
Uncontained engine failure, Overseas National Airways, Inc., Douglas DC-10-30, N1032F, John F. Kennedy International Airport, Jamaica, New York, November 12, 1975

Micro-summary: **This Douglas DC-10-30 rejected takeoff after multiple bird strikes; the RTO was compounded by a #3 uncontained engine failure and tire failures.**

Event Date: **1975-11-12 at 1310 EST**

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

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

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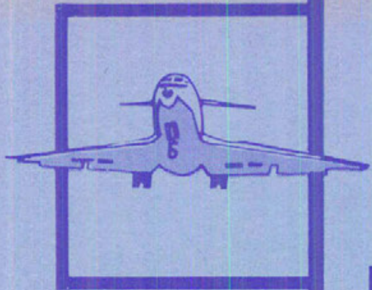

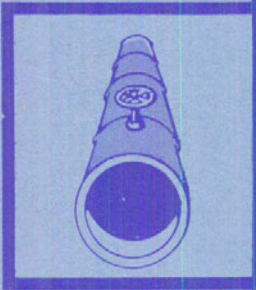

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

OVERSEAS NATIONAL AIRWAYS, INC.
DOUGLAS DC-10-30, N1032F

JOHN F. KENNEDY INTERNATIONAL AIRPORT

JAMAICA, NEW YORK

NOVEMBER 12, 1975

REPORT NUMBER: NTSB-AAR-76-19

UNITED STATES GOVERNMENT

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OVERSEAS NATIONAL AIRWAYS, INC.
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SYNOPSIS

At 1310 e.s.t., November 12, 1975, Overseas National Airways, Inc., Flight 032, a Douglas DC-10-30 (N1032F), crashed while attempting to take off from runway 13R at the John F. Kennedy International Airport, Jamaica, New York. During the takeoff roll, as the aircraft accelerated past 100 kns but before it reached V_1, sea gulls rose from the runway. The aircraft struck many of the birds, and the takeoff was rejected. As the aircraft was being decelerated, the No. 3 engine disintegrated and caught fire. The aircraft continued to roll out; several tires and wheels disintegrated; and the aircraft did not decelerate as expected. When the aircraft approached the end of the runway, the captain steered the aircraft onto a taxiway; the landing gear collapsed and, ultimately, most of the aircraft was consumed by the fire. Of the 139 persons aboard the aircraft, 2 persons were seriously injured, and 30 persons were slightly injured.

The National Transportation Safety Board determined that the probable cause of the accident was the disintegration and subsequent fire in the No. 3 engine when it ingested a large number of sea gulls. Following the disintegration of the engine, the aircraft failed to decelerate effectively because: (1) The No. 3 hydraulic system was inoperative, which caused the loss of the No. 2 brake system and braking torque to be reduced 50 percent; (2) the No. 3 engine thrust reversers were inoperative; (3) at least three tires disintegrated; (4) the No. 3 system spoiler panels on each wing could not deploy; and (5) the runway surface was wet.

The following factors contributed to the accident: (1) The bird-control program at John F. Kennedy Airport did not effectively control the bird hazard on the airport; and (2) the FAA and the General Electric Company failed to consider the effects of rotor imbalance on the abradable epoxy shroud material when the engine was tested for certification.

1. INVESTIGATION

1.1 History of the Flight

At 1256 [1] on November 12, 1975, Overseas National Airways (ONA) Flight 032, a DC-10-30 (N1032F), departed the gate at the John F. Kennedy International Airport (JFK) on a ferry flight to Jeddah, Saudi Arabia; an intermediate stop was scheduled for Frankfurt, West Germany. The flight was dispatched on an instrument flight rules (IFR) computer-stored flight plan. The cockpit crew consisted of the captain, first officer, and flight engineer. An ONA employee occupied the observer's seat on the flight deck; he had no assigned duties. (The observer operated a sound/movie camera during the takeoff and filmed most of the accident sequence. The film was used to reconstruct the cockpit activities described below.) The 128 passengers were ONA employees.

