
Smoke emergency, Boeing 737-436, G-DOCH

Micro-summary: This Boeing 737-436 diverted after detecting electrical smoke.

Event Date: 2002-11-08 at 1458 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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Boeing 737-436, G-DOCH

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Report Information

AAIB Bulletin No: 6/2004	Ref: EW/C2002/11/02	Category: 1.1
INCIDENT		
Aircraft Type and Registration:	Boeing 737-436, G-DOCH	
No & Type of Engines:	2 CFM56-3C1 turbofan engines	
Year of Manufacture:	1991	
Date & Time (UTC):	8 November 2002 at 1458 hrs	
Location:	Near Clacton, Essex	
Persons on Board:	Crew - 6	Passengers - 68
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage and shorting within electrical wiring loom in cabin ceiling and associated failure of water supply hose	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	35 years	
Commander's Flying Experience:	4,400 hours (of which 4,150 were on type)	
	Last 90 days - 144 hours	
	Last 28 days - 52 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Whilst climbing through FL240 the flight crew noticed a small amount of smoke appear on the flight deck, accompanied by a smell of electrical burning. They decided to carry out a diversion but were hampered by difficulties in communications with the cabin crew and locating the appropriate checklist, since it was not clearly identified on the index page of the QRH. Fire damage had occurred to electrical wiring in the area of the 'drop-down' ceiling panel immediately aft of the flight deck door. A braided steel water supply hose to the forward galley had been attached by means of a simple electrical 'tie-wrap' to a wiring loom, and there was evidence of abrasion and arcing between the wires and the hose. This had resulted in the severing and shorting of a number of wires. It was determined that the hose was too long for this application and that the excess length had been looped through this overhead area and then secured by the tie-wrap to adjacent wire bundles. It was not conclusively determined when this had been done but it was most likely that the attachment was simply a short-term expedient while systems were being disconnected and disassembled, and that the error was then missed during reassembly.

History of the flight

The flight was operating from London (Heathrow) to Kiev and took off at 1445 hrs with the first officer (FO) as the handling pilot. The departure was uneventful until 1458 hrs when, climbing through FL240, the commander heard three or four electrical 'crackling' sounds. Shortly afterwards the cabin call aural warning sounded on the flight deck, but despite several attempts neither pilot was able to establish contact with the cabin crew via the interphone. At about this time the FO noticed a small amount of smoke in the area behind the commander. The commander could not see the smoke but was aware of an electrical burning smell and therefore instructed the FO to don his oxygen mask. The commander put on his own mask and re-established communication with the FO, thus completing the recall items for the '*Electrical Smoke / Fumes or Fire*' checklist. He then took control of the aircraft whilst the FO retrieved his Quick Reference Handbook (QRH) in order to complete the remainder of the checklist.

Both pilots were aware of continued banging on the locked cockpit door, which had commenced after their failed attempts to reply to the cabin crew on the interphone. This heightened the pilots' concerns about what was happening, since they were unable to either communicate with the cabin crew or establish the cause of the smoke.

The commander was unsure whether his oxygen hose was long enough to allow him to reach the flight deck door. Therefore, in the absence of any visible smoke, and having briefed the FO, he cautiously removed his mask. He could still smell the smoke but had no difficulty breathing and decided that it was safe to leave his mask off. He went to the door and checked through a peephole for signs of fire or possible intruders. Seeing neither he opened the door and was met by a flow of water coming from a panel in the roof between the forward toilet and the galley. The cabin services director (CSD), who had been the person banging on the door, explained that about fifteen minutes after takeoff he had seen sparks and flames coming from the panel, followed shortly thereafter by a continuous stream of water.

The CSD had attempted to notify the flight deck at the time by using the cabin interphone and had initially heard the commander's voice reply, but the interphone had then ceased working. One of the cabin crew working at the rear of the aircraft then reported to him that the rear galley and some of the cabin lights were no longer working. Another member of the crew turned the water isolation valve off but, despite this, water continued to pour from the roof. Concerned that the water might find its way into the avionics bay the crewmember plugged the gap under the flight deck door with towels. The CSD had then started to bang on the flight deck door in an attempt to get the pilots' attention and, looking through the peephole, could see that both pilots were wearing their oxygen masks. Still unable to establish communications with the flight deck the CSD gathered the cabin crew together in the forward galley to explain the situation and to brief them for an anticipated return to Heathrow. It was at this point that the commander opened the flight deck door.

After satisfying himself that he was fully informed of the situation in the cabin, and that there was no longer any fire, the commander briefed the CSD that they would be returning to Heathrow and advised him to prepare for a possible emergency evacuation. The commander also told him that he would make an announcement to the passengers.

Before the commander left the flight deck in order to check the cabin, the aircraft had been levelled at FL260 and ATC notified that they had a "technical problem". No emergency had been declared at this point since the flight crew were still unsure of the situation in the cabin. However, whilst the commander was in the cabin ATC asked whether they wished to declare an emergency. The FO replied that they did and on a further suggestion from the controller agreed to commence a turn towards Stansted Airport, which was then about 55 nm to the west.

