

AAIU Report No.:2003-002

AAIU File No.: 2002/0008

Published:

Operator:	World Airways
Manufacturer:	Mc Donald Douglas
Model:	DC10-30
Nationality:	U.S.A
Registration:	N 526 MD
Location:	Shannon, Co.Clare, Ireland
Date/Time (UTC):	14 Feb. 2002 17.02 hours

SYNOPSIS.

The cargo aircraft was in a descent to Shannon and was about 10 minutes out when the yellow smoke caution and the Captains “master caution” light illuminated in the cockpit. The No.2 pneumatic manifold failure light then illuminated quickly followed by a cargo area fire warning light and Captains master fire warning light. The Captain declared an emergency and ATC notified the Airport Fire Services. As the aircraft came to a halt on Runway 24 (RWY 24) it was met by sections of this Service. Immediate evacuation of the crew of the aircraft and two passengers was made using a crash rescue ladder and exiting through the front LH door. When the smoke cleared it was found that the air bleed duct of the No.2 engine had ruptured and the impinging hot air charred the insulation, generating the smoke in the process. There were no injuries.

1. FACTUAL INFORMATION

1.1 History of the Flight.

At approximately 16.55 hours and about 10 minutes to landing at Shannon, a Main Deck Cargo smoke light No.9L and the Captains master caution light illuminated in the cockpit. The Captain called for a cargo smoke checklist and for oxygen masks and smoke goggles to be donned. He then requested a fire services turnout and a “shorter finals” was expedited from ATC. At 16.57 hours the crew declared an emergency. The aircraft was positioned for a five-mile final approach and given further immediate descent. The Flight Engineer then went out to ask the two passengers to don oxygen masks. As the crew were running the checklist another light illuminated indicating that the No.2 pneumatic manifold system had failed. Within two minutes main deck cargo smoke lights No. 4 to No.12 illuminated. Whilst the crew were running the second checklist for the manifold failure, the Lower Forward Cargo Fire Warning light and the Captains “master warning” light illuminated. The crew discharged fire-extinguishing agent in the forward cargo area as the third checklist was running. There was a heavy amount of smoke in the upper deck area and moderate smoke in the cockpit. The aircraft landed on RWY 24 and came to a halt on that runway at Taxiway Alpha.

The crew prepared for an emergency evacuation and called for stairs to be brought to the aircraft. The aircraft was met on landing by 7 sections of the Airport Fire Services and 2 sections of the local fire brigade. A crash rescue ladder was raised to the front left hand door where the crew and passengers evacuated the aircraft. The members of the Fire Service entered the aircraft and used heat-seeking devices to check the cargo pallets. As the smoke cleared, the cause of the smoke was not immediately obvious. The runway was closed for a short time following this incident.

In a fault finding procedure conducted later on, it was discovered that the smoke reappeared when the APU was switched on and run for some time.

1.2 Injuries To Persons

There were no injuries to crew or military personnel.

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor	0	0	0
None	3	2	

1.3 Damage To Aircraft

Fault-finding revealed the source of the smoke to be the degeneration of the white insulation around the air pressure duct coming from the No. 2 engine at a point adjacent to the rear bulkhead. The duct was found ruptured at this point, causing hot air at pressure to exit the duct, impinge on the insulation, char the insulation and the resulting smoke leak into the cargo areas. A missing section of the duct measuring 3 X 1 inches was blown out at the rupture and was not recovered.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information:

1.5.1 PF (Commander)

Personal Details

Licence:	USA ATP-DC-10
Last Periodic Check:	12 Nov. 2001
Medical Certificate :	6 Feb.2002

Flying Experience:

Total all types:	8500	hours
Total all types PI:	5000	hours
Total on type:	6500	hours
Total on type PI:	2000	hours
Last 90 days:	150	hours
Last 28 days:	50	hours
Last 24 hours:	5	hours

Duty Time:
 Duty Time up to incident : 6 hours
 Rest period prior to duty : 31 hours

1.5.2 PNF (Captain Under Training)

Personal Details

Licence: ATP DC-10
 Last Periodic Check : 1 June 01
 Medical Certificate : 10 Dec. 01

Flying Experience:

Total all types: 14095 hours
 Total all types PI: 8838 hours
 Total on type: 46 hours
 Total on type PI: 0 hours
 Last 90 days: 58 hours
 Last 28 days: 46 hours
 Last 24 hours: 5 hours

Duty Time:

Duty Time up to incident: 6 hours
 Rest period prior to duty : 19 hours

1.6 Aircraft Information

1.6.1 The Operator took delivery of this aircraft on 13 May 2001. The conversion of the aircraft from a passenger aircraft to a cargo aircraft had already been accomplished in Singapore on 10 Oct 2000.