The captain had requested runway 13R for takeoff because of the weight of his aircraft; runway 13R was a nonconforming runway [2]. According to the crew, the first portion of the takeoff roll was normal and the aircraft accelerated as expected. Shortly after the aircraft's speed passed 100 kns, however, the captain saw a flock of birds on the runway. He estimated that a flock of about 100 birds rose off the runway, separated, and then grouped in front of the aircraft. The captain alerted the crew to "watch the EGT's."[3] The crew then heard birds strike the aircraft, and recalled one to three explosions or bangs. The captain began procedures to reject the takeoff. Coincident with bringing the thrust levers to the idle position, the thrust reversal of the engines, and the application of heavy braking, the master warning and master caution lights appeared. As the engines went into reverse thrust, the engineer stated that they had "lost" the No. 3 engine. The Nos. 1 and 2 engines attained normal reverse thrust.

The flight engineer also noticed that the No. 2 brake system pressure had dropped to zero; the No. 1 brake system pressure remained normal with 3,000 lbs of pressure. He advised the captain that brake pressure was available. The No. 2 brake system is powered by the No. 3 hydraulic system on the No. 3 engine. The No. 3 hydraulic system also operates 2 of the 10 spoiler panels.

Within seconds, the fire-warning light illuminated on the captain's glare shield. The fire lights in the fire handle on the overhead panel and in the fuel control lever illuminated for the No. 3 engine. The flight engineer also heard the fire warning. The first officer and the flight engineer attempted to shut down the No. 3 engine

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[1] All times herein are Eastern standard, based on the 24-hour clock.

[2] A nonconforming runway is one which is not being used as an active runway because of wind and noise considerations.

[3] Exhaust gas temperature.

by closing the fuel shutoff lever to it; the lever could not be moved. The engineer then pulled the engine fire handle to shut down the engine, to close the fuel shutoff valve, and to activate the fire extinguishing units to the engine. However, he did not see the light which would have illuminated had the extinguishing agent discharged. The crew estimated that the No. 3 engine was shut down within 7 seconds after they realized that the engine had failed.

Initially, the aircraft seemed to decelerate effectively; however, as it continued to roll out, crewmembers believed that its rate of deceleration decreased to a level at which the aircraft could not be stopped on the runway. The captain did not recall that the antiskid released; however, the runway surface was rough, so he was not able to determine if the system operated properly.

In spite of its fast roll, the crew believed initially that the aircraft was under control and that it could be guided safely onto taxiway "Z" -- the last taxiway at the end of runway 13R -- without striking the blast fence at the departure end of the runway. However, during the turn the aircraft left the paved surface before entering the taxiway. The crew estimated that the aircraft was traveling at 40 kns as it was turned left onto the taxiway. The aircraft proceeded a short distance to the northeast before it stopped on the shoulder of the taxiway. As the aircraft rolled to a stop, the cockpit was shaken violently. The crew believed that the right gear had collapsed; they did not know that the aircraft was on fire.

After the aircraft stopped, the engineer pulled the fire handles for Nos. 1 and 2 engines. The captain stated that he closed the engine fuel shutoff levers to these engines before he left the cockpit. The public address microphone had become displaced during the stopping sequence, and an evacuation order could not be given.

When the first officer opened the right front cockpit window, he saw fire on the right wing. By that time, another crewmember had opened the cockpit door and black smoke could be seen in the cabin. Since there was a group of passengers around the right front exit, the three flightcrew members exited out the right front cockpit window and down the escape rope. The jumpseat occupant escaped through the right front exit.

The accident occurred during daylight hours and at N 40° 38' latitude and W 73° 46' longitude. The elevation was 12 feet m.s.l.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	0	0	0
Nonfatal	6	27	0
None	5	101	

1.3 Damage to Aircraft

The aircraft was destroyed by impact and fire.

1.4 Other Damage

On the south shoulder of taxiway "Z", holes were gouged in the hard surface. A tractor that was parked at the Pan American World Airways tire shop, left of runway 13R, was damaged when struck by the compressor rotor from the No. 3 engine. Several oil drums burned.

1.5 Crew Information

The flightcrew was certificated and qualified in accordance with existing Federal Aviation Administration (FAA) requirements. (See Appendix B.)

1.6 Aircraft Information

The aircraft was certificated, equipped, and maintained in accordance with FAA requirements.

The aircraft was approximately 1,000 lbs below its maximum allowable takeoff weight of 555,000 lbs. When the aircraft departed the ramp, it weighed 556,000 lbs and consumed 2,000 lbs of fuel as it taxied to runway 13R. The center of gravity was 18.6 percent MAC. The flap setting established for the takeoff was 5.5°. The forward and aft limits MAC were 12 percent and 19.4 percent, respectively.

