Engine failure, McDonnell Douglas MD-88, March 15, 2001

Micro-summary: This McDonnell Douglas MD-88 experienced a failure of the #2 engine during takeoff.

Event Date: 2001-03-15 at 1239 MST

Investigative Body: National Transportation Safety Board (NTSB), USA

Investigative Body's Web Site: http://www.ntsb.gov/

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3. Reports may or may not represent reality. Many many non-scientific factors go into an investigation, including the magnitude of the event, the experience of the investigator, the political climate, relationship with the regulatory authority, technological and recovery capabilities, etc. It is recommended that the reader review all reports analytically. Even a "bad" report can be a very useful launching point for learning.

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National Transportation Safety Board

FACTUAL REPORT AVIATION

NTSB ID: LAX01IA118	Aircraft Registration Number: N996DL
Occurrence Date: 03/15/2001	Most Critical Injury: None
Occurrence Type: Incident	Investigated By: NTSB

Location/Time

Nearest City/Place	State	Zip Code	Local Time	Time Zone	
Tucson	AZ	85706	1239	MST	

Airport Proximity: On Airport	Distance From Landing Facility:	Direction From Airport:

Aircraft Information Summary

Aircraft Manufacturer	Model/Series	Type of Aircraft
McDonnell Douglas	MD-88	Airplane

Sightseeing Flight: No Air Medical Transport Flight: No

Narrative

Brief narrative statement of facts, conditions and circumstances pertinent to the accident/incident:

HISTORY OF FLIGHT

On March 15, 2001, at 1239 mountain standard time, a McDonnell Douglas MD-88 twin turbo-fan airplane, N996DL, experienced a loss of right engine power during takeoff from the Tucson International Airport, Tucson, Arizona. The airplane sustained minor damage; however, the 2 crewmembers, 3 flight attendants, and 96 passengers were not injured. The airplane was registered to and operated by Delta Air Lines, Inc., Atlanta, Georgia, as flight 1634, a scheduled domestic passenger flight, under the provisions of 14 CFR Part 121 when the incident occurred. The flight was originating in Tucson at the time of the incident and was scheduled to terminate in Cincinnati, Ohio. Visual meteorological conditions prevailed and an instrument flight rules (IFR) flight plan had been filed and activated.

According to the captain's written statement, he first felt a vibration at VR (rotation speed) during the takeoff roll from runway 11R. The crew then noted a loss of right hydraulic system quantity and pressure. The captain conducted a turn to downwind while the first officer performed the right hydraulic system failure checklist. During the turn to downwind the amber "reverse thrust unlock" light for the right engine flickered, followed by a steady illumination of the right engine's blue "reverse thrust on" light. The captain brought the right engine to an idle power setting. He reported the N1 (low rotor rotation speed), N2 (high rotor rotation speed), and exhaust gas temperature (EGT) gauge readings appeared normal; however, the engine pressure ratio (EPR) was reading low. The flight crew declared an emergency, performed an abbreviated landing checklist, and landed the airplane on runway 11L at 138,000 pounds gross weight. Touchdown was accomplished at an indicated airspeed of between 120 and 130 knots, and with a final rate of descent of less than 360 fpm.

The captain used the number one engine thrust reverser along with asymmetric braking to slow the airplane while both main landing gear doors dragged along the runway. During the braking process he attempted to maintain runway alignment with the nose wheel tiller until he was able to bring the airplane to a stop on the runway. After the airplane came to a stop, the flight crew secured the right engine, and the airplane was towed to the gate. The passengers deplaned via the jet way.

The first officer's written statement was similar to that of the captain's.

The lead flight attendant's statement indicated as the airplane was on takeoff roll, she received a call from one of the flight attendants seated near the aft end of the airplane. The aft-seated flight attendant requested that the lead attendant call the captain to report vibrations in the airplane's aft end. She added the vibrations were making it difficult to stay on the flight attendant jump seat. The airplane was beginning to rotate when the lead attendant contacted the flight crew. The flight crew requested that the lead attendant check out the vibration. As the lead attendant proceeded to the aft end of the airplane, she heard and felt the vibration as she

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passed row 15. It increased significantly the further aft she went. She reported her observations to the flight crew, but was told to stand-by as the flight crew completed a checklist. The flight crew then reported they were returning to the gate and made several public announcements (PA) for the passengers to remain seated. The lead attendant then heard a rough sputtering noise shortly after the first PA, and assumed the engine was being shutdown. She added the landing was smooth, but it "seemed forever before we stopped."

