NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

June 5, 1997

POWERPLANTS GROUP CHAIRMAN'S FACTUAL REPORT

NTSB ID No.: NYC96IA036

A. INCIDENT

Location: John F. Kennedy International Airport, Jamaica, New York

Date: December 6, 1995

Time: 2215 eastern standard time (EST)

Aircraft: Boeing 747-240, AP-BAK, Pakistan International Airlines, Flight No. 722

B. POWERPLANTS GROUP

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C. SUMMARY

On December 6, 1995, at about 2215 eastern standard time (EST), Pakistan International Airlines (PIA) flight No. 722, a Boeing 747-240 airplane, registered in Pakistan as AP-BAK, experienced an uncontained low pressure turbine (LPT) event because of a fan mid shaft (FMS) fracture in the General Electric Aircraft Engines (GEAE) CF6-50E2 engine installed on the No. 2 position, following takeoff from runway 22R at John F. Kennedy International Airport (JFK), Jamaica, New York. The flightcrew reported that as the airplane climbed through 1,000 feet, they heard a loud thud and grinding noise, and that the airplane then yawed to the left. The flight engineer reported that immediately after he heard the thud, he noted that the No. 2 engine oil pressure and quantity gages were both indicating zero. The flightcrew continued the climb, and then later shutdown the No. 2 engine. The flightcrew declared an emergency, and proceeded to the fuel dump area where they dumped approximately 65,000 kilograms (143,000 pounds) of fuel. The airplane returned to JFK, and landed without further incident. There were no injuries to the 240 occupants, which included 7 infants, and 15 crew members. The airplane was operating on an instrument flight rules (IFR) flight plan under the provisions of Title 14 Code of Federal Regulations (CFR) Part 129 as a regularly scheduled flight from JFK to Charles de Gaulle Airport, Paris, France.

Examination of the engine and airplane at the American Airlines maintenance hangar at JFK revealed that portions of the LPT module, which included the LPT rotor assembly, the rear portion of the FMS, exhaust cone, exhaust nozzle, and most of the turbine rear frame (TRF), were missing. The LPT case had separated from the turbine mid frame (TMF) and was found wedged into the aft section of the core cowl, which had almost completely separated from the forward part of the core cowl. The airplane sustained damage to the left wing leading edge adjacent to the No. 2 engine and to the left main body landing gear door. The No. 1 engine also had damage to the fan cowl and fan blades. The engine was removed from the airplane and shipped to the GEAE Engine Maintenance Center in Ontario, California, for disassembly. A search of the marshes at the departure end of runway 22R and the waters under the flight path of the airplane were not successful in locating the LPT rotor.

The disassembly of the engine commenced on January 3, 1996 at the GEAE Engine Maintenance Center in the presence of the Powerplants Group. The disassembly showed that the

FMS had multiple fractures between 21- and 26-inches aft of the forward end. The high pressure compressor (HPC) Stage 1 and 2 disk and the 3 - 9 spool had separated from one another, but the disks and spool were intact. Aside from the uncontained damage to the LPT, there was no other uncontained damage noted on the engine. The disassembly of the engine was completed on January 10, 1996.

Following the disassembly, the FMS, air duct, center vent tube, compressor rotor retainer adapter (muff spline), adapter retainer, horizontal drive shaft, and the Stage 1 and 2 HPC disks were shipped to the Safety Board's materials laboratory for metallurgical examination. The visual and scanning electron microscope (SEM) examination of the fracture face on the forward end of the FMS showed there were multiple fatigue origins and circumferential cracks on the outer diameter (OD) of the shaft. The air duct forward and center stiffener rings were also found to have fatigue cracks that were parallel to the centerline of the air duct. (See Metallurgist's Factual Report No. 96-129 Revision 1, dated August 8, 1996.)

Following the examination of the parts at the Safety Board's laboratory, the parts were shipped to GEAE's Engineering Materials Technology Laboratory, Cincinnati, Ohio, for further metallurgical examination. GEAE's examination of the FMS showed that there were areas on the FMS OD that were heat affected, but the Sermetel paint over those areas was not rubbed. Fatigue cracks that were located in the heat-affected areas were found to have Sermetel paint and debris in the cracks.