The aircraft had 235,000 lbs of jet-A fuel on board at the time of the accident. The aircraft was equipped with three General Electric CF6-50A high-bypass ratio turbofan engines. (See Appendix C.)

1.7 Meteorological Information

At 1312 a special weather observation for JFK Airport indicated: Ceiling -- 4,400 feet broken, 10,000 feet overcast, visibility -- 15 miles, wind -- 160° at 8 kns, altimeter setting -- 29.97 in.

1.8 Aids to Navigation

Not applicable

1.9 Communications

No communications difficulties were experienced between the flightcrew and the control tower. The controllers in the tower cab heard the explosion and saw fire emanate from the right side of the aircraft. They did not communicate this information to the flightcrew. There was no standard for the transmission of this type of information by tower personnel.

1.10 Aerodrome and Ground Facilities

John F. Kennedy International Airport is located in the southeast portion of New York City and on the north side of Jamaica Bay. The Jamaica Bay area has numerous mud and sand flats, swampy islands, and garbage dumps. An area southwest of the airport is a bird sanctuary.

Two sets of parallel runways and a single runway are available. Runway 13R is 14,572 feet long and 150 feet wide and has a concrete/asphalt surface, which is ungrooved. A blast fence is located just beyond the departure end of the runway.

The airport is operated by the Port Authority of New York and New Jersey (PONYNJ); the operating certificate was issued March 6, 1973, under provisions of 14 CFR 139. There were no exemptions to the regulation in effect on the day of the accident. Airport certification safety inspections were conducted on September 23, 1973, and on September 9, 1974. Both inspections determined that birds at the airport represented a hazard to aviation. Bird control techniques were used which included "scare-away guns," "trap," and "shotguns."

1.11 Flight Recorders

N1032F was equipped with a Sundstrand digital flight data recorder (DFDR) model 573A, serial No. 2272, and a Sundstrand model V-577 cockpit voice recorder (CVR). Both recorders were installed in a pressurized area below the floor near fuselage station 1787.

Because electrical power was lost, the DFDR ceased to record soon after the aircraft attained an indicated airspeed of 168 kns. Although the unit sustained moderate to severe fire damage, data up to the 168-kn point were usable for data reduction, and 44 parameters had been recorded. The CVR tape was severely burned and was not usable.

1.12 Wreckage

The aircraft came to rest about 135 feet right of the centerline of taxiway "Z" on a magnetic heading of 060°. The left and centerline main gears had separated from the aircraft and the right main gear had collapsed. The wreckage was scattered over an area 1,086 feet wide and 8,460 feet long. (See Appendix D).

Most of the separated aircraft parts were scattered to the right of the runway centerline and between 6,400 and 9,400 feet from the takeoff end. These separated parts consisted of pieces of the No. 3 engine's compressor, fan module, fan thrust reverser and cowling; the main landing gear wheels and tires, and the right, aft centerline landing gear door.

Sea gull feathers were found on the runway 6,000 feet from the takeoff end of runway 13R and continued for 400 feet. A vent port recoup duct was found 6,400 feet from the end of runway 13R and to the right of the runway centerline; the bleed duct was from the inner flow path wall of the left-hand fan thrust reverser assembly of the No. 3 engine. A large sea gull was found near the bleed duct, to the left of the runway centerline. High pressure compressor (HPC) blades and vanes were also found near the recoup duct and others were found scattered several hundred feet in the direction of takeoff on both sides of the runway centerline. About 20 sea gulls were found scattered across the runway between 6,400 and 7,100 feet from the takeoff end of the runway. The largest bird weighed 5 lbs., and the average weight of the other birds was between 3 and 4 lbs. Additional engine and cowling parts were located between 6,400 and 9,400 feet from the takeoff end of runway 13R. The largest single piece was the complete fan module located at the 9,400-foot point. A large piece of tire and several smaller pieces were located about 7,000 feet from the takeoff end of runway 13R and to the right of the runway centerline.

The landing gears and spoilers were down and locked. The settings of the leading-edge slats and trailing-edge flaps could not be determined. The horizontal stabilizer was set at 5.1° aircraft noseup, within the operating range for the weight and configuration of the aircraft.

The Nos. 1 and 2 engines remained attached to the aircraft. The thrust reverser assemblies were intact. The fan thrust reverser for the No. 1 engine was deployed while the fan thrust reverser for the No. 2 engine was stowed.