The flight data recorder (FDR) was removed from the airplane and shipped to the National Transportation Safety Board Vehicle Recorder Laboratory, Washington, D.C., for readout. The following information was extracted from the FDR factual report. During takeoff (1239:25; release of brake pressure was used as the start of the takeoff roll), the EPR was set at 2.08, and the hydraulic system depicted a "normal" situation. At 1239:36, the right engine's EPR began to decrease from its takeoff setting. At 1239:38, the air/ground squat switch changed from a "ground" indication to "air." At 1240:43, the FDR recorded low hydraulic pressure for the right side system. Throughout the entire event, the FDR recorded the left and right thrust reversers/thrust reverser locks to be in the stowed/unlock position, with the exception of the landing sequence (1248:52 - 1249:13), when both the left and right thrust reversers/thrust reverser locks were deployed and unlocked.

AIRCRAFT INFORMATION

The airplane was equipped with two Pratt & Whitney (P&W) JT8D-219 turbofan engines. The JT8D-219 engine is of a dual-spool design, with the low pressure compressor (LPC) and high pressure compressor (HPC) rotating independently of each other. The LPC drive shaft (connecting the low pressure compressor to the low pressure turbine) is located coaxially within the HPC drive shaft (which connects the high pressure compressor to the high pressure turbine). The LPC drive is supported within the HPC shaft via a roller bearing (No. 4 1/2 bearing).

The number 2 (right) engine (serial number 725394) was on a 50-cycle continue-in-service limit for fractured 4th stage turbine blade shroud/shrouds (Internal Engineering Notice, IEN 00HCC12). According to Delta, at the time of the incident, the engine had accumulated 13 cycles of the 50-cycle limit.

The engineering notice addressed several P&W JT8D-217C and 219 series engines that were found with broken 4th stage turbine blades. The notice indicated that all of the broken blades were found during routine torque check inspections or routine maintenance, and none were found as a result of operational discrepancies. According to the IEN, the blades were found fractured at the "convex side airfoil-to-shroud fillet radius, which liberated the convex portion of the shroud." The cause of the failures had been determined and a new shroud was being designed/manufactured; however, was not available at the time of the event. In the interim, maintenance personnel, who found broken blades, were to adhere to a field management plan, which placed a 50-hour continue-in-service limitation that allowed for no more than two fractured shrouds that had to be at least 10 blades apart.

The No. 2 hydraulic system consists of a single-stage hydraulic pump that produces 3,000 psi. The system's fluid capacity is 11.36 gallons. The number two hydraulic system exclusively operates the airplane's main landing gear, aft air stairs, number two thrust reverser, outboard spoilers, and the number one and three flap actuators.

WRECKAGE AND IMPACT INFORMATION

The airplane/right engine area was examined the same day as the incident by Delta Air Lines maintenance personnel. The post flight inspection of the number two engine revealed there were several breaks in the pressure tailpipe (PT7) line (which also supplies EPR data), the thrust reverser position switch was displaced, and the fire warning indicator light wiring was separated.

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The number two engine tail cone was missing; however, all the attaching bolts were undamaged and in place. One of the bolts still had a torn fragment of the tail cone attached. The number two thrust reverser outer fairing was missing and was later found and recovered on the runway.

There was no obvious foreign object ingestion damage in the engine inlet. Metal fragments were found in the tailpipe, the 4th low pressure turbine (LPT) blades were found damaged, and the mixer support struts were missing.

Initial attempts to rotate the N1 section immediately after the incident were unsuccessful; however, on the next day, the N1 section was successfully rotated by hand. The starter was removed and the N2 section was also successfully rotated with the aid of a splined wrench. The number 2 engine chip detector plug and oil filter were removed and inspected for evidence of metal; however, only carbon particles were found. The number 2 engine was removed and the engine mounts and isolation dampeners were inspected with no damage noted.

The pylon and airframe mounts were inspected using the hard landing criteria, and no damage was found. The inspection criteria had been agreed upon jointly by Delta Liaison Engineering, a Boeing representative, and the Delta maintenance control center (MCC,) after they had determined that a structural engineer would not be required to examine the engine pylon.

The section 48 tail compartment revealed several fractures to the bleed air system ducting along with a hydraulic line leak at the rudder control valve. There was evidence of the leakage of hydraulic fluid within the tail compartment.

The right engine was transported to the Delta headquarters facility for further examination.

FLIGHT RECORDER INFORMATION

The FDR was manufactured by Lockheed Aircraft Services and was a digital recorder model 209F, serial number 4462. The FDR was opened at the Safety Board Vehicle Performance Division, Washington, D.C. The recorder was examined for damage. The dust cover, internal electronic components, and tape transport exhibited no indication of damage or excessive wear. The tape medium was then wound onto an empty 5.5-inch tape reel in preparation for readout. The tape was placed onto the Safety Board's tape playback platform. The tape's tracks were searched for data consistent with the incident sequence. Once discovered, the incident flight was transcribed into a computer file, which was used for all further processing.

