AC and DC circuit breakers are located forward of the racks on the left side.

Fuel leaks

The fuel tanks are formed as sealed cells integral with the wing, centre fuselage and rear fuselage structure. Intermediate ribs and spars within the tanks reduce fuel surging and sloshing. As a result of recent modifications, tank Nos 5, 6, 7 and 8 are fitted with liners on the wing lower surface, which limit fuel leakage to a minimum in case of foreign object damage. The tanks also have structural expansion joints, located on the lower surface between the wing and fuselage, to allow for expansion and contraction of the aircraft structure caused by the thermal cycle induced by the supersonic/subsonic flight profile. The expansion joints are formed from two top hat sections which ramp down to a flat surface at either end where they attach to the spar cap flanges. The inner expansion joint forms part of the aircraft fuel tanks.

As a result of these sealed cells expanding and contracting, as part of normal flight, cracks can develop, which results in fuel seepage/leakage from the tanks. Fuel leaks are continually assessed by engineering staff and monitored in accordance with the Aircraft Maintenance Manual (AMM). They are categorised as 'seepage' or a 'running leak'. Seepage is assessed for an area six inches square such that once the area is wiped clean, fuel should not flow or fall in droplets for a period of 15 minutes. For a 'running leak', fuel reappears immediately after the surface is wiped clean and falls in drops; the leak rate is assessed as the number of drops per minute. Allowable fuel leaks and seepage are classified by specific aircraft regions, according to risk, and are detailed in the AMM. For seepage or a running leak of less than 15 drops per minute, no immediate action is required for some areas, but frequent checks must be conducted to ensure that a leak is not worsening and repair work must be carried out at the next scheduled maintenance check. For other, more critical areas with the same condition, repairs are required before the next flight.

There were no fuel leaks being monitored in the area of tank No 3 around the time of the incident.

History of reported defects in the FQI system

The aircraft flew a sector from LHR to JFK on 13 June 2003. During refuelling operations at JFK engineers noted that tank No 7 fuel gauge had failed. The tank was filled and the quantity checked using the tank No 7 magnetic fuel level indicator and the aircraft returned to LHR where the FQI probe in the tank was replaced. A functional check was performed satisfactorily.