The first parts of the No. 3 engine were located near the first bird carcasses. The lower HPC stator case assembly, the HPC stage 1 and stage 2 discs, the complete fan module, and miscellaneous engine parts, including the engine fuel feed line, were on the runway. A 3-foot section of the fan midshaft was located to the right of the runway. The HPC rotor assembly, stages 3 through 13, came to rest 1,000 feet from the takeoff end of runway 13R and 951 feet to the left of the runway centerline. These stages were without blade airfoils. The stage-14 HPC disc was not recovered. None of these engine parts showed evidence of fire.

All the No. 3 engine cowl components showed exposure to higher-than-normal internal pressures which blew the nose cowl, fan cowl, fan thrust reverser, and core cowl doors off the engine. Overload failures were documented in the hinges, latches, and the basic cowl structure. The cowling and latches were apparently properly latched before the overpressure began.

The left core cowl was damaged and the metal was folded. There was a heavy black scrub mark on the cowl, and a piece of tire tread was embedded in the folds of the metal. This piece of tread matched a section of tire tread from the No. 10 wheel.

The upper and lower compressor stator case assembly had separated from the engine at the circumferential flanges and horizontal split lines. All attaching bolts and nuts were missing from the assembly. About 20 percent of the bolts were recovered on the runway.

The No. 3 engine was disassembled and examined at the General Electric Company, Evendale, Ohio. Disassembly and examination revealed evidence of at least six significant bird strikes on the lip assembly of the No. 3 engine inlet cowl; some of the bird residue ran back to the exterior skin of the inlet cowl. An individual bird strike pattern was also found on the exterior skin of the inlet cowl assembly. Evidence of a bird strike was found on the translating cowl of the right-hand fan thrust reverser; this strike was approximately perpendicular to the normal installed position of the engine. The outer, fixed structure of the right-hand fan thrust reverser also featured evidence of bird residue at various locations. There was more bird residue on the low-pressure side of the fan blades than on the high-pressure sides of the fan blades. Bird residue was dispersed randomly at various locations on the surfaces of the fan blades and was found on the fan rotor spinner. The forward face of the constant speed drive oil heat exchanger was coated with bird debris at various locations. Bird feathers had also adhered to the stage 1 vanes of the fan stator assembly at various locations. A heavy deposit of bird debris was found at the No. 7 valve of the fan frame's variable bypass valve system.

An examination of the fan module revealed that first stage fan blade Nos. 5 and 36 (blade numbers are clockwise, looking forward) had the outer portions broken off approximately 4 inches below the midspan shroud. All blades had varying degrees of panel-tip and leading- edge damage. Many blades had pieces broken out of the leading edge of the tip approximately 3 inches axially by 4 1/2 inches radially. Seven blades had leading edge damage which extended below the midspan shroud by up to 5 inches. Most blades were split from the tip 0.5 inch to 2 inches radially through one or more of the outer panel's drilled holes. All damage was impact related; there was no evidence of fatigue on the blade fracture surfaces. The blade tips exhibited heavy smearing in a direction opposite normal fan rotation. Net fan rotor assembly imbalance was 122,852 gram-inches.

The fan stator assembly (fan booster stages) did not appear to be damaged. All three rows of blades were intact with only sporadic nicks and tears in the blades' leading and trailing edges. All three stages of blades rubbed heavily into the stator microballoon material, however, not all blades showed evidence of rubbing.

The recovered HPC stator case's horizontal split-line flange bolts showed primarily tensile/bending fractures in the threads. No fatigue was noted in any fracture surfaces. The recovered fan frame/HPC circumferential flange bolts exhibited primary tensile/bending fractures in the first thread. The shank failures of the circumferential flange bolts in the recovered compressor rear frame/HPC stator case appeared to be primarily shear-type failures -- the failure surface made a 60° to 80° angle with the bolt centerline in most cases. The thread failures appeared to be tensile/bending failures with a smeared shear lip over part of the failure surface.

The compressor rear frame's sump cone was cracked circumferentially 360° near the midpoint of the cone; this crack was between the mounting flange and the outer sump wall. The crack transversed circumferentially around the cone and intersected the 10 pressure equalization holes in the cone near the center of each hole; the cracks followed a circumferential path around the cone in most cases.

