NATIONAL TRANSPORTATION SAFETY BOARD

AIRCRAFT INCIDENT REPORT

CONTINENTAL AIRLINES, INC.

MCDONNELL DOUGLAS DC-10, N68041

TUCSON, ARIZONA

MAY 2, 1972

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
REPORT NUMBER: NTSB-AAR-72-29 c.1

FILE NO. 4-0001

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ADOPTED: OCTOBER 18,1972

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REPORT NUMBER:NTSB-AAR-72-29

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.
NTSB-AAR-72-29

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle Aircraft Indident Report-
Continental Airlines, Inc., McDonnell Douglas DC-10 N68041, Tucson, Arizona, May 2, 1972

5. Report Date
October 18, 1972

6. Performing Organization Code

7. Author(s)

8. Performing Organization Report No.

9. Performing Organization Name and Address
National Transportation Safety Board
Bureau of Aviation Safety
Washington, D. C. 20591

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591

13. Type of Report and Period Covered
Aircraft Incident Report
May 2, 1972

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Continental Airlines, Inc., McDonnell Douglas DC-10, N68041, on a crew training flight, departed from Tucson International Airport, Tucson, Arizona, at 1152 mountain standard time, on May 2, 1972. There were nine personnel on board.

Approximately 1 hour after takeoff, while in a holding pattern, the No. 2 engine low-pressure turbine assembly, turbine rear frame, and reverser assembly separated from the aircraft. The crew conducted a standard in-flight engine shutdown procedure and landed the aircraft at Tucson International Airport without further incident. There were no injuries.

The National Transportation Safety Board determines that the probable cause of this incident was the failure of a stiffener ring on the pressure tube located within the high-pressure turbine shaft of No. 2 engine. This failure resulted in a condition of rotor imbalance which precipitated a sequence of component failures culminating in separation of the aft portion of the engine.

Two recommendations have been made to the Federal Aviation Administration.

17. Key Words
Aircraft Incident, Holding Pattern, Vibration, Oil Quantity, Oil Pressure, Low-Pressure Turbine, Turbine Rear Frame, Turbine Reverser Assembly, In-Flight Separation.

18. Distribution Statement
Released to Public
Unlimited Distribution

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	12	

TABLE OF CONTENTS

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AIRCRAFT INCIDENT REPORT

Adopted: October 18, 1972

CONTINENTAL AIRLINES, INC.
MCDONNELL DOUGLAS DC-10, N68041
TUCSON, ARIZONA
MAY 2, 1972

SYNOPSIS

Continental Airlines, Inc., McDonnell Douglas DC-10, N68041, on a crew training flight, departed from Tucson International Airport, Tucson, Arizona at 1152 mountain standard time, on May 2, 1972. There were nine persons on board the flight.

Approximately 1 hour after departure, the No. 2 engine low-pressure turbine assembly, turbine rear frame, and reverser assembly separated from the aircraft. The crew conducted a standard in-flight engine shut-down procedure and landed the aircraft at Tucson International Airport without further incident at 1306 mountain standard time. There were no injuries.

The National Transportation Safety Board determines that the probable cause of this incident was the failure of a stiffener ring on the pressure tube located within the high-pressure turbine shaft of No. 2 engine. This failure resulted in a condition of rotor imbalance which precipitated a sequence of component failures culminating in separation of the aft portion of the engine.

As a result of the investigation of this incident, the Safety Board recommended to the Federal Aviation Administrator on June 22, 1972, that the provisions of General Electric Service Bulletin (CF6-6) 72-177, which proposed adding a sleeve tube to strengthen the high-pressure turbine pressure tube, be enforced at an early date. The Board further recommended that "C" sump borescope inspection and engine oil consumption monitoring, similar to the procedures recommended in General Electric Alert Service Bulletin (CF6-6) A72-273, with attendant appropriate action, be required until an improved "C" sump assembly is provided.

INVESTIGATION

Continental Airlines, Inc., McDonnell Douglas DC-10, N68041, departed from Tucson International Airport (TUS), Tucson, Arizona, at 1152 m.s.t. 1/ on May 2, 1972. The purpose of the flight was to conduct type ratings for captains and training for second officers.

