Engine fire, McDonnell Douglas DC-10-30, N68065

Micro-summary: **Following a return to the stand for strange odors,the #2 engine on this McDonnell Douglas DC-10-30 started venting fuel and eventually caught fire.**

Event Date: **1998-03-08 at 1145 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), United Kingdom**

Investigative Body's Web Site: **http://www.aaib.dft.gov/uk/**

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AAIB Bulletin No: 2/2000 **Ref: EW/C97/12/2** **Category: 1.1**

Aircraft Type and Registration:	McDonnell Douglas DC-10-30, N68065	
No & Type of Engines:	3 General Electric CF6-50C2 turbofan engines	
Year of Manufacture:	1979	
Date & Time (UTC):	8 March 1998 at 1145 hrs	
Location:	Manchester Airport	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 14	Passengers - 249
Injuries:	Crew - Nil	Passengers – 2 (minor)
Nature of Damage:	No 2 engine replaced. No damage to the aircraft	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	51 years	
Commander's Flying Experience:	20,650 hours (of which 300 hours were on type) Last 90 days - 120 hours Last 28 days - 47 hours	
Information Source:	AAIB Field Investigation	

Description of the ground incident

The aircraft and crew were planned to operate a scheduled passenger service from Manchester to Newark Airport, USA, and the crew reported for duty at 1000 hrs. The aircraft was serviceable for the flight and the forecast meteorological conditions for the take off were good. The relevant Automatic Terminal Information Service (ATIS) information included a surface wind of 090˚/15 kt with a temperature of +6˚C.

Runway 06 was the runway in use and the aircraft was cleared to taxi for the holding point at 1132 hrs. At 1136 hrs the aircraft was transferred to the Tower frequency and at about his time, a strange odour was noted in the cabin and reported to the flight crew. There were no unusual flight deck indications, although the flight crew believed that they could detect a slight smell of gasoline. The commander instructed the flight engineer to ventilate the aircraft and made an announcement to the passengers explaining that they would be returning to the stand. At 1139 hrs, as the aircraft was approaching the holding point for Runway 06, the first officer asked for permission to taxi back to the

stand, but gave no reason for this request. After a short hold, to await the landing of another aircraft, the DC-10 was cleared at 1142 hrs to enter the runway, backtrack and clear at intersection Bravo. As the aircraft cleared the runway and turned onto taxiway Bravo at 1144:42 hrs, the Tower controller saw vapour from the No 2 engine and informed the commander that the aircraft appeared to be venting fuel. The bird control patrol, which had also observed vapour/fuel emanating from the No 2 engine, had already informed the Ground movements controller of this at 1144:35 hrs, and he had passed the message to the Tower controller. However, by the time the Tower controller received this message he had already seen the problem and informed the commander and so did not repeat the message. The aircraft was then transferred to Ground Control who reiterated the information about fuel/vapour from the No 2 engine. At 1445:57 hrs the commander brought the aircraft to a halt on taxiway Bravo, at the intersection with taxiway Charlie, and asked for the Airport Fire Service (AFS) to attend because of a possible fuel leak. Inside the aircraft the fumes were becoming more noticeable but there were still no flight deck warnings or unusual indications; nor was there any visible smoke or vapour in the cabin. At 1446:10 hrs ATC initiated a Ground Incident and the AFS fire tenders reacted promptly and arrived at the aircraft almost immediately (the aircraft had come to a halt some 200 yards from the airport fire station).

When the AFS arrived at the aircraft, the chief fire officer asked ATC to instruct the crew to change frequency to 121·6 MHz. Having changed frequency, the commander informed the chief fire officer that there were fumes in the cabin, and he in turn was advised that fuel was now running from the No 2 engine. At about this time, a fire started in this engine and so the chief fire officer suggested that the commander should order an evacuation. The commander immediately initiated an evacuation and the appropriate Checklist actions were completed. Very shortly afterwards, passenger emergency slides deployed from the aircraft. ATC were not advised by the flight crew that an evacuation had been initiated. As the evacuation commenced, the fire crews discharged media onto the No 2 engine, extinguishing the fire. By 1449:18 hrs the bird control patrol, which had followed the aircraft, had also observed the onset of the fire in the No 2 engine and informed ATC.