The FDR was readout using the Safety Board's laboratory instrumentation recorder and interface connected to a Hewlett-Packard HP9000 minicomputer running Flightscape, Incorporated Replay and Presentation System (RAPS) software. Readout was accomplished without significant data loss throughout transcription of the incident flight. Inspection of the transcribed data revealed the recorder operated normally, except for several losses of synchronization during the incident sequence. In these segments of lost synchronization, RAPS digitized the waveforms. After completion of the waveform recovery techniques, the final composite file of the incident flight data did not contain synchronization loss, and a complete, anomaly-free recording of the incident sequence resulted.

Seven plots of selected parameters detailing the incident flight were produced. The plots, along with tabular listings of the flight, detailed the takeoff/initial event, the approach and landing, and the landing rollout. The event recordings took place between 1238:15 and 1240:54.

TESTS AND RESEARCH

The engine was disassembled on April 10, 2001, at the Delta Air Line facility in Atlanta, and was examined by the Safety Board, the FAA, and representatives from Delta Air Lines and P&W. The high

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pressure turbine (HPT) disk bore and the aft HPT shaft hub were found rubbed around the entire circumference. Metal was deposited on the HPT disk bore, and measured about 1.5 inches wide and 270 degrees around the circumference. There were approximately 9 HPT blades with minor object damage on the convex side of the airfoil on the outer 40 percent span (span is the airfoil's radial length, with 0 percent being on the inner platform and 100 percent being at the tip shroud). The HPT's outer air seal was rubbed its entire circumference and down to the honeycomb base metal. The HPT rotor was free and easy to rotate.

The low pressure shaft displayed a rubbed area, which corresponded to the HPT disk bore and aft HPT shaft hub location. An irregular shaped hole, approximately 3 inches in diameter, was found rubbed through the low pressure shaft. The shaft material appearance at the edge of the hole was melted from high temperature.

The bazooka tube, which supplies oil to the number 4 1/2 inner-shaft bearing, and transfers the number 6 bearing scavenge oil and breather air to the number 4 to number 5 bearing compartment, displayed an irregular shaped hole (approximately 3/4-inch x 3/4-inch). The bazooka tube hole aligned with the hole found in the low pressure shaft, and was located just forward of the tube's support to the inside of the low pressure shaft. The material on the edge of the hole appeared to be melted and burned.

The number 4 1/2 and number 6 bearing rollers and bearing cages were undamaged. The number 4 1/2 carbon seal aft of the number 4 1/2 bearing was intact and not broken.

The 4th stage LPT blades had two groups of blade tip damage with six undamaged blade shrouds in between. The one group consisted of three damaged blades; two of which had shrouds and airfoil tips missing, and one had 1/2 of its shroud missing. The second group of damaged blades consisted of three blades with 1/2 of their shrouds missing, and two blades with their shrouds and airfoil tips missing. Numerous blades in the 4th stage displayed trailing edge damage. The front inner flow guides for the 4th stage LPT blades displayed rubbing damage through a 90-degree arc.

The remaining inner air seals, outer air seals, and knife edges displayed varying degrees of rubbing damage.

All eight of the turbine exhaust case inner flow path struts were cracked at the trailing edge casting. Ten mixer support struts (between the mixer and the outer exhaust duct) were missing.

The bazooka tube with its "O" ring seal, the low pressure shaft, all of the 4th stage turbine blades, the 4th stage outer air seal, and the gearbox oil were shipped to Pratt & Whitney's facility for further examination.

According to a Pratt & Whitney Customer Parts Return Report, "the engine event was caused by the imbalance of the LPT rotor due to a significant loss of the 4th stage blade airfoil and shroud material. This imbalance resulted in rub between the LPT shaft and the [HPT shaft]. Oil in the vicinity of this shaft rub was ignited giving the LPT shaft the appearance of burn through." The extent of the damage to other engine systems (hydraulic lines, PT7 lines, fire warning systems, etc.) "can be attributed to the duration of excessive vibration experienced until the engine was safely shut down."