GEAE provided the Safety Board with a summary of the maintenance history of the FMS that fractured. The FMS had previously been installed in a PIA CF6-50 engine that had sustained a No. 3 bearing inner race failure. The records did not show that PIA had inspected the FMS for heat affected material that would have occurred if the FMS had been rubbed following the bearing failure or at any of the subsequent maintenance exposures.

D. DETAILS OF INVESTIGATION

1.0 ENGINE INFORMATION

1.1 Engine History

The No. 2 engine on AP-BAK was a GEAE CF6-50E2 turbofan engine, serial number (SN) 455-954. PIA records indicated that at the time of the FMS shaft fracture, engine SN 455-954 had a total time and total cycles since new of 42,459 hours and 15,385 cycles, respectively. The engine had been installed on the No. 2 position of AP-BAK on May 16, 1995, and had operated 388 cycles since installation. There were no reported discrepancies for engine SN 455-954 at the time of departure of AP-BAK from JFK.

1.2 Engine Description

The GEAE CF6-50E2 engine is a dual-spool, axial-flow, high-bypass turbofan that has a 1-stage fan, 3-stage booster or low pressure compressor (LPC), 14-stage high pressure compressor (HPC), annular combustor with 30 fuel nozzles, 2-stage high pressure turbine (HPT), and a 4-stage LPT. The fan and LPC, and the HPC are connected with drive shafts to the LPT and the HPT, respectively. The data plate on the engine showed that the CF6-50E2 turbofan engine has takeoff and maximum continuous thrust ratings of 50,400 and 46,300 pounds, respectively, which are flat-rated to 86°F.[1]

1.3 Fan mid shaft description

The FMS connects the fan and LPC module to the LPT module and transmits the torque from the turbine to the fan rotor. The FMS is about 10-feet long, and is made of Marage 250, a steel alloy.

2.0 On-Site Examination of Engines and Airplane

The following personnel participated in the on-site examination of the airplane and engines: Jerome Frechette - NTSB, Charles Fowler - Federal Aviation Administration (FAA), Imtiaz Ul Haque - PIA, Michael Schneider - GEAE, and James Rauf - GEAE.

2.1 No. 2 engine

The No. 2 engine core cowl had a nearly 360°-circumferential separation of the aft section in the LPT Stage 1 plane of rotation. The aft section of the core cowl remained attached at the top with the lower half pushed rearward and rotated upward against the strut fairing. The LPT case had a 360°-separation at the front flange and the case was hung up in the aft section of the core cowl. The LPT rotor module, TRF, and exhaust cone were missing. The fractured end of the FMS was visible through the bore of the HPT Stage 2 disk. The fan could be turned without any rotation of the FMS.

2.2 No. 1 engine

The No. 1 engine fan cowl had four holes in the right side: a 1 ½-inch long diagonal split at 9 o'clock[2] that was 16 inches aft of the inlet lip, a ¾-inch long x ³/₈-inch wide hole and a ½-inch long x ³/₈-inch wide hole at the 8:45 location that was 75-inches aft of the inlet lip, and a 1 ½-inch long x ½-inch wide hole at 8 o'clock that was about 102-inches aft of the inlet lip. The right side of the fan cowling had numerous other impact marks that chipped or scratched the paint, but did not penetrate the skin. The left side of the inlet duct acoustic panel had several small impacts that did not penetrate the skin. One fan blade had a 1-inch deep x ½-inch wide deep tear in the leading edge that was 1 inch inboard from the tip. There were 18 other fan blades that were found to have impact damage to the leading edges and the spinner had 3 small impact marks. There was no apparent ingestion of material into the booster stages. The HPC was

[1] Flat-rated to a specific temperature indicates that the engine will be capable of reaching the rated thrust levels up to the specified temperature.
[2] All locations on the engine, or directions, as referenced to the clock, will be as viewed from the aft looking forward (ALF), unless otherwise specified.

borescope-inspected by PIA maintenance personnel who found several airfoils with nicks and dents, but determined that the damage was within serviceable limits.

2.3 Airplane

The airplane fuselage sustained numerous impacts along the left side. The most severe damage was to the left main body landing gear door, which had 3 $^{3}/_{8}$-inches high x 2 ½-inches wide hole in the center of the door. The left wing also had numerous holes in the leading edge skin outboard of the No. 2 engine pylon. Several internal ribs in the left wing leading edge slat bay were also penetrated. Pieces of LPT blades were recovered from the leading edge slats and rib bays.