Approximately 1 hour after departure, the aircraft was at an altitude of 5,000 feet m.s.l., in the Ryan Radio Beacon holding pattern. The training schedule called for one circuit of the holding pattern prior to commencing the VOR DME 2/ approach to TUS. As the aircraft completed the last 45° turn from the fix and onto the outbound leg of the holding pattern, the crew felt a mild vibration. Shortly thereafter, the second officer instructor reported zero oil quantity and zero oil pressure on No. 2 engine. Immediately thereafter, the No. 2 engine low oil pressure and master warning lights came on, the No. 2 engine reverser unlock lights flickered on and off, and a thumping sensation was noted in the cockpit. The crew then shutdown No. 2 engine, and the aircraft returned to TUS, landing on Runway 11L at 1300.

Ground inspection of N68041 revealed the No. 2 engine low-pressure turbine (LPT) assembly, turbine rear frame (TRF), and the turbine reverser assembly had separated from the aircraft. The aircraft sustained minor damage incident to the loss of the aft section of No. 2 engine.

There were no injuries amoung the nine persons aboard at the time of the incident.

N68041 was ferried to the Continental Airlines maintenance base at Los Angeles, California, where a detailed examination was initiated. The remaining portion of No. 2 engine was removed for shipment to the San Francisco, California, maintenance base of United Air Lines for shop examination. Most of the missing portion of the engine had been recovered from the ground near Tucson and had been shipped to the San Francisco facility for examination.

During teardown examination of the engine, it was discovered that the failed components relevant to the in-flight separation were a stiffener ring of the high-pressure turbine (HPT) pressure tube, the "C" sump assembly, the No. 5 main bearing, the LPT shaft, and the turbine midframe (TMF) to LPT stator case retention bolts.

Examination of the "C" sump showed the presence of cracks in the No. 5 and the No. 6 bearing housing cone support area. Further examination in

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1/ All times herein are mountain standard, based on the 24-hour clock.
2/ VOR DME - Very High Frequency Omnidirectional Range with colocated Distance Measuring Equipment.

the metallurgical laboratory revealed 24 fatigue crack segments of a nature indicating rapid progression. There was evidence of an intense fire in the "C" sump/LPT hub area.

Upon disassembly of the HPT, the forward stiffener ring was found separated from the pressure tube. The location of the stiffener ring and abrasion markings, both on the ring and the inside of the turbine, indicated that the turbine had been rotating with the ring against the inside of the HPT front hub and the front face of the first-stage turbine disk. The fracture surfaces of the stiffener ring indicated fatigue-crack propagation under very high-frequency loading. The weld zones of the two other stiffener rings were also cracked, but these rings were still in their proper position.

The No. 5 bearing assembly was devoid of residual oil, and showed evidence of overtemperature. The inner race indicated heavy side loading and skidding, and was cracked circumferentially 270° through the roller path. About 160° of the forward portion of the inner race was broken into small pieces, but the race was in position prior to disassembly. The outer race was cracked at the anti-rotation slot, at the 9 o'clock position, with the appearance of short-duration fatigue marks on a portion of the fracture surface. The bearing retainer was cracked, and eight rollers had been released. Roller flattening as a result of skidding was in evidence.

The oil jets of both No. 5 and No. 6 bearings were open. The outer race oil line of the No. 5 bearing had been broken off at the fitting.

There was no residual oil in the No. 6 bearing, but the bearing was intact and did not show evidence of overtemperature. Also, the silver plating of the retainer was intact. The heat shield for No. 5 and No. 6 bearings was burnt, torn, and bent 90° from its normal position.

The No. 7 bearing showed no evidence of oil starvation or overheating.

The first-stage LPT disk had separated from the second-stage disk at the bolt circle. Forty-three consecutive first-stage blades had separated through the airfoil root. The remaining blades were deformed and severely gouged on the rear side of the shroud. Eleven shrouds were broken away. The trailing edges of the airfoils were generally gouged and torn.

The second-, third-, and fourth-stage LPT disks and the separated portion of the LPT front hub had remained together.