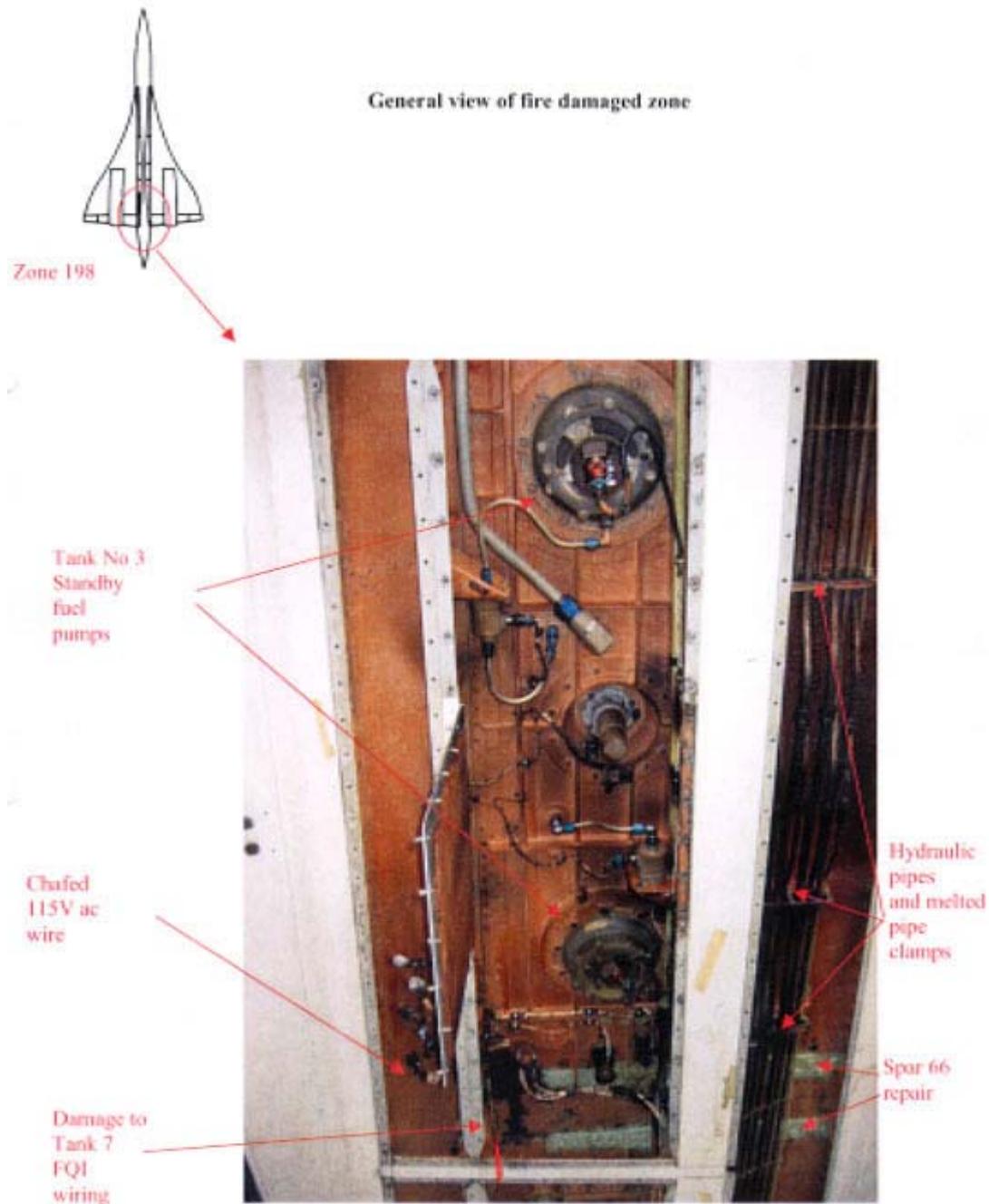
The aircraft next flew to JFK on 20 June 2003, subsequent to which it was reported that the FQI gauge had a 'fail' flag visible and that it read incorrectly. The aircraft was dispatched from JFK on 21 June 2003 with this allowable deferred defect but, during the return flight the crew reported multiple 'fail' flags on several fuel gauges (as described in the 'History of Flight'), and that fuel was slow to transfer from tank No 3 to tank No 7A during the descent.

During investigation of the reported defect on tank No 7 FQI, a short circuit condition was identified in the wiring. Further investigation revealed that this had been caused by a short duration, low intensity fire inside the wing to body fairings below fuel tank No 3 on the right side of the aircraft.

Aircraft examination

The area damaged by the fire was contained within the wing/fuselage fairing area aft of the main landing gear, below and adjacent to tank No 3 (zone 198), Figure 2.