2.4 Airport and underwater search

Following the incident, GEAE, using a helicopter, conducted an air search of the airport grounds and Jo Co marsh that were adjacent to the departure end of runway 22R for the LPT rotor module. GEAE also contracted with an underwater search and salvage company that used a side-scanning sonar to search the waters of Grass Hassock Channel of Jamaica Bay, which was under the flight path of AP-BAK, based on air traffic control radar data. The surface and underwater searches did not locate the LPT rotor module.

3.0 Engine Disassembly

The following personnel participated in the disassembly of the No. 2 engine at GEAE's Engine Maintenance Center at Ontario, California, on January 3 - 10, 1996: Gordon Hookey - NTSB, Anjum Saeed Hashmi - PIA, Michael Schneider - GEAE, James Rauf - GEAE, Frank Stagg - GEAE, Jerome Juenger - GEAE, Michael Mulkey - GEAE, and Elmer Lavertu - GEAE.

3.1 Fan Mid Shaft

The FMS part number (PN) 9032M12P18, serial number (SN) MPOE3573, was broken into at least 11 pieces. There were 10 pieces of the FMS that were recovered from the engine during the disassembly. The aft section of the FMS was missing with the LPT rotor module. The pieces of the FMS were numbered for identification purposes as they were removed from the engine. The location of where each piece was found and the description is as follows:

NO.	LOCATION	DESCRIPTION[3]
1	3-9 spool bore	About 52-inches long, that was fractured at 27 and 79 inches. 2-inch wide (circumferential) x 1 ½-inch long (axial) rub adjacent to forward fracture at 6 o'clock.[4] 2-inch wide x 3-inch long rub with a ⅝- inch wide circumferential groove at 32 ¾ inches at 6 o'clock. 1-inch x 1-inch rub at 47 ¼ inches at 6 o'clock. 4-inches wide x 1-inch long rub at 51 ¾ inches at 6 o'clock. 5 ½-inches wide x 1-inch wide rub with material transfer and cracking at 58 inches at 6 o'clock. 4-inches wide x ¾-inches long rub at 59 ½ inches at 6 o'clock. 360° 1-inch long (axial) rub with a 180° circumferential fracture at 6 o'clock and the FMS bent around the fracture at 64 ½ inches. 4 ¼-inch wide x 3-inch long rub at 66 ¾ inches.
2	3-9 spool flowpath between Stage 6 and 7.	Triangular-shaped piece, about 1 ½ x 1 ¼ x 2 inches, with a shiny metal appearance and random scratches on all surfaces.
3	Stage 1 disk bore, below piece No. 7	Triangular-shaped piece, about 2 ¼ x 2 x 1 inch, with metal spatter and circumferential scratches on the outer diameter (OD). The OD surface had a dark gray and purple color and the inner diameter (ID) surface had a light gray color.
4	3-9 spool, under No. 1, at Stage 3, at 6 o'clock.	L-shaped piece, 3 ¾ x 2 ¼ x 2 ½ x 1 x 1 x 1 ¼ inches. The OD had a dark gray circumferential rub and all of the other surfaces had a light gray color.
5	Lower HPC case, at Stage 6	1 inch x 1 inch piece that had a gray color on all surfaces and all of the fracture surfaces were battered.
6	Lower HPC case, at Stage 2	1 ½ inch x 1 inch arc shaped piece that had one end folded back to the convex side. The exposed surface (not under the fold) had purple and gold color. The remainder of the piece had a gray color. The ID surface had a series of four axial cracks.

[3] All rubs on the FMS were circumferential. All dimensions listed are referenced from the FMS forward mating surface (Surface C).

[4] Clock position for FMS pieces is relative to a reference mark that was placed on the top of FMS, Piece No. 1, indicating 12 o'clock, as it was found in the engine.