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Landing Facility/Approach Information

Airport Name	Airport ID:	Airport Elevation	Runway Used	Runway Length	Runway Width
Tucson Intl.	TUS	2643 Ft. MSL	11L	10996	150

Runway Surface Type: Asphalt

Runway Surface Condition: Dry

Type Instrument Approach: NONE

VFR Approach/Landing: Precautionary Landing

Aircraft Information

Aircraft Manufacturer	Model/Series	Serial Number
McDonnell Douglas	MD-88	53363

Airworthiness Certificate(s): Transport

Landing Gear Type: Retractable - Tricycle

Homebuilt Aircraft?	Number of Seats:	Certified Max Gross Wt.	Number of Engines:
No	149	149500 LBS	2

Engine Type:	Engine Manufacturer:	Model/Series:	Rated Power:
Turbo Fan	Pratt & Whitney	JT8D-219	21000 LBS

- Aircraft Inspection Information

Type of Last Inspection	Date of Last Inspection	Time Since Last Inspection	Airframe Total Time
Continuous Airworthiness	03/2001	21 Hours	25852 Hours

- Emergency Locator Transmitter (ELT) Information

ELT Installed?	ELT Operated?	ELT Aided in Locating Accident Site?
No		

Owner/Operator Information

Registered Aircraft Owner	Street Address		
Delta Air Lines Inc.	Hartsfield Atlanta Intl. Airport		
	City: Atlanta	State: GA	Zip Code: 30320

Operator of Aircraft	Street Address		
Same as Reg'd Aircraft Owner	P.O. Box 20706		
	City: Atlanta	State:	Zip Code: 30320

Operator Does Business As:

Operator Designator Code: DALA

- Type of U.S. Certificate(s) Held:

Air Carrier Operating Certificate(s): Flag Carrier/Domestic

Operating Certificate:

Operator Certificate:

Regulation Flight Conducted Under: Part 121: Air Carrier

Type of Flight Operation Conducted: Scheduled; Domestic; Passenger Only

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Occurrence Date: 03/15/2001

Occurrence Type: Incident

First Pilot Information

Name	City	State	Date of Birth	Age
On File	On File	On File	On File	50

Sex: M | Seat Occupied: Left | Principal Profession: Civilian Pilot | Certificate Number: On File

Certificate(s): Airline Transport; Flight Instructor; Commercial; Flight Engineer

Airplane Rating(s): Multi-engine Land; Single-engine Land

Rotorcraft/Glider/LTA: None

Instrument Rating(s): Airplane

Instructor Rating(s): Airplane Single-engine

Type Rating/Endorsement for Accident/Incident Aircraft? Yes | Current Biennial Flight Review? 10/2000

Medical Cert.: Class 1 | Medical Cert. Status: Valid Medical--w/ waivers/lim. | Date of Last Medical Exam: 11/2000

- Flight Time Matrix	All A/C	This Make and Model	Airplane Single Engine	Airplane Mult-Engine	Night	Instrument Actual	Instrument Simulated	Rotorcraft	Glider	Lighter Than Air
Total Time	12585	3513								
Pilot In Command(PIC)										
Instructor										
Last 90 Days	201	201								
Last 30 Days										
Last 24 Hours	11	11								

Seatbelt Used? Yes | Shoulder Harness Used? Yes | Toxicology Performed? No | Second Pilot? Yes

Flight Plan/Itinerary

Type of Flight Plan Filed: IFR

Departure Point	State	Airport Identifier	Departure Time	Time Zone
Same as Accident/Incident Location		TUS	1239	MST

Destination	State	Airport Identifier
Cincinnati	OH	CVG

Type of Clearance: IFR

Type of Airspace: Class C

Weather Information

Source of Briefing: Company

Method of Briefing: Unknown

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Occurrence Type: Incident

Weather Information

WOF ID	Observation Time	Time Zone	WOF Elevation	WOF Distance From Accident Site	Direction From Accident Site
TUS	1155	MST	2643 Ft. MSL	NM	Deg. Mag.

Sky/Lowest Cloud Condition: Clear Ft. AGL | Condition of Light: Day

Lowest Ceiling: None Ft. AGL | Visibility: 10 SM | Altimeter: 30.00 "Hg

Temperature: 20 °C | Dew Point: -5 °C | Wind Direction: Variable | Density Altitude: Ft.

Wind Speed: Light and Variable | Gusts: | Weather Condtions at Accident Site: Visual Conditions

Visibility (RVR): Ft. | Visibility (RVV) SM | Intensity of Precipitation:

Restrictions to Visibility: None

Type of Precipitation: None

Accident Information

Aircraft Damage: Minor | Aircraft Fire: None | Aircraft Explosion None

Classification: U.S. Registered/U.S. Soil

- Injury Summary Matrix	Fatal	Serious	Minor	None	TOTAL
First Pilot				1	1
Second Pilot				1	1
Student Pilot					
Flight Instructor					
Check Pilot					
Flight Engineer					
Cabin Attendants				3	3
Other Crew					
Passengers				96	96
- TOTAL ABOARD -				101	101
Other Ground					
- GRAND TOTAL -				101	101

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Occurrence Date: 03/15/2001

Occurrence Type: Incident

Administrative Information

Investigator-In-Charge (IIC)

Robert R. Crispin

Additional Persons Participating in This Accident/Incident Investigation:

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