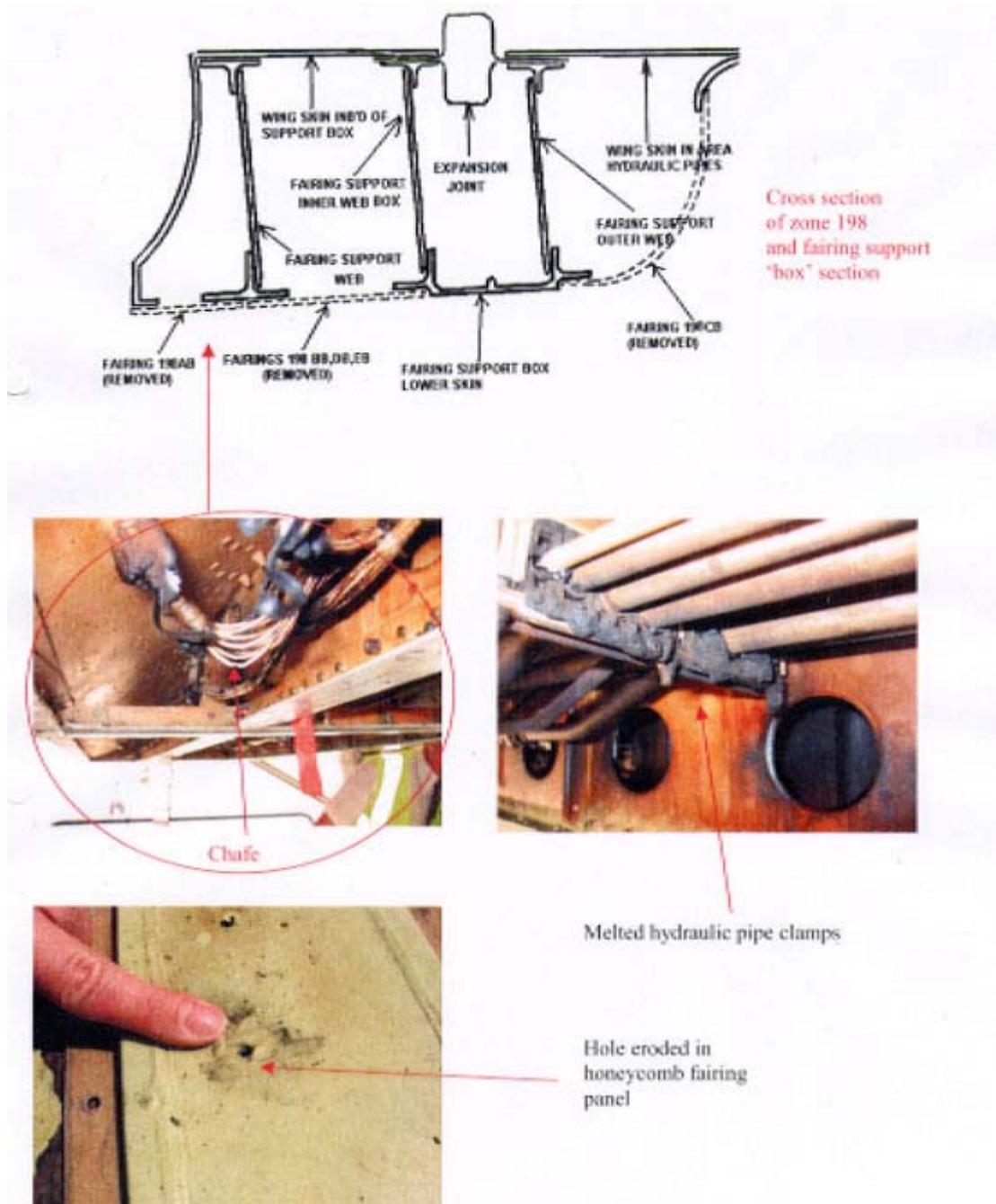
Figure 2: General view of fire damaged zone



This area contains a number of hydraulic pipe runs, together with wiring for the fuel pumps and FQIs. There was little overall evidence of sooting, indicating that only a small quantity of fuel had been consumed. There was more localised evidence of sooting within a 'box' fairing support structure, and this also showed evidence of a ventilation airflow direction through the area, indicating that the fire was likely to have occurred during flight. Conductivity testing on the aluminium 'box' fairing structure showed this area had been heat affected. There was little damage to the paint and thus the

temperature of the fire was estimated to have been approximately 400°C. Tank No 3 115V AC main fuel pump wiring, from the rear fuselage, was found to be loose within its bundle in this zone and one wire had chafed on fairing panel 198AB, Figure 3.

Figure 3: Cross section of Zone 198



The chaffing of the wire on the inner aluminium skin of the honeycomb filled panel eventually led to an electrical arc of a 115V AC supply, which ignited the fuel/air mixture. The fire had also caused damage to the FQI wiring, leading to the reported defects, initially on tank No 7 FQI system and then on other tank FQI systems and the CG computer. Although there was fire damage to the FQI and No 3 fuel pump wiring, there was no evidence of arc-tracking along the length of the wires. Arc tracking is not a feature associated with the Concorde PTFE wiring insulation.