7	HPC Stage 1 disk bore	Oval-shaped section of the FMS that was 3 - 6-inch long (fracture surfaces were not perpendicular to the FMS centerline), with a 3-inch wide x 2-inch long tab on the aft edge. The forward fracture surface was rubbed and battered. The OD surface was rubbed circumferentially. About 2/3 of the aft fracture surface on the counterclockwise side of the piece had been rubbed.
8	3-9 spool bore at Stage 3	2 ½ inch x 1 inch piece that had a dark gray color. All of the surfaces were battered. There were several small axial cracks on OD in the center across the narrow width. The ID surface had many deep axial cracks across the narrow width.
9	3-9 spool	1 ¼ inch x 1 inch piece that had a dark gray color. All of the surfaces were battered.
10	In place, in the fan forward shaft	23 5/8-inch long piece that was fractured at 21 3/8 inches. 180° of the fracture surface was in one circumferential plane, with the remainder of the fracture surface extending aft from that plane. The piece was rubbed at 15 5/8, 16 7/8, 18 7/8 and from 19 7/8 inches to the end.

3.2 Center Vent Tube

There were six identifiable pieces of the center vent tube found, which included two of the three supports. One support was free of any tube section and the other support was attached to the end of a collapsed section of tube that was 29 ½-inches long. The center vent tube pieces that were found were a 20-inch long piece that had been rubbed and was discolored, a 7-inch long section that numerous nicks and scratches, and a 14 ½-inch long piece that had been folded over itself like an accordion repeatedly. The remaining section of the center vent tube was the forward threaded section, which was fractured at the point where the cone transitioned to a constant diameter cross-section.

3.3 Air Duct

The compressor air duct was severely damaged with only three pieces remaining in 360° barrel-shaped segments.

The largest 360° piece of the air duct that was found was a section that contained the third through fifth stiffener rings (the rings are numbered from front to rear). Some sheet metal extended forward from the third stiffener ring, although it varied from no material up to 3 inches. There was a 3/8-inch wide (axial) x 3 ¼-inch long (circumferential) strip of sheet metal that extended aft of the fifth stiffener. This piece had two radially inward dents that were 5-inches long (circumferential) x 1 ½-inches wide (axial) with the first dent beginning ¼-inch aft of the third stiffener and the second dent beginning 2-inches aft of the fourth stiffener. The OD of the fourth and fifth stiffeners were rubbed in the same angular location as the dents were located. The third stiffener and the remainder of the fourth and fifth stiffeners were not rubbed.

The second 360° piece of air duct included the sixth and seventh stiffener rings. The sheet metal on the aft side of the seventh stiffener ring was rubbed off flush to the rear face of the stiffener. The forward edge of the sixth stiffener was rolled radially inward up against the front face of the sixth stiffener web. The sixth stiffener OD was rubbed for 360°. The sheet metal between the sixth and seventh stiffeners had a blue discoloration and was buckled about ¼ inch forward of the seventh stiffener.

The third 360° segment of the air duct was in an oval-shape, and was wrapped tightly around FMS, piece No. 1, about 1 ½ inches aft of the forward fracture surface on the FMS. This piece included the first stiffener ring and about half of the "O" ring groove. The first stiffener was rubbed at 6 o'clock, as referenced to the FMS.

Many loose fragments of the air duct were found within the engine including the second stiffener and the surrounding sheet metal and the small fragments of air duct that were believed to be the sheet metal portion of the duct aft of the seventh stiffener. None of the pieces that were found included the aft threads of the air duct.. The forward portion of the air duct that contained the vent holes was a bent distorted ring, which was axially split, that was found under the Stage 1 disk aft cylindrical section.

3.4 Fan and Booster Rotor

The fan disk and blades were intact. The fan blades did not have any apparent damage to the airfoils and the tips did not have any bluing. There were seven sets of fan blades that were shingled[5] at the mid span shrouds, and all of the other fan blade mid span shrouds were damaged indicating they had been shingled as well.

The booster stages appeared to be in good condition. The booster spool was intact and all of the blades and vanes were in place and intact. Several Stage 4 blades had small nicks on the trailing edge.

The fan and booster rotor could be moved slightly, with force, about 1 ¼-inches at the fan blade tip. After the fan and booster stages had been separated from the rear portion of the engine, the fan and booster stages could be rotated freely.

3.5 High Pressure Compressor

The HPC upper and lower forward compressor stator cases were intact and did not have any holes or penetrations. The upper forward compressor stator case left horizontal split line flange had a ¼-inch wide gap about 10-inches aft of the case forward flange, "N"

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[5] Shingled is the condition of the mid span shroud overlapping the shroud of an adjacent blade in lieu of abutting at the contact surfaces.

flange.[6] The remainder of the compressor case flange surfaces were intact with no open gaps. The rear compressor stator cases were intact with no penetrations or dents, and all of the mating flange surfaces were tight to the adjoining flange with no visible gaps.