The evacuation of the 239 passengers (including 3 infants) and 14 crew members was completed successfully, with only 2 minor injuries. However, problems were encountered with the slide at door 3L (ie the left overwing exit). The first section of this slide, which formed a horizontal walkway across the wing to the leading edge, inflated normally but the second section, which formed the escape slide from the wing to ground level, failed to inflate. About a dozen passengers evacuated through the overwing exit and made their way along the inflated first section, only to find that there was no means getting to the ground. These passengers were instructed by the firemen to go back into the cabin and find another exit, which they did.

In addition, the slide at door 1R (ie forward right) had adopted a rather steep angle and two firemen had to hold it in an extended position to allow it to be used. Videotape evidence suggested that this slide had failed to achieve full inflation pressure, resulting in reduced rigidity of the slide and consequently increased vulnerability to wind and to 'sagging' under the weight of passengers using the slide.

The slides at doors 2L, 2R and 4R were each tilted by the wind upon initial inflation, however each slide was quickly captured and held down by firemen, allowing passengers to use them.

The cause of the fire

Preliminary information suggested that the probable cause of the fire was an internal failure of the fuel cooled oil cooler (FCOC) on the No 2 engine which had allowed fuel to leak into, and ultimately to flood, the engine lubricating system before affecting the vent system. This was subsequently confirmed when sectioning of the FCOC revealed a large rupture in one of the fuel matrix tubes within the unit which had allowed pressurised fuel to enter the engine oil system. Associated fuel vapours would then have been able to enter the oil vent system and become ignited in the jet pipe.

The matrix tube rupture had occurred close to the end of one of the group of tubes immediately adjacent to a central divider plate, which separated the inlet and outlet regions of the oil circuit. Fatigue cracks were found on each side of this divider plate where it joined the casing of the unit. These cracks had allowed the end region of the plate to 'flex' in response to pressure fluctuations within the oil circuit, resulting in repeated contact between the plate and the walls of adjoining fuel tubes at the manifold end of the unit, which had caused fretting and wear of the tube walls. This had resulted in localised thinning of the tube walls, followed by cracking of the walls and rupture one of the weakened tubes due to internal fuel pressure.

The mode of failure of the FCOC from N68065 were identical, for all practical purposes, to a previous failure of a brazed tube FCOC investigated by the AAIB. This earlier failure also occurred on a DC-10-30 aircraft, registration G-NIUK, and was the subject of a detailed report published in AAIB Bulletin 4/99 to which the reader should refer for further technical information. In the case of the earlier failure on G-NIUK, deficiencies in the material properties of the divider plate in the area of the brazed attachment of the plate to the casing, attributed to poor grain structure due to inadequate control of the post-braze quenching processes during manufacture, was identified as a factor contributing to the initiation of the fatigue cracks in the divider. Metallurgical examination of the FCOC divider plate from N68065 revealed similar deficiencies in the strength of the divider material in the area of the

fatigue fractures, but in this case it was attributed to a failure of the material to meet the required specification rather than due to poor grain structure.

This FCOC was last subject to inspection and testing in January 1996. There was no record of rising engine oil contents or abnormal oil consumption during the period leading up to this incident.

Action by the FCOC manufacturer

As a result of such failures, the FCOC manufacturer had introduced a revised overhaul inspection procedure in Service Bulletin 158210-79-2030, issued on 28 July 1997, which comprised an amalgamation of the existing boroscope inspection contained in the Component Maintenance Manual and an X-ray inspection which had been introduced in June 1997. This revised inspection, which applied to all 'brazed tube' units (ie all dash numbers except Part Nos 158210-14 and 158210-16 series 1 and 2), required those FCOCs which exhibited divider cracking or "excessive oil baffle movement" to be scrapped. Since the above improved inspection requirements had been directed towards brazed tube FCOCs, the previously mentioned AAIB Bulletin 4/99 arising from the earlier FCOC failure on G-NIUK included a Safety Recommendation (No 99-4) directed to the FCOC manufacturer, AiResearch, to take action in conjunction with the engine manufacturer, General Electric, to extend the revised overhaul inspection procedures to include non-brazed tube FCOC units, at least until statistical evidence of failure rates and characteristics could allow a valid assessment of the risks associated with each type of FCOC unit.