When he returned to his seat the commander decided to leave his oxygen mask off since there was now no smell of any smoke. He instructed the FO to remove his oxygen mask, in order to facilitate communications, before briefing him on the situation in the cabin. The commander then declared a

MAYDAY, requesting an immediate diversion to Heathrow. This was acknowledged by ATC and new vectors were given for them to fly. The crew then completed the remainder of the smoke checklist from the QRH and the commander briefed for a monitored approach for an ILS to Runway 27R at Heathrow, with the FO flying the approach and the commander taking control for the landing.

Meanwhile, after being informed of their intention to return to Heathrow the CSD had commenced briefing the passengers for a precautionary landing. Since the cabin interphone was not working he decided the most expeditious method was to arrange for the four cabin crew members to walk through the cabin personally briefing the passengers. Having done this they isolated the cabin electrical services and the CSD went onto the flight deck to inform the commander that the cabin had been secured for landing. The commander had previously explained the situation to the passengers, successfully using the public address (PA) system but he told the CSD that should the system subsequently fail and in the absence of any other instruction the doors should be left in 'auto' after landing. The CSD then returned to the cabin and the cabin crew took their seats for landing.

During the approach the commander requested that the ILS be protected so that they would be able to carry out an autoland should the smoke return and their view be restricted. ATC replied that a CAT III ILS would be available but that protection could not be guaranteed: they also advised that a surveillance radar approach would be available if necessary. The approach was continued and the commander took control at 1,000 feet and completed a normal landing, bringing the aircraft to a halt on the runway, as requested by ATC. The FO, as briefed, then went immediately into the cabin to check for any more signs of fire. There were none, and the commander relayed this information to the fire services who were now at the aircraft and speaking to the commander on a discreet frequency.

The fire service requested that the engines be shut down before carrying out an external check for signs of fire or damage. None were found and they boarded the aircraft and used thermal imaging equipment to look for hot areas in the ceiling. Again none were found but, on pulling down the damaged ceiling panel, a burnt wiring loom could be seen. Next to this was the water supply hose to the forward galley, from which water was still pouring. Whilst the fire crews were investigating the source of the fire the passengers were disembarked from the rear of the aircraft onto awaiting buses, following which the aircraft was towed clear of the runway.

Flight Recorders

There were three recorders fitted to this aircraft. The tape-based CVR and DFDR were replayed by the AAIB whilst the Quick Access Recorder (QAR) was replayed by the operator and all were successful in providing data for the investigation. Relevant data is described below.

The CVR tape, being of half-hour duration, had been overwritten at the beginning of the event and recording effectively began 12 minutes after its onset. The DFDR and QAR both recorded in excess of 300 parameters, but the only one that related to the electrical problem encountered on the aircraft was 'lavatory smoke', a discrete parameter. At 1458 hrs, whilst passing FL240, this parameter changed to an indication of 'smoke detected' and this indication remained for the rest of the recording. No other alerts or warnings were recorded.

The ILS approach and landing (at 1527 hrs) were uneventful and the aircraft came to a halt on the runway. Both engines were shut down and the APU was started. This action cut power to the CVR, terminating the recording. Total flight time was 42 minutes.

Flight Deck Door

The flight deck door fitted to this aircraft was a 'Phase 1' door and since September 2001, it has been a CAA, and latterly a DfT (Transec) requirement that during flight, the flight deck door should be secured, in advance of the ICAO standard, effective November 2003. The policy of keeping the door secured during flight is strictly enforced but, during an emergency, the door may be opened at the commander's discretion, in order to enhance communication between the flight deck and cabin crews. However, such action could clearly compromise the security of the flight deck. Ultimately, it is the responsibility of the flight crew to assess the situation at the time and take what action they feel appropriate to best secure the safety of the aircraft. The door on G-DOCH was fitted with two 'peepholes', one allowing the pilots to look into the cabin and one allowing the cabin crew to look into the flight deck. Thus, in this instance, in the absence of any verbal communication, the cabin crew could at least check on the state of the pilots on the flight deck and the pilots, in turn, could check for signs of fire in the cabin. Faced with smoke from an undetermined source coupled with a failure of the cabin interphone system, the commander determined that his only option was to unlock the flight deck door and speak directly to the CSD.

All of the larger public transport aircraft registered in the UK are now fitted with a door that, amongst other changes, has been significantly strengthened; this is designated a Phase II door.

Checklist

Until October 2001 the operator used its own QRH, which had been evolved over several years of use within the fleet. The index for each of the non-normal procedures in this QRH was printed on the front cover with the title '*Smoke*' appearing in a bolder and larger type face than other titles on the index page, thus making it distinctive. Items that required immediate action from memory were contained in a clearly identified box at the start of each checklist. The single checklist for '*Smoke*' then guided the pilot to the appropriate procedure depending upon whether the smoke was suspected to be from either the air conditioning system or from an electrical source.