ANALYSIS

The in-flight loss of a portion of the No. 2 engine was the result of a progressive structural failure which originated with the fatigue fracture of a stiffener ring in the HPT assembly.

The three stiffener rings, the forwardmost one of which was found failed in fatigue, had been an "add on" fix by the engine manufacturer to prevent failures of the pressure tube, which carries cooling air through the HPT hub and bell-shaped HPT shaft. The rings had been secured to the tube by circumferential welding.

There had been a history of weld cracking in both the CF6 engine and the military counterpart, the TF39 engine. However, General Electric reported that in the total of 300,000 hours of combined military and commercial engine time, this was the first known instance of cracking of the ring itself. After the forward stiffener ring welded bond in the subject engine was dissipated, and the ring itself cracked through radially, centrifugal force would have operated to spread the ring until it was thrown off of the pressure tube and lodged against the maximum ID 3/ area of the shaft, at the forward face of the HPT first-stage disk. With the ring in this position, it is estimated that the resulting turbine imbalance would be in the order of 46 inch-ounces.

Once the broken and displaced stiffener ring created an unbalanced condition, and thus applied vibrational stress to the "C" sump, fatigue cracks were induced in the "C" sump support cone. The large number of fatigue cracks, their pattern, uniformity and short duration characteristics, all provided confirmation that the failed stiffener ring had been the initiating element in the overall engine failure sequence. It was noted, for example, that three fatigue progressions emanated from each of four design holes in the support cone, and four from each of the remaining three holes.

One effect of the final fracture of the "C" sump cone support was to allow a portion of the No. 5 and No. 6 bearing housings to rotate. This rotation brought about rupture of the bearing oil lines.

During the course of this investigation, it was noted that there had been "C" sump replacements in several other CF6-6D engines because of cracking in airline service.

There was evidence of an intense fire in the "C" sump and LPT hub area. It was deduced, therefore, that an air-oil mixture was formed

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3/ ID-Inside Diameter.

from the released oil until the oil fire was set off by the normally high temperatures in the area. The additional heat from the oil fire then overtemperatured the LPT shaft hub section, reducing its strength until failure occurred. Vibratory stresses from the rotor imbalance undoubtedly contributed to the failure.

The No. 5 bearing failure would have developed as a result of a combination of housing misalignment, vibration forces from turbine imbalance, and oil starvation after oil line rupture.

After most of the rotating portion of the LPT assembly had broken loose, the last major failure in the sequence occurred at the rear flange of the TMF when the bolts attaching the LPT stator case failed in overload.

The engine manufacturer has been working on an improved "C" sump and has also issued Alert Service Bulletin (CF6-6) A72-273, dated May 8, 1972, as interim remedial action. This bulletin prescribes the inspection of the "C" sump and oil consumption monitoring as a means of detecting an incipient "C" sump failure.

Cracking of the ring welds bonding the stiffener ring to the HPT pressure tube has been a problem. In order to reduce the cracking of the weld bonding to the stiffener ring, the engine manufacturer issued Service Bulletin (CF6-6) 72-177 on March 28, 1972.

CONCLUSIONS

From the investigation of this incident, the Board concludes the following:

1. The failure of a stiffener ring on the pressure tube within the HPT initiated the progressive engine structural failure.

2. Turbine imbalance developed when the failed stiffener ring became dislocated within the HPT assembly.

3. The "C" sump failed as the result of a large number of fatigue crack progressions caused by HPT imbalance vibration.

4. The oil fire developed from the release of engine oil upon failure of the "C" sump support cone.

5. The No. 5 bearing failed as a result of misalignment caused by "C" sump cracking, vibration from HPT imbalance, and loss of oil.

6. The LPT hub failed primarily as a result of overtemperature caused by an oil fire.

7. The final structural failure occurred when the TMF/LPT stator case attachment bolts failed in overload at the time the LPT shaft failed. This failure, in turn, allowed the LPT assembly, the TRF, and the turbine reverser to separate from the No. 2 engine and fall from the aircraft.