Emergency slide malfunctions

Preliminary investigations

After the incident, the emergency slides were removed by maintenance staff prior to the aircraft being towed clear of the taxiway.

Personnel involved in recovering the slides found that the inflation cylinder for the outboard section of the door 3L slide, ie the slide section which failed to inflate during the evacuation, was still fully charged. Because of the potential hazard associated with an accidental slide inflation inside the recovery vehicle, they manually discharged the inflation cylinder to inflate the slide, before deflating it again for carriage in the vehicle. They reported that the slide had inflated immediately and apparently to normal pressure.

Subsequent AAIB examination of the door 3L outer slide at Manchester Airport did not reveal any obvious defect in the mechanism which could have explained its failure to inflate automatically during the evacuation. However, it was noted that the two halves of a steel cable (lanyard) connecting the manual inflation handle to the discharge head on the inflation cylinder were uncoupled at a joiner between two sections of the cable. The joiner concerned took the form of a barrel type housing connected to one part of the cable, into which a ball fixed to the end of the other cable was retained by a ring nut. As found, the ball was still attached to its half of the cable but was separated from the barrel; the ring nut was still in place on the barrel part of the connector. This suggested that the joiner had been intentionally disconnected at some time, and the nut replaced on the barrel for safe keeping, however it was not possible to establish when this disconnection had occurred. The manual inflation handle was still attached to its part of the cable, and was retained in the normal stowage position by its velcro retraining straps.

Had the manual inflation cable been disconnected at the time of the evacuation, it would have prevented inflation of the slide in the event of the manual inflation handle being pulled; however, it should not have affected automatic inflation of the slide. So far as could be established, no attempt was made during the evacuation to manually inflate the second section of the slide using this handle. Therefore whilst the disconnection was a cause for concern, it did not account for the failure of the outer slide to inflate in this case.

Detailed investigation

The slides were returned to the associated manufacturer in the USA where they were subject to a defect investigation under the direction of the National Transportation Safety Board (NTSB), with participation by the FAA and the aircraft operator. Copies of the video and photographs, taken by witnesses on the ground at Manchester during the course of the evacuation, were made available to the NTSB to assist in the investigation.

Left overwing slide

This unit was manufactured and shipped in April of 1996 from BF Goodrich (BFG) in Phoenix, Arizona, to the BFG Los Angeles Service Centre. There, it was installed in an aircraft slide container and shipped to the aircraft operator. So far as could be established, at the time of the incident to N68065 the slide was in the 'as delivered' condition. Examination of this slide unit was limited to the slide/raft portion, Part No 5WD230102-300, Serial No LA0008, DOM 4/96, ie the outer section which failed to inflate during the evacuation.

The NTSB investigation report described tears, abrasions and other minor defects in the slide body which had clearly been caused by dragging of the slide on the taxiway after post-incident removal from the aircraft, but no abnormalities were found which explained the failure of the slide to inflate.

The regulator valve was inspected and tested separately by the regulator manufacturer, under NTSB supervision. The pressure gauge electrical indicating system was found to be slightly out of tolerance and a cut was found in the electrical wire from the gauge at the plug end of the cable, but neither defect would have caused the failure to inflate. The condition of the 'O' ring seals was good and, after re-charging the cylinder with nitrogen, the pull force required to initiate a discharge was tested and found to be within limits.

In summary, no defects or anomalies were found which explained the failure of the left overwing outer slide to inflate automatically during the emergency evacuation at Manchester Airport.