In October 2001 the operator adopted the QRH produced by the aircraft manufacturer, as part of an effort to standardise on the use of manufacturer supplied Operations Manuals and Handbooks. Again, the index was printed on the front cover but the title '*Smoke*' did not appear. Instead, the relevant checklists came under titles of either '*Unannounced Checklists*' or '*Fire Protection*'. Neither title led intuitively to the checklist for smoke events, and neither was prominent in the index, appearing as it did in the same size and style of font as the other titles. In addition, there were two separate checklists for smoke, one headed '*Air Conditioning Smoke/Fumes*' and the other headed '*Electrical*'

Smoke/Fumes or Fire'. Whilst the memory items were 'boxed' for the checklist related to electrically generated smoke, they were not for the check list related to air conditioning smoke.

The pilots stated that they had trouble locating the appropriate section in the QRH and expressed concern about how difficult it would be to read through and action effectively in a cockpit contaminated with a significant amount of smoke.

As a result of this incident the operator has revised the manufacturer's original QRH and the relevant checklists now come under the title of '*Smoke*' on the index page. This title is in large (20 pt) bold text and the associated numbered tab is printed in reverse print (yellow number on a black tab) to clearly differentiate it from other pages; checklists related to smoke should thus be easier to locate in a smoke filled environment. Memory Recall items for both smoke related checklists are now boxed and the typeface used throughout is larger than for other checklists, making them easier to read.

Damage to the aircraft

The visible damage to the aircraft was found principally in the area above the 'drop-down' ceiling panel immediately aft of the flight deck door, Figure 1, in the forward vestibule of the cabin: this panel is hinged on the left side and secured by two latches on the right side. There was also some scorching and sooting of this panel and around the top of the cockpit door frame.

Figure 1: Damaged loom and hose, G-DOCH



Figure 1 Damaged loom and hose, G-DOCH

Within this area, damage had occurred to a wiring loom where a braided steel hose had been secured by means of a single electrical 'tie-wrap' strap (the generic cable tie system formed of nylon-type UV-resistant material). It appeared that there had been abrasion and arcing between the wires and the hose, resulting in the severing and shorting of a number of the wires. The braided steel hose was lying against the frame of the ceiling panel and it appeared that there had also been electrical shorting to this portion of the airframe.

The hose involved was a water hose which supplied potable water from an aircraft connection in the crown of the fuselage, to the back of the No 1 galley; this was located at the right-hand side of the forward cabin. An area of this hose in which the steel braid appeared to have melted, was apparent, and at least two holes had been created in the PTFE inner hose, Figure 2, which resulted in the substantial water leak.

Figure 2: Damaged hose, G-DOCH

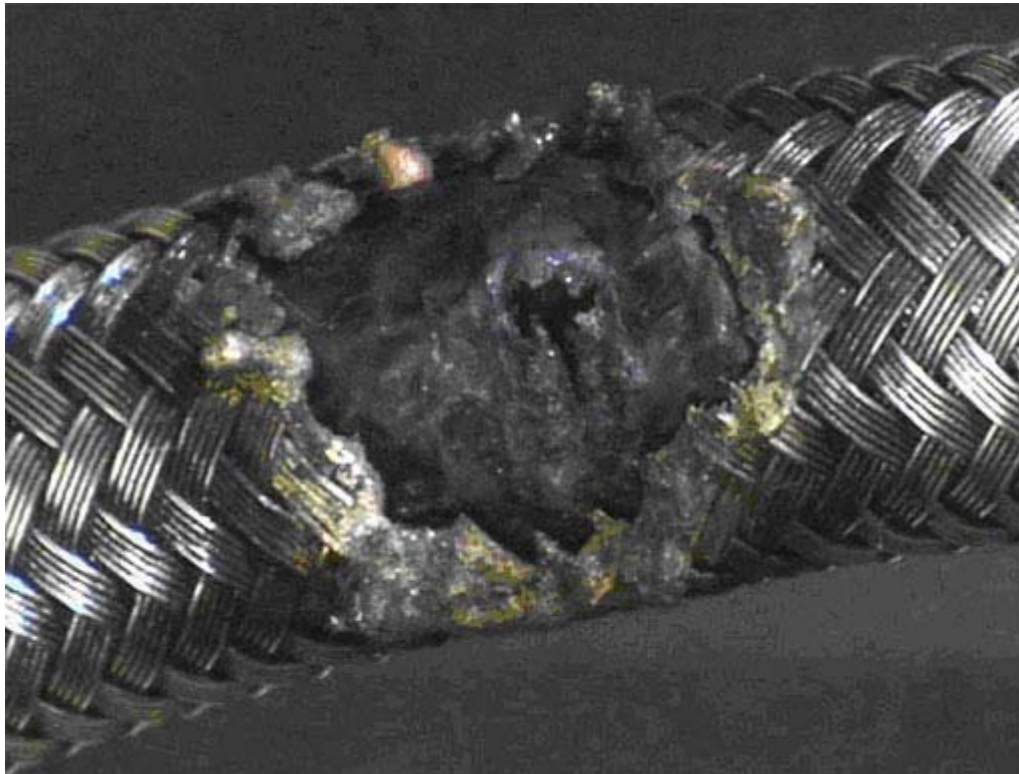


Figure 2 Damaged hose, G-DOCH

Comparison with a sister aircraft, G-DOCW, indicated that the hose was too long for this application and that the extra length in G-DOCH had been looped through this overhead area and then only secured by a tie-wrap to adjacent wire bundles. Part of the hose was protected by plastic spiral wrap but this did not extend to the portion of the hose in contact with the wire bundles.