The compressor inlet guide vanes and Stage 1 vanes were rotated 90° to the closed position in the respective inner support shrouds. The Stage 1 vanes were buckled and bent about 1- to 2-inches out from the actuation ring. All of the Stage 2 vanes were in place, but were missing the inner pins. All of the Stage 3 through 11 HPC vanes were bent over in the direction of rotation and had hard body impact damage[7] to the leading and trailing edges. Five Stage 8 vanes were fractured transversely across the airfoil adjacent to the case wall.

The Stage 1 and 2 disks and the HPC Stage 3 - 9 spool were intact, but the bolted joints that join the three pieces had separated. The Stage 1 disk was shifted forward so the integral shaft on the front of the disk was into the No. 3 bearing. The front face of the disk had been rubbed 360° between the triple knife edge seal and the blade roots. The Stage 2 disk was found displaced from the rotor center line to the lower right side of the compressor case. The disk bore and adjacent front and rear faces had been rubbed and melted. The HPC Stage 3 - 9 spool front flange mating face was rubbed circumferentially. A 90°-sector of the flange ID had been displaced rearward. The HPC Stage 3 - 9 spool spacer land ID surfaces had a bright iridescent blue color. The spool bores at Stages 6 through 9 were rubbed on the ID.

About half of the Stage 2 blades remained in the disk blade slots, although all of the Stage 2 blades were accounted for, either in the disk slot or recovered in the compressor case. One Stage 3 blade was fractured transversely across the airfoil adjacent to the blade root platform. All of the other HPC blades were in place in their respective disk blade slots. All of the HPC blades had hard body impact damage to the leading and trailing edges and the tips. The leading edges of the Stage 1 blades were curled towards the convex side of the airfoil. The tips of all of the HPC blades were bent away from the direction of engine rotation.

3.6 No. 3 Bearing

The No. 3 bearing was broken. The cage ring was intact, but it was bent and twisted and several cage pockets were cracked. The silver plating on the cage was still in place. All of the No. 3 bearing rollers were recovered, either from the No. 3 bearing area or the fan frame. The outer race was broken up into many pieces. The rollers have some gouges on the roller surfaces. However, the rollers and raceways did not have any apparent spalling or rotational distress.

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[6]Gas turbine engine convention is to identify case flanges alphabetically from the front of the engine going rearward. A cross section of the CF6-50 engine identifying the case flanges is attached.

[7]Hard body impact damage is characterized by a serrated appearance and deep cuts or tears to the airfoil's leading and trailing edges. Hard body impact damage can result from the impact with metal parts, concrete, asphalt, and rocks.

3.7 Compressor Rear Frame

The compressor rear frame (CRF) had a circumferential fracture that translated radially aft on the left side of the engine so the fracture ends overlapped on the upper right side of the engine. The fracture extended from the 12:30 location just forward of the fuel nozzle mount pads, about 8-inches aft of "R" flange, circumferentially clockwise to the 7:30 location, where the fracture translated radially aft through the No. 19 fuel nozzle mount pad to the 8 o'clock position, and then continued circumferentially about 3 to 4 inches forward of "S" flange to 3 o'clock where the fracture terminated in a Y-shape. The fracture on the left side was open about $^5/_8$ inches and about $^1/_8$ inch on the right side of the CRF. There was no indication of any burning or fire damage on the outside of the engine.

The fuel nozzles at positions No. 12 and 19 were missing the three retaining bolts and were partially out of the case mount pads. All of the other fuel nozzles were secure in the case. The fuel nozzles had metal spray on the front face.

The combustor was intact. There was no apparent thermal distress to the inner or outer liners. The dome did not have apparent thermal distress, but was cracked axially from both of the igniter plug ports aft to the edge of the dome.

3.8 High pressure turbine

The turbine mid frame (TMF) aft flange had the LPT turbine case forward flange attached with all of the bolts in place. The honeycomb on the LPT Stage 1 seal was intact with no impact or rub marks. The LPT Stage 1 nozzle guide vane support was intact and in place and did not have any punctures or impact damage. The TMF toroid was intact and did not have any impact marks. Four of the eight stud bolts were sheared off and missing. The remaining stud bolts were in place.