Right forward door slide

The reported failure of the right forward door slide was confirmed from an examination of the videotape evidence which showed that after a puff of gas from the aspirator, near the end of the inflation cycle, both of the support tubes appeared to be under-inflated on completion of inflation.

The slide unit was manufactured at the BFG plant in Phoenix in July 1997 and was shipped initially to the BFG Los Angeles Service Centre for installation in an aircraft slide container, before being delivered to the operator. It was also in the 'as delivered' condition at the time of the incident. Upon being returned to the manufacturer for post-incident investigation, this unit was routed in error to the overhaul shop, and work had started to inspect and test the unit as part of the normal overhaul procedure before the error was discovered, and the slide unit quarantined for NTSB investigation. The work carried out during this period had been fully documented, however, and was taken into account during the subsequent defect investigation by the NTSB.

The associated NTSB investigation report identified a number of minor scuffs and some superficial damage consistent with that normally found on slides which have been used for an evacuation, caused by contact with the runway surface and during subsequent recovery of the unit. Notwithstanding this, when the unit was inflated no obvious leaks were found. Testing of the pressure relief valves showed that the upper valve opened at the correct pressure and that the lower valve opened at a higher than normal value; however the latter would have tended to result in over-inflation, as opposed to under-inflation. The inflation hoses were checked at 600psi, and no leaks found. In summary, no defects or anomalies were found in the right forward door slide unit to account for its failure to inflate fully.

The associated regulator valve, Part No 30001-6, Serial No N-365, was also subject to detailed investigation and testing. The actuation pull force was measured with the valve pressurised to the correct value and found to be within limits. The electrical pressure gauge was checked for accuracy and found to be slightly out of tolerance, but this could not have been a factor in the under-inflation. The unit was disassembled, and detailed scrutiny of the component parts revealed the following:

a) The regulating spring Part No 300185/1 was below the requirements for both free length and spring force.
a) The static cap 'O' ring, Part No 680145-013, was frayed.
a) The static cap, Part No 30204-1, had a dent in the top of the cap, evidently made by the spring.
a) The truarc ring, Part No 7-M-37, which retained the static cap, was slightly 'dished'.
a) The snap ring groove in the bottom of the valve body was slightly dented by the ends of the snap ring.

Separate checks subsequently showed that all components were within tolerance dimensionally, except in the areas identified above.

In summary, no abnormalities or defects were found on the slide unit itself, or the inflation hoses, which could have explained the low inflation pressure. However, abnormalities and damage were found on the internal components of the regulator valve consistent with abnormal vibration within the unit during operation, during which the regulator spring had evidently become coil bound. This malfunction offered the most likely explanation for the low inflation pressure achieved by the right forward door slide during the evacuation.

Actions of the cabin crew

The NTSB was requested by the AAIB to investigate the actions of the cabin crew of the USA based operator, with particular reference to the difficulties encountered with door 3L.

The operator's 'Inflight Manual', which provided instructions for the flight attendants, included instruction in the operation of the emergency slides. In the section covering the overwing doors, it described a 'patch' or 'barber pole' type indicator located on the outer section of the slide, which should be visible from the doorway if the outer slide section has inflated correctly. If the indicator is not visible, a flight attendant should be dispatched to the end of the first (walkway) section to pull the manual inflation handle for the outer section of the slide. If the outer slide still does not inflate, the flight attendant is instructed to block that overwing exit and redirect passengers to another useable exit.

In this incident, it appears that passengers arrived at the end of the walkway section where they found themselves stranded and then returned to the cabin on the instructions of fire service personnel positioned outside the aircraft. The flight attendant at door 3L reported opening the door and seeing the slide "inflate over the edge of the wing", and so he then started directing passengers out of the door. He recalled that the first passenger out of this overwing door subsequently called back to report that the rest of the slide had not inflated properly, and so the flight attendant redirected passengers to alternative useable exits. The flight attendant made no reference to checking for a visible indicator on the outer slide section before he directed the passengers out onto the wing, or to any attempt to manually inflate the outer section of slide.