Some 25 circuit breakers on the P18 panel in the flight deck were found to have tripped. These were principally circuits providing passenger services, such as cabin lighting, but included the cabin interphone system. It was considered likely that the lavatory smoke alert, recorded by the FDR, was due to the relevant circuit breaker having tripped.

Supply hose details

The water supply hose was removed from the aircraft for examination. The galley, Figure 3, was designed and manufactured by the JAMCO manufacturing company in Japan as buyer-furnished equipment (BFE), specified by the customer but fitted, in this case, at the time of the aircraft's manufacture.

Figure 3: Illustration from galley Component Maintenance Manual

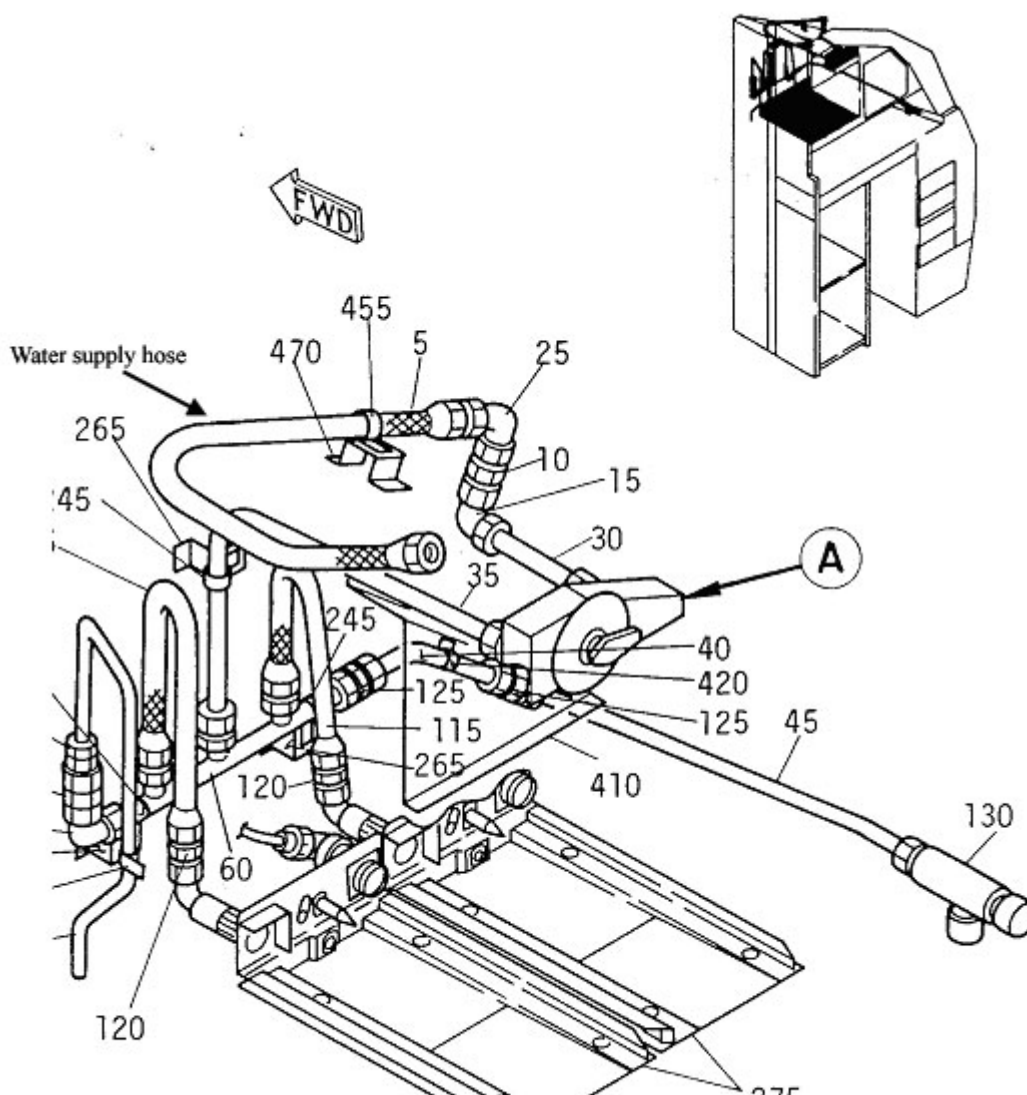


Figure 3 Illustration from galley Component Maintenance Manual

In this installation, the supply hose is considered to be a part of the galley unit and does not, therefore, appear in the aircraft Maintenance Manual. It was approximately 1,500 mm long and carried a band which designated its part number as 124027-8CR0593 (the last three digits of the part number (593) refer to its length in inches, ie, $59\frac{3}{8}$ inches = 1,510 mm), which was the hose part number as specified in the JAMCO component Maintenance Manual. This length, however, seemed excessive for the installation, especially when compared with measurements taken from other aircraft, which suggested that the required length should have been closer to 600 mm. From the parts stores records it was established that the hose was fitted to G-DOCH in August 1998 and that it had been manufactured by the Stratoflex Division of Parker Hannifin.

A review of the other 737-400 aircraft in this operator's fleet, all equipped with the same hose, showed that, in general, the excess length of hose had been accommodated by allowing it to lie looped behind the galley. Viewed from the area above the 'drop-down' ceiling panel, this extra length was not visible.

The same operator also flies the -300 and -500 version of the B737 aircraft and measurements were made of the actual and, approximate, required hose lengths on these models. This showed that the length needed between the aircraft and galley connections was some 500 mm greater in these aircraft,

Boeing 737-436, G-DOCH

than in the -400 aircraft, but that the hoses were only 1,170 mm in length, in comparison with the 1,510 mm found in the -400 aircraft. The length of the hose on G-DOCH was, therefore, much better suited to the operator's B737-300 and -500 aircraft.

As noted above, the water supply hose is part of the galley BFE and would have been specified as part of the design of that galley. As such, it would have been included in the reviews between the operator, Boeing and JAMCO, so that that the design would meet the specification from Boeing and comply with their interface and safety issues. This specification states that there should be six inches of slack in the supply line but neither Boeing nor JAMCO were aware that an over-long hose had been specified for the installation in the B737-400 aircraft.