8. The in-flight loss of the portion of the No. 2 engine entailed only superficial damage to the airframe.

9. A massive engine failure, such as occurred in this incident, has the potential to cause the loss of an aircraft by inflicting damage to adjacent aircraft structures or systems.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of this incident was the failure of a stiffener ring on the pressure tube located within the high-pressure turbine shaft of No. 2 engine. This failure resulted in a condition of rotor imbalance which precipitated a sequence of component failures culminating in separation of the aft portion of the engine.

RECOMMENDATIONS

On June 22, 1972, the Safety Board recommended (Safety Recommendations A-72-82 & 83) that the Federal Aviation Administration: (1) require that the provisions of GE Service Bulletin (CF6-6) 72-177, dated March 28, 1972, which recommended adding a sleeve tube to strengthen the high-pressure turbine pressure tube, be incorporated in all the affected CF6-6D engines at an early date; and (2) require "C" sump borescope inspection and engine oil consumption monitoring, similar to the procedure recommended in GE Alert Service Bulletin (CF6-6) A72-273, and require repetition and continuation according to experience, with attendant appropriate action, until an improved "C" sump assembly is provided by GE.

On June 30, 1972, in reply to these recommendations, the Administrator stated:

> "This problem is being studied extensively by the manufacturer and the Federal Aviation Administration. The preliminary indication that the loosening of the stiffening rings on the pressure tube in the high-pressure turbine region was the primary cause of the problem has since been discounted as a result of most recent investigation of the occurrence. Nevertheless, the modification to strengthen the high-pressure air tube is being incorporated in all early production engines at the first opportunity.

"The subject failure and cracking incidents on other service engines found through borescope inspection have proven to be due mainly to stress concentrations in critical locations of the "C" sump support structure. Corrective action has been initiated to circumvent this problem by strengthening the assembly in new designs being developed. A meeting between the manufacturer, air carriers, and the FAA was held and a course of action was developed to be followed until such time as the increased strength parts are available for retrofit.

"Experience with borescope inspection in this area has proven to be quite effective from the standpoint of early crack detection and in sufficient time to prevent a flight safety problem.

"General Electric Service Bulletin A72-273 calls for repetitive borescope inspections at 75 cycles on the center engine and 150 cycles on the wing-mounted engines. The results of the field inspections are being forwarded to the FAA for evaluation on a timely basis. It is not believed that issuance of an airworthiness directive would contribute to increased airworthiness of the DC-10 aircraft as compliance with this service bulletin is being obtained through voluntary adoption by the carriers involved, and is being closely monitored by FAA inspectors."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

Francis H. McAdams, Member, was not present and did not participate in the adoption of this report.

October 18, 1972

APPENDIX A

CREW INFORMATION

The instructor pilot-in-command, Captain K. R. Bellerue, held a valid FAA Airline Transport Rating, Certificate No. 1419009, as well as a current first-class FAA medical certificate. Captain Bellerue held type ratings for McDonnell Douglas DC-9 and DC-10, and Boeing 727, 720B, and 707.

His total flying time as of May 1972, was approximately 6,100 hours, 17 hours of which were accumulated in the McDonnell Douglas DC-10.

Captain M. V. Dixon, who was being type rated in the DC-10, held a valid FAA Airline Transport Rating, Certificate No. 1381727, as well as a current first-class FAA medical certificate. Captain Dixon held type ratings for Boeing 707, 727, 720B.

His total flying time as of May 1972, was 9,000 hours, 6 hours of which were accumulated in the McDonnell Douglas DC-10.

The second officer trainee, P. H. Branner, held a valid FAA Flight Engineer's Certificate No. 1746913. He also held Commercial Pilot Certificate No. 1411425 and a current FAA medical certificate. His total flying time, as a flight engineer, was 2,100 hours, 3.5 hours of which were accumulated in the McDonnell Douglas DC-10.

APPENDIX B

AIRCRAFT INFORMATION

N68041, a McDonnell Douglas DC-10, was accepted by Continental Airlines, Inc., on April 14, 1972. It was powered by three General Electric CF6-6D engines. The engine involved in this incident, Serial No. 451-221, had a total operating time of 182:54 hours and had accumulated a total of 635 operating cycles.