Aircraft type	DC-10-30F
Manufacturer	Mc Donald Douglas
Constructor's number	46998
Year of manufacturer	20 Dec. 1978
Certificate of registration	N 526MD, 10 May 2000
Certificate of airworthiness	DART 505005NM, 9 Sept. 2000
Total airframe hours	66,167 hours
Total cycles	15,515 hours
Engines	3 X CF6-50C2
Maximum authorised take-off weight	572,000 lbs
Actual Take off weight	572,000 lbs

1.6.2 General information on smoke, heat and fire detection.

- The main deck cargo compartment smoke detection system of this aircraft consists of 12 standard smoke detectors in the ceiling throughout the length of the compartment. Any individual detector will actuate the smoke caution system when smoke is detected.
- The Pneumatic Manifold Failure system is comprised of a number of strategically placed temperature sensors. These sensors surround the outside of the actual duct. When there is a duct rupture the surrounding temperatures increase dramatically, thereby triggering the Pneumatic Manifold Fail warning. There are other Pneumatic Temperature sensors inside the duct, which are displayed on the Pneumatic Temperature instrument on the Flight Engineer's panel.
- The forward lower cargo compartment fire detection system consists of four (4) smoke detectors in the compartment ceiling and one (1) heat detector in the ventilation exhaust duct. Any individual detector will actuate the fire warning system when smoke or heat is detected. The air flow in the lower cargo compartment is from rear to front, the air enters the Rear Cargo Compartment passes to the Forward Cargo Compartment and then exits the aircraft.. So all the smoke, and heat, would have to pass into the forward compartment before leaving the aircraft.

The Manifold Failure Procedure includes:

- (a) shutting off the affected pneumatics supply selector
- (b) closing the affected isolation valve
- (c) turning off the affected pack selector.

If after this, the pneumatics pressure is greater than 10 psi, a secondary failure is indicated. In such a case, conditions permitting, reduce the associated engine thrust to idle.

However, if the affected system is from No.2 engine (rear), the following note in the procedure suggests the engine be shutdown. *"If pneumatics pressure decreases to 10psi or less and manifold fail light remains illuminated, engine shutdown or power reduction is not required."*

1.7 Meteorological Information

1.7.1 Met Eireann, the Irish Meteorological Service, provided the following information after the incident.

General Situation: A complex low pressure system south of Greenland and a large anticyclone southwest of Ireland maintained a southwest to west airflow over the area. A warm front had passed through the northern part of Ireland during the 14th February 2002, causing an increase in dewpoint in the northwest of Ireland. Further south dry anticyclonic conditions prevailed.

Wind: 2000 feet: 25010 KT

Surface: 24004 KT

Visibility: 10 km

Weather Nil

Cloud: FEW 025

Temperature/ DP 09°C/01°C

Pressure: 1034 hPa (MSL)

1.8 Aids to Navigation

Not a factor

1.9 Communications

The following Shannon frequencies were used:

Approach: 121.4

Tower: 118.7

Ground Fire Crew: 121.8

1.10 Aerodrome Information

Shannon Airport is a Category 9 airfield. RWY 24/06 is 3200 metres long by 45 metres wide, with an available landing distance of 3060 metres. The elevation is 46ft AMSL.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The aircraft was equipped with a Sundstrand Cockpit Voice Recorder (CVR). Part No.980-6020-001. This recorder was not removed from the aircraft as part of this Investigation.

1.11.2 Flight Data Recorder

The aircraft was equipped with a Sundstrand Flight Data Recorder (FDR). Part No.980-4700-001. This recorder was not removed from the aircraft as part of this Investigation.

1.12 Wreckage and Impact Information

There was no wreckage following this incident

1.13 Medical Information

The crew and passengers were examined by a doctor following the incident.

1.14 Fire

There was no evidence of fire aboard the aircraft. The Captain reported a heavy amount of smoke in the upper deck area on landing.

1.15 Survival Aspects

Seven crash rescue vehicles from the Airport Fire Service and two from the local authority met the aircraft as it came to a halt. They put up a ladder to the front LH exit and the crew exited the aircraft. The rescue team used heat seeking devices to ensure that the cargo was not the source of the heat. The Captain praised the personnel of Shannon ATC for their help during this incident and their prompt responses to his requests during the descent, approach and landing on RWY 24. On immediate landing, the Captain was able to speak to the crash rescue service directly on their ground frequency and said that this helped to allay their anxiety as they immediately confirmed the absence of any visible on-board fire.

1.16 Tests and Research

A one foot length of the duct incorporating the rupture was sent to the aircraft manufacturers for material testing.

They carried out the following tests:

- (a) Visual Evaluation.
- (b) Bend Test.
- (c) SEM Analysis.
- (d) EDS Analysis.
- (e) Fourier Transform Infrared Analysis (FTIR).
- (f) Chemistry.
- (g) Dimensional Measurements.
- (h) Tensile Tests.

The following is a summary of the above test results:

The missing 3x1 inch piece became detached when circumferential and longitudinal cracks intersected. A sample of the duct material in the vicinity of the rupture snapped with very little deflection indicating brittleness. A majority of the fracture surfaces were oxidized or attacked by etchant (decomposed hydraulic fluid). Tests showed that the duct was embrittled from the outside.