Previous maintenance

G-DOCH received scheduled maintenance at Heathrow Airport over the period 25 to 27 September 2002, but there were no activities recorded in the area above the galley or the flight deck door. A review of ramp maintenance in the Technical Log over the preceding months showed two entries related to reports of water around the No 1 galley, but both of these were minor, easily rectified and could not be linked to the routing of the water supply line.

The maintenance input during which it was considered most probable that the water supply line was misrouted and attached to the electrical looms, was a major check at another maintenance station between 29 June and 15 August 2002. During this period, a number of structural inspections took place, which necessitated the removal of cabin furnishings, such as the No 1 galley. During the time of these structural inspections the galley was sent away for refurbishment.

Interviews were conducted with a number of the engineering staff involved in the maintenance work during the time the No 1 galley was refitted and the surveillance inspections carried out prior to the aircraft returning to service. The engineer who had removed the galley had performed this task a number of times previously and stated that he would always make the disconnection at the aircraft connection, and remove the hose with the galley, as this was the more accessible point. On the other hand, the engineers who had refitted the galley considered it more likely that the hose would have been disconnected at the galley end and thus the hose would have remained in the aircraft while the galley was being refurbished elsewhere. There was no apparent reason why it would have been necessary to secure the excess hose length by the use of electrical tie-wraps, but it was considered most likely that this occurred as a short-term, and unrecorded, expedient during disassembly of the aircraft interior. There was, clearly, variation in the way the disconnection of the water supply hose would be made prior to removal of the galley unit and one factor in this was that the Aircraft Maintenance Manual (AMM) did not state precisely how this should be done. The text stated:

'S 084-061

Disconnect the electrical power and water supply at the connections in the ceiling above the galley',

but the associated diagram, Figure 4, showing a generic galley unit, labelled the water connection as being on top of the galley and did not indicate any hose between this connection and the point in the aircraft ceiling at which it should be disconnected.

Figure 4: Illustration from aircraft Maintenance Manual

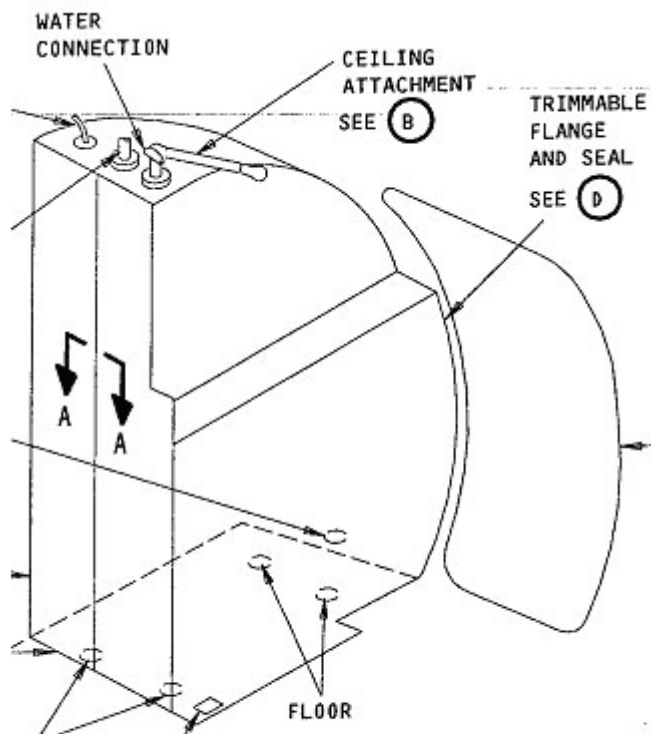


Figure 4 - Illustration from aircraft Maintenance Manual
Generic diagram identifying water connection. No information concerning supply hose or its method of installation