The Stage 1 and 2 HPT disks were intact and all of the blades were in place in the respective disks. The Stage 1 HPT blades were broken radially from the leading edge about ½-inch above the blade root platform to the airfoil mid-chord about 1 ¾-inches above the blade root platform and then transversely to the trailing edge. All of the HPT blades had impact damage to the leading edges and metal spray build up on the convex side of the leading edge.

All of the Stage 1 HPT guide vanes were intact and in place except for eight segments that were dislodged from the Stage 1 HPT vane support. All of the Stage 2 HPT vanes were intact and in place. All of the HPT vanes had impact damage to the leading edges and had metal spray build up on the leading edge and concave side of the airfoil.

3.9 Low pressure turbine

The LPT stator case, which had been pushed aft and up against the airplane pylon, had a 360°-circumferential fracture about 3 ½-inches aft of the case front flange, "U" flange. The forward section of the case remained attached to the TMF. The aft section of the

LPT stator case, which was about 15-inches long, was bolted to the turbine rear frame (TRF) front flange. The LPT case horizontal split lines were tight with all of the flange bolts in place. All of the Stage 2, 3, and 4 LPT guide vanes were missing from the case. The Stage 4 LPT segments were battered and pressed into the case wall. The Stage 2 and 3 LPT segments were missing. The LPT case had numerous impact marks on the walls and 31 penetrations. The largest holes in the case were a 9-inch long circumferential x 1-inch wide axial hole in the plane of the Stage 3 LPT rotor and a 2 ½-inch long circumferential x 1 ½-inch wide axial hole and a 2-inch long circumferential x 1-inch wide axial hole at the 9:30 and 6:45 locations in the plane of the Stage 2 LPT rotor. Several of the holes in the LPT case were airfoil-shaped.

The front flange and a 1-inch wide section of the TRF was bolted to the LPT case. The remainder of the TRF was not recovered.

There were seven LPT blade airfoil or root sections that were found during the on-site examination of the airplane and engine that were returned to the GEAE facility, Ontario, California, with the engine. The three Stage 1 LPT blades were fractured transversely across the airfoil about 1-inch above the blade root platform. All of the Stage 1 blades were battered on the convex side of the airfoil and rubbed on the rear face of the roots. The two Stage 4 LPT blades were fractured transversely across the airfoil about 1- and 1 ½-inches above the blade root platform. Both of the Stage 4 blades were rubbed on the leading edges, which were curled back away from the direction of rotation, and on the root face below the angel wing. Both of the Stage 4 blades had a ¼-inch wide circumferential groove rubbed into the rear face in line with the blade root serration. There were two pieces of LPT blade airfoil, which could not be identified to a particular stage, that were 2 ½- and 5- inches long. The 5-inch long piece had multiple impact marks that were parallel to the full length of the trailing edge.

4.0 Metallurgical examination

The following parts from CF6-50E2 engine SN 455-594 were returned to the Safety Board's materials laboratory for metallurgical examination: Stage 1 HPC disk, Stage 2 HPC disk, horizontal drive shaft, air duct, center vent tube, FMS, adapter retainer, and compressor rotor adapter (muff spline retainer).

The examination of the fracture surface on the forward piece of the FMS revealed that most of the fracture surface was obliterated by heavy mechanical damage. The remainder of the fracture surface that was undamaged was heat-tinted from a straw color to a blue black color. There was one area of the intact fracture area that had multiple fatigue fractures that originated at the OD and progressed inward. The remaining undamaged fracture area was typical of torsional overstress. The metallographic examination of the FMS adjacent to the fracture showed the microstructure was consistent with localized heating. The hardness of the FMS adjacent to the fracture was 28 to 33 HRc, with the FMS blueprint specification requiring a hardness of 41 to 49 HRc.

The examination of the air duct revealed that both the first and second stiffener rings had a fatigue fracture that originated at the ring OD and progressed inward. The examination of the remaining pieces of the air duct and stiffener rings showed that the fractures were overstress or that the fracture surfaces were obliterated by mechanical damage.