The presence of high concentrations of titanium, oxygen and phosphorous were confirmed in the etched area on the outside of the duct. The charred area of the outside of the duct contained high concentrations of phosphorous, oxygen and silicon, the latter having come from the insulation material. The black charred residue, when analysed by FTIR, had contained evidence of a presence of a hydraulic fluid. The area around the rupture contained significantly more hydrogen than the material specification allowed, whilst away from the rupture the hydrogen content was below the maximum allowed. The material thickness at the rupture area was only 40% of that existing elsewhere.

Finally, material in the vicinity of the rupture suffered a loss in elongation when compared to material taken from the other side of the duct.

The Manufacturer concluded:- *“the duct failed by hydrogen embrittlement which was caused by the presence of decomposed hydraulic fluid. The material thickness in the area of the failure was reduced by etching which weakened this particular area allowing operating pressure to bulge and overload the reduced material cross-section. No manufacturing defects were noted”*.

1.17 Organizational and Management Information

The aircraft had the number 302 painted on the nose undercarriage door whilst the aircraft registration number N526MD was painted on the fuselage. The operator said that 302 was an internal “ship number” and was for internal company use only. However, it was stated that this policy was under review and a change was anticipated.

1.18 Additional Information

The hydraulic fluid, specified by the aircraft manufacturers for use in this aircraft, offers high temperature thermal stability and component reliability, density, toxicity and paint compatibility. It has met the performance demands of commercial aircraft and is approved by all airframe manufacturers specifying phosphate ester hydraulic fluids

However, the fluid manufacturer states in the product specification that the use of the fluid in contact with titanium is not recommended for service at elevated temperatures greater than 163° C. They state that hydrogen embrittlement will occur from the phosphate ester fluid.

The aircraft manufacturers also stated that the fluid becomes highly acidic when heated and is known to eat through ceramic fibre insulation and titanium ducts. As a rough estimate, they said they would expect significant degradation in duct material in anywhere from several days to a couple of weeks for a duct at 350 deg F to 450 deg F exposed to a relatively slow dripping phosphate ester fluid.

Hydraulic lines are located inside the fuselage on each side of the aircraft for the purposes of separated redundancy. Some are not far from the ducting in question. However, they would normally expect the insulation wrapping around the duct to prevent hydraulic fluid intrusion into the insulation.

The insulation is essentially a fibreglass batting with a fluid-proof silicon-rubber wrapping. According to DC-10 Service Bulletin 25-368, blankets installed in areas subject to high temperatures or chemical contamination are fabricated entirely from silicone materials or from silicone materials in combination with other materials.

In normal operation, the maximum duct temperature would be approximately 450 degrees F. In certain failure modes of the pneumatic system the temperature might reach 500 degrees F for very brief periods.

2. ANALYSIS

The lab tests conducted by the manufacturers found that the duct rupture was due to hydrogen embrittlement which was caused by etching due to the presence of decomposed hydraulic fluid.

It is not possible to say how the hydraulic fluid came to be in contact with the outside of the titanium duct. It is likely that at some stage, probably during servicing, the hydraulic fluid escaped from an adjacent hydraulic pipe and spilled on to the duct insulation where it got trapped between the duct and the insulation.

The heat from the duct would also hasten the onset of the embrittlement until the wall of the duct became so thin that it was no longer able to contain the duct gases under pressure.

During this incident the three smoke, heat and fire warnings illuminated in quick succession. The crew followed the Operating Manual instructions for “Cabin Cargo Smoke Light On” by running the appropriate checklists. The crew donned their smoke goggles and oxygen masks in accordance with the checklist, but hardly had time to run the checklist when the other warning lights illuminated.

If the incident had taken place further out in the Atlantic, time would have allowed trouble shooting to identify the source of smoke and heat. As it was, the pneumatic manifold warning system indicated an over-temperature manifold duct associated with the No.2 engine. However, that said, the crew were fortunate to be so close to their destination.

3. CONCLUSIONS

3.1 Findings

- 3.1.1** The aircraft and crew were properly certificated for the flight.
- 3.1.2** The aircraft had been correctly maintained in accordance with the appropriate schedules.
- 3.1.3** The flight crew followed the correct procedures laid down in the Flight Crew Operating Manual.
- 3.1.4** As was commented by the Captain, the Air Traffic Control and Shannon Airport Fire Services combined most efficiently to bring this incident to a safe conclusion.

3.2 Causes

The cause of the duct rupture was due to hydrogen embrittlement which in turn had been caused by the presence of a quantity of decomposed hydraulic fluid

4. SAFETY RECOMMENDATIONS

- 4.1 The aircraft manufacturer should use their internet based system to advise operators of DC10 and MD 11 aircraft, having titanium ducts, of the relevant and pertinent information contained in this report. **(SR 3 of 2003)**

Note: *The manufacturers have offered to send an all-base message to operators to inform them of the circumstances of this event. In addition, the manufacturers said that they were tracking this internally and may or may not develop some sort of action other than the above recommended advisory.*