In summary, when the galley had been removed from the aircraft, it was not possible to identify positively whether the water supply hose had been disconnected at the aircraft connection or at the galley.

Detail examination - hose and electrical wires

An analysis of the cable and hose failures was commissioned by the AAIB from ERA Technology, an organisation with expertise in electrical and power system failure investigations. Their work included optical, Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) examinations of the components and a series of calculations. These calculations were performed to determine the order of magnitude of the energy released during the arcing events and also to determine the current required to melt the conductors without arcing.

The calculation of the energy released during the fault arcing was made from an estimate of the amount of metal (steel braid and copper conductor) melted. A number of simplifying assumptions were made and it was acknowledged that the total energy release calculated by this method (1.8 kJ) would certainly be an underestimate. For instance, the process was assumed to be adiabatic, some of the cables had only one melted end and there was no account for metal heated above its melting point, or even vaporised. The probable current involved was also estimated, based on event times of 1.0 sec and 0.1 sec.

The analysis indicated that the probable sequence of failure was that one or more wires chafed against the steel braid of the water hose. The wire's insulation was worn through to the point of establishing an arcing fault with the steel braid portion of the hose, which is effectively earthed at both ends, and this initial arcing would have damaged the insulation on surrounding conductors. The process of arcing would then spread through the bundle. The arcing on some conductors would then stop, either due to the circuit breaker tripping or melting of the conductors. It is also possible that arcing may have stopped at some stage and then restarted as some movement occurred between wires with damaged insulation. Polyimide (Kapton) was used for the insulation on some of the wires and this, when subjected to arcing, will degrade to produce conductive carbon, allowing additional tracking paths to be formed ('carbon-arc tracking'). This could have contributed to the spread of the fault within the wiring bundle.

Circuit breakers

The investigation by ERA also considered the effect of this arcing mechanism on the circuit breakers for the wires involved. The specification for the circuit breakers identifies them to be of the 'thermal trip' type, where the circuit breaker is tripped, and the electrical circuit broken, by heat generated within the breaker from the current in excess of the rating. The specification includes a set of limits for time and current: this is most suitable for a 'solid' and continuous short-circuit but less reliable for arcing faults, where high currents, insufficient to trip the circuit breaker, may exist for very short periods. For instance, currents required to operate the breaker within one second could be between three and six times the rating of the device being served by the wires.

Operational analysis

General

The flight crew was presented with a situation where smoke was present on the flight deck whilst they were unable to communicate with the cabin crew. They had problems in locating the appropriate checklist since it was not clearly identified on the index page, but in the absence of any significant smoke they were able to complete the drill effectively. Afterwards the flight crew expressed concern about how difficult it would have been to read through the non-normal procedure in an environment filled with smoke. Smoke on the flight deck should have an associated checklist that is easy to locate and follow, even in a smoke filled environment.

In the event of smoke or fire in the air the commander should accomplish a landing at the nearest suitable airfield unless he has positively determined that the smoke has been eliminated and the fire has been extinguished. In this instance the commander believed that the source of the smoke had been identified and that there was no longer a fire. He therefore decided that his best option was to return to Heathrow rather than brief for an instrument approach, in poor weather, at an unfamiliar airfield.

Unbeknown to the commander, his decision to return to Heathrow rather than accept a diversion to Stansted created significant problems for ATC. Nevertheless, ATC complied fully with the commander's request and organised a safe and expeditious recovery. A brief telephone conversation between ATC and the commander or operator, after such events, would serve to keep both sides aware of the problems involved and resolve any misunderstandings that may arise.

Diversion

The commencement of the diversion was delayed by the crew's desire to have a full understanding of the situation before deciding upon a course of action. It was indeed only a suggestion from ATC four minutes after the onset of the incident that induced the FO to accept a turn back towards Stansted. At this point the aircraft was about 55 nm due east of Stansted. When the commander returned to the flight deck and requested a diversion to Heathrow some five minutes later they were advised that they were then 80 nm from touchdown at Heathrow.

Despite the aircraft being considerably closer to Stansted the commander stated that he chose to return to Heathrow because it was their home base and both pilots were familiar with the procedures. Neither pilot was familiar with Stansted and, with low cloud cover over the area, a more thorough briefing for the instrument approach would have been required. All indications were that the fire was out and with the communication problems being experienced it made sense to reduce their workload where possible. It did however leave the aircraft vulnerable should fire have unknowingly spread or re-ignited, and it also resulted in the aircraft over-flying London prior to landing.