For additional information, see NTSB Metallurgist's Factual Report No. 96-129 Revision 1, dated August 8, 1996 (Attached).

Following the examination of the parts at the Safety Board's materials laboratory, the parts were forwarded to GEAE's Engineering Materials Technology Laboratory, Evendale, Ohio, for further metallurgical examination. In a report to the Safety Board, GEAE stated that their examination of the FMS revealed that there were areas with heat-affected material and fatigue cracking that did not have any damage to the Sermetel coating on the OD of the shaft. In addition, there was Sermetel paint and other debris that was detected down in the fatigue cracks. There was no indication of any inclusions or other material defects on the FMS. A summary of GEAE's materials laboratory examination of the FMS is attached.

5.0 Maintenance records

GEAE provided the Safety Board with a summary of the maintenance history of the FMS that fractured, PN 9032M21P18, SN MPOE3573. At the time of the event, the FMS had a total cycles since new of 13,829 cycles. The shaft had been installed in engine 455-954 on May 16, 1995, and had accumulated 388 cycles since installation. The maintenance history showed that the FMS had been installed in engine 455-927 that had been removed from service on September 26, 1986, for a No. 3 bearing inner race failure. The maintenance records showed that following the bearing failure, the FMS had been overhauled, painted, a tang repaired, magnetic particle inspected, hardness checked in Area B, and dimensionally inspected. There was no record that the shaft had been inspected by etching the surface[8] following the No. 3 bearing inner race failure or at any of the other subsequent times the shaft had undergone maintenance. (A copy of the history of FMS PN 9032M21P18, SN MPOE3573, is attached.)

[redacted]

Gordon J. Hookey
Powerplants Group Chairman

Rev 6/5/97

[8] Etching the surface is a non-destructive test procedure that will show if the base metal had been locally overheated because of a rub.

ATTACHMENTS

1. Cross section of CF6-50 engine identifying flange locations.
2. NTSB Metallurgist's Factual Report No. 96-129 Revision 1, dated August 8, 1996.
3. Summary of GEAE's examination of fan mid shaft PN 9032M21P18, SN MPOE3573.
4. History of fan mid shaft PN 9032M21P18, SN MPOE3573.

PHOTOGRAPHS

1. Left side of airplane showing engines No. 1 and 2
2. View of left wing of airplane showing engines No. 1 and 2
3. Left side of No. 2 engine
4. Right side of No. 2 engine
5. View of Stage 1 vane trailing edges, vane support, and toroid
6. Right side of No. 1 engine cowling
7. Damaged fan blade in No. 1 engine
8. View of No. 2 engine from No. 1 engine inlet
9. View of left wing main landing gear door showing hole
10. Close up of hole in left wing main landing gear door
11. View of left wing leading edge over No. 2 engine showing damage to the leading edge
12. View of damage to left wing rib bay bulkhead behind leading edge flap
13. Fractured fan mid shaft and air duct with an exemplar fan mid shaft and air duct for comparison
14. Fan mid shaft piece No. 1
15. Fan mid shaft pieces No. 2 and 3
16. Fan mid shaft pieces No. 4 and 5
17. Fan mid shaft pieces No. 6 and 8
18. Fan mid shaft piece No. 7
19. Fan mid shaft piece No. 9
20. Fan mid shaft piece No. 10
21. Close up of fan mid shaft showing multiple fractures

PHOTOGRAPHS (continued)

22. Close up of rear section of fan mid shaft showing rubs and crack

23. Left side of forward compressor stator case showing ¼ inch wide gap

24. High pressure compressor rotor

25. Close up of high pressure compressor blades Stages 1 through 6

26. Close up of high pressure compressor blades Stages 4 through 12

27. High pressure compressor Stage 1 disk

28. High pressure compressor Stage 2 disk

29. High pressure compressor front stator vane case and stator vanes

30. No. 3 bearing

31. Close up of No. 3 bearing rollers

32. Compressor rear frame showing overlapping fracture

33. Fractured Stage 4 low pressure turbine blade showing groove rubbed in rear face of root with exemplar Stage 4 low pressure turbine blade for comparison

34. Low pressure turbine case at 12 o'clock

35. Low pressure turbine case at 3 o'clock

36. Low pressure turbine case at 6 o'clock

37. Low pressure turbine case at 9 o'clock