The fire had damaged a number of nylon clamp blocks supporting hydraulic pipes. The hydraulic pipe clamps are made from Polyamide (Nylon) 66, which has a heat distortion temperature (ie the temperature at which the material will flow) of between 150°C and 180°C, and a melting temperature of 264°C. Around the area of the 'box' section of the fairing support structure outboard of the chafed wire, the pipe clamps displayed varying thermal effects. Some clamps had been completely consumed while others had been burnt and the material had flowed. Below one group of hydraulic pipes a 'pool' of burnt pipe clamp material had formed by melting and then flowing onto the inside of the fairing panel 198CB. The surface of the burnt material was black and smooth, indicating flow had continued after the burning had finished, although one small area had a rough texture indicating that the burning had continued here for a longer period. Around the 'pool' there was evidence of plastic spatter on the fairing. The lack of damage to the fairing panel suggested that burning of the hydraulic pipe clamps was localised and of low heat intensity. There was no apparent damage to the inner painted surface of the fairing panel and no delamination had occurred.

During the flight, tank No 3 main fuel pump circuit breaker did not trip and the pump had continued to operate, despite the chafed wire and arcing to the panel. The circuit breaker was of the conventional thermal/mechanical type, and this was removed and later tested satisfactorily. (This type of circuit breaker is designed to protect against electrical overheating of wires and does not protect against transient arcing faults, which develop high energy over a very short period of time.)

The area under tank No 3 in the region of the fire, was cleaned and examined for fuel leaks. At the forward end of the expansion joint at wing spar 66, one drip of fuel occurred every 6 minutes and an additional drip every 1 minute 40 seconds from the area of the lower panel support structure, Figure 3. The bolts on a repair plate on spar 66 were damp but did not form droplets. There was also a drip every minute at the aft end of the expansion joint at spar 68. Zone 198, the region in which the fire occurred, is classed as 'zone two' for fuel leakage purposes and seepage only is permitted before repairs are required.

Airworthiness requirements for areas adjacent to fuel tanks

Concorde is certificated to Supersonic Transport TSS requirements. TSS 6.1, paragraph 4.7.3, specifically states *'To prevent the accumulation of flammable fluids or vapours, spaces adjacent to tanks shall be ventilated and drained.'* This requirement is consistent with current JAR 25 requirements for Large Aeroplanes.

Ventilation in the wing/fuselage fairing area aft of the main landing gear is provided by means of an air conditioning supply which is shared with the main landing gear bay. The airflow is routed through the fairing area and any fuel which leaks into this region is expelled through a dedicated shrouded external port. Ventilation holes were also originally provided in this area. However, flight testing by the manufacturer showed that the pressures in the adjacent rear equipment bay were such that vented fuel, in the form of spray, could find its way into the bay and constitute a fire hazard. Therefore, a mandatory Service Bulletin (SB) SST-53-053) was issued in August 1983, which introduced improvements to the venting, sealing and drainage in the area of the rear equipment bay but also specifically required twelve additional ventilation holes in panels 197GB and 198GB to be blanked.

Safety action

The aircraft wiring in the area of the fire was installed at original manufacture in 1975. In 2001, routine inspection of the wing structure had detected cracks in the area of spar 66, Figure 2, and in order to complete the structural repair, it was necessary to disturb the wiring. It is likely that in reinstating the wiring the possibility for the chafe to occur was introduced. This area is not routinely inspected and, given the low number of hours flown by each aircraft, is unlikely to have been inspected within the period since the repair to spar 66. The operator carried out a visual inspection on the remaining aircraft to inspect for any similar wiring defects which could result in chafed wire, but none were identified. The operator also introduced a modification to introduce additional 0.25 inch diameter drain holes in the underside of the wing/fuselage fairing 'box' support structure aft of the

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main landing gear (zones 195, 196, 197 and 198). All five aircraft in the fleet were modified prior to the aircraft leaving service.

This incident highlighted airworthiness issues which were not limited to Concorde, but which reflected broader concerns on all aircraft types regarding wiring condition, particularly as aircraft age and modifications are introduced. The broader concerns are addressed in the overview document included in this issue of the AAIB Bulletin.