Air Traffic Control

The initial diversion was commenced four minutes after the start of the event at the suggestion of the ATC controller. Had this suggestion not been made, it is conceivable that the diversion would not have commenced until after the return of the commander to the flight deck, some five minutes later. The controller then advised the FO of the proximity of the nearest suitable airfield and gave him vectors towards it, as well as advising him of a suitable descent point. In the absence of the commander, the FO was happy to accept a turn towards Stansted but was unwilling to commence a descent. On returning to the flight deck and having suitably assessed the situation the commander then declared a "MAYDAY" and requested a diversion to London Heathrow. ATC accepted this without question and provided vectors and descent guidance to the new diversion destination, thereby considerably reducing the pilots' workload.

However, the handling of the incident posed problems for ATC. Controllers are trained to appreciate the dangers associated to aircraft from onboard fires and to advise crews of the nearest achievable airfield. The original call from the crew of G-DOCH, announcing they had a problem was clearly made with the crew wearing oxygen masks and the controller expected that the aircraft was likely to require an immediate landing. To the controller the suggested diversion to Stansted was achievable and its acceptance by the FO logical. There was surprise, therefore, when some five minutes later the crew made a further call, this time without the use of oxygen masks, requesting a diversion to Heathrow. Considerable work had already gone into co-ordinating an unimpeded descent for an expeditious approach to Stansted.

At the time, there was a holding period of between 30 to 45 minutes for aircraft landing at Heathrow. In itself, the volume of traffic did not cause any particular concern to ATC but any increase in the complexity of dealing with this traffic represented, to them, an increase in risk. This is because they were now not only having to co-ordinate an unimpeded approach for G-DOCH to Heathrow, but they were also having to deal with other inbound aircraft diverting due to the significant increase in holding time that resulted. There can be no doubt that ATC acted correctly throughout, offering practical assistance and accepting crew requests without question. Without being aware of the true situation on board the aircraft there was, however, an atmosphere of some scepticism as to why the crew had chosen to reject Stansted in favour of a diversion to their home base of Heathrow.

This incident is a reminder that the handling of emergencies can create additional risks, increasing as it does the complexity of controlling traffic in an already busy airspace. Current ATC training enables the controllers to provide suitable assistance to flight crews but ultimate control over decisions must lie with the flight crew since only they are fully aware of the on-board situation.

In-flight communications

Communication played a key role in the handling of this incident. Following the terrorist attacks on aircraft in the USA on 11 September 2001 flight deck doors on the larger UK registered, public transport aircraft have been reinforced and strict procedures have been adopted to ensure that they remain secured during flight. This response, however, introduced additional problems related to communication between the flight deck and the cabin, in this incident, as the interphone system was rendered unserviceable by the damage to the wiring. Having discovered smoke and other indications of burning both the flight crew and cabin crew were initially hampered in their efforts to deal with the incident promptly due to their inability to communicate with each other across the locked flight deck door.

Analysis of recorded data shows the incident probably commenced at 1458 hrs. However, it was a further four minutes before any effective communication could be established between the flight deck and the cabin. Whilst some of this time was taken up in completing the appropriate non-normal checklist, the inability to communicate led to a feeling of isolation and urgency on both sides of the locked door. During this time neither the flight crew nor the cabin crew could ascertain the true extent of the problem and therefore did not know whether their initial actions had been correct.

This in turn led to a delay in declaring an emergency to ATC. The first report made to ATC, two minutes after the smoke was first identified, described simply a "technical problem". Only after being prompted by ATC four minutes after the event, and in the absence of the commander, did the FO declare "an emergency". However, it was not until the commander's return to the flight deck some nine minutes after the event that a full "MAYDAY" was declared. Had either the interphone been working or the flight deck door not been locked then there is little doubt that the decision to declare an emergency and commence a diversion could have been made considerably earlier.

Effective communication between the cabin crew at either end of the cabin and between the cabin crew and passengers, was further hampered by the failure of the cabin interphone. Whilst a loud hailer was available, the CSD considered that briefing the passengers personally would be more effective since some of the passengers had a poor understanding of the English language. The cabin crew subsequently stated that the use of the company's standard procedures had been valuable, since

each person knew exactly what they had to do and this significantly reduced the need for additional communication.

When the smoke initially appeared on the flight deck the pilots had correctly donned their oxygen masks. The commander's decision to subsequently remove his mask had been driven by the uncertainty that his oxygen hose was long enough to allow him to reach the flight deck door. (It has subsequently been demonstrated that both pilots' oxygen hoses were indeed long enough to allow them to reach the door.) It was only on his return from the cabin that he considered it safe for both pilots to dispense with their masks. Although the oxygen masks allow communication between each pilot and with ATC, such communications are awkward. It is therefore understandable that the commander wished to be without this extra limitation, especially considering the other communication problems prevalent at the time. There is, however, a significant risk when breathing, without protection, in an atmosphere that has been contaminated by smoke or fumes of an unknown nature¹. Even a low concentration of contaminants might lead to impaired performance and potential incapacitation, although no ill effects were apparent on this occasion.

Finally, the commander also reported that he had been concerned as to whether the public address system and emergency evacuation alarm were still operable from the flight deck. With his over-riding priority being to complete an expeditious diversion he did not have the time or opportunity to test them, but was mindful of the potential problem of initiating an evacuation should neither be working when required.

¹ This subject is addressed in AAIB Aircraft Accident Report 1/2004

Engineering analysis

In this particular instance there were three principal causal factors for the initial shorting around the overhead wire loom in G-DOCH. These were:

- the excessive length of the steel braided water hose to the forward galley
- the lack of an established routing or restraint of this extra hose
- the unexplained securing of this hose to the electrical loom

Despite an extensive series of interviews with maintenance personnel, it could not be determined how or when the hose came to be attached to the electrical loom. It is most likely that it occurred during the period of maintenance from 29 June and 15 August 2002 and that the attachment was simply a short-term expedient while systems were being disconnected and disassembled, and that the 'temporary' tie-wrap was then missed during reassembly.

In each of these three cases (excessive length, informal routing, inappropriate securing), the hazard created was inadvertent and in each case there existed, in principle, a procedure to avoid this type of hazard. In principle, the interface documents between the airframe manufacturer and the suppliers of customer-specified equipment (such as galleys) should have prevented the JAMCO galley being supplied with a hose of excessive length. In principle, the quality processes of the maintenance organisation should have identified the hazard consistently posed by the excessive hose length and the lack of routing or restraint; the same quality processes should, in principle, have prevented the securing of the water hose to the electrical loom and identified the hazard after it occurred.

However strenuous the efforts to avoid these design and maintenance quality lapses, their essentially random natures make them very difficult to eliminate. This has been apparent in the AAIB investigations of a number of recent accidents and serious incidents, where a range of circumstances have led to electrical arcing failures, where conventional circuit-breakers have not tripped. The approach of reducing or eliminating the hazardous effects of these failures by the introduction of some form of 'intelligent' circuit-breaker, has been pursued, but a number of factors, including cost and the lack of a mature technology has, so far, generally prevented this solution being carried forward to Civil Air Transport aircraft.

Safety Recommendations

The flight crew were presented with a situation where smoke was present on the flight deck whilst being unable to communicate with the cabin crew. They had problems in locating the appropriate checklist, since it was not clearly identified on the index page of the QRH, and they had concerns that it would not have been possible to accomplish this had the flight deck been filled with smoke. Subsequent action by the operator has addressed these issues but in order to widen the safety action to include other operators the following safety recommendation is made.

Safety Recommendation 2004-16

It is recommended that the Boeing Commercial Airplane Company review the B737 non-normal checklist for 'Smoke' to ensure that the procedure for smoke on the flight deck is unambiguous and clearly identified in order to give flight crews the best opportunity to locate it in conditions of low visibility.

In response to this recommendation, the manufacturer has stated that they recognise there are issues with the current checklist(s) for smoke identification and resolution. As such, they are currently conducting an in-depth review and are applying human factor research to improve the checklist selection via the indexes in the QRH.

There is no positive evidence as to whether the galley illustration in the airframe Maintenance Manual, Figure 4, was used as reference in the disconnection of the water hose in G-DOCH. The illustration does, however, have the potential to mislead in suggesting that the connection is made adjacent to the galley unit rather than at the interface with the aircraft water system in the crown of the fuselage. The following recommendation is therefore made:

Safety Recommendation 2004-17

It is recommended that the Boeing Commercial Airplane Company review the illustration and text material of the Maintenance Manual relating to the installation of the forward galley installation in the B737-400, and any other affected model, to give clear instruction as to where the galley water supply hose disconnection should be made when removing the galley.

In response to this recommendation, the manufacturer has made the following comments:

Due to the wide variety of installations of the subject galley (for example, the operator of G-DOCH has some six different installations in their B737-300/400/500 fleet alone), the water lines are unique for each galley installation. The manufacturer's main concern, therefore, has been to ensure the proper removal/installation of each galley in accordance with intended fit and function. As such, it has been acceptable for maintenance personnel to disconnect the water hose from any fitting in the system that is appropriate for a particular installation. Thus, the AMM instructions are often generic in nature for this type of application. However, the manufacturer plans to review this hose installation to ensure the security of the extra length of hose and validate any necessary changes to the galley installation and/or its procedures. This review will include the necessary specific instructions for securing the extra length of hose, or consider alternative solutions.

This incident has highlighted airworthiness issues which reflect broader concerns on all aircraft types regarding wiring condition, particularly as aircraft age, modifications are introduced and maintenance carried out. These broader concerns are addressed in the overview document included in this issue of the AAIB Bulletin.