The forward end of the combustion system's combustor outer liner skirt was buckled inward into an approximate 20 nodal pattern from fuel nozzle positions Nos. 13 through 28. Maximum buckling occurred at position No. 19 and was approximately .7 inch deep. There were no indications of overtemperature or other evidence of pre-existing combustor distress. The fuel nozzle tips were withdrawn from their proper interface with the swirlers; the nozzles were completely withdrawn in the region between positions 15 to 25.

The front flange of the high-pressure turbine's (HPT) stage 1 nozzle support assembly was coned rearward about 0.1 inch from its inside diameter to its outside diameter. The sheet metal cone of the support had a 16 to 20 node buckling pattern which was fully circumferential and which indicated a high-pressure pulsation in the cavity containing the combustor. A 12-inch circumferential tear occurred at the 11 o'clock position. The tear, which appeared to be a result of a buckling load was a wide, flat V-shaped flap; the resultant flap then split into two flaps. A mark, made when one of the flaps rubbed against the turbine rotor's front shaft, was noted on the front shaft.

Five high-pressure turbine stage 1 nozzle guide vanes, located at the 11 o'clock position, were distorted by an apparent high internal pressure, such that the concave side of the guide vanes had become convex in the area forward of the rib. This represented a contour displacement of approximately .1 inch. There was no evidence of any vane heat distress.

Seven of the ten main landing gear wheels showed evidence of flange damage, flat spots, or failures. Tire pieces on the runway were examined and found to have come from at least three different tires, one of which was the tire on the No. 10 wheel. The carcass of this tire was examined, and it showed evidence of having been penetrated from the outside while inflated. Other pieces of recovered tread and carcasses showed evidence of slipping and skidding. One tire showed evidence of scrubbing after the tire had been deflated. In addition, cuts in the lower sidewall of the tire appeared to have been made by a wheel rim flange rolling on the tire after it deflated. This tire also showed stress marks that are associated with overdeflection or overloading of an inflated tire.

Tire and wheel marks on the runway indicated that, as the aircraft turned off the runway onto the taxiway, the nose gear left tire marks, the Nos. 1, 2, 3, and 4 wheels left metallic marks on the runway, and the Nos. 5, 6, 7, and 8 wheels left serpentine rubber marks. The centerline gear wheels, 9 and 10, also left serpentine rubber marks, which were visible from a point 800 feet from the primary wreckage area to a point 300 feet from the primary wreckage area. No marks associated with these latter wheels were evident for the last 500 feet of aircraft travel.

None of the antiskid components tested showed evidence of preexisting defects or malfunctions that would have kept them from operating normally.

All the brakes were removed and examined by the manufacturer. All the brake disks were free, and there was no evidence of sticking. All the components were assembled properly and the friction surfaces were intact and capable of further energy absorption. All the frictional surfaces showed evidence of previous energy absorption. There was no evidence of previous defects or malfunctions that would have prevented proper braking action. The disks on No. 3 wheel brake were "flat spotted" over a 70° arc at the bottom of the brake.

The fire shutoff valves for the three engines and the auxiliary power unit (APU) were closed.

1.13 Medical and Pathological Information

Medical histories revealed no evidence of abnormal conditions which would have affected the flightcrew's performance.

None of the passengers were injured seriously. Twenty-seven passengers sustained minor injuries consisting of sprains, abrasions, contusions, lacerations, and muscle strains.

The first officer sustained rope burns to one hand and sprained an ankle during the evacuation. The second officer sustained serious rope burns to both hands; the captain sustained minor rope burns. Three cabin crewmembers sustained minor sprains, contusions, and lacerations.

1.14 Fire

After the birds were ingested and the No. 3 engine had disintegrated, fire erupted on the right side of the aircraft. Cabin crewmembers and passengers who were seated on the right side of the aircraft and who were able to see the No. 3 engine generally agreed that fire erupted on the right wing as soon as the engine disintegrated and separated. When the aircraft left the paved surface, integrity of the wing fuel tanks was lost and the structure of the aircraft was damaged.

The aircraft came to rest near an underground drain and large quantities of the aircraft's fuel entered a storm drain system. The fuel was ignited and control of the fire by airport crash/fire equipment was virtually impossible. The fuselage, between fuselage stations (FS) 239 and 2007, was consumed by fire. The fire was confined to the area where the aircraft came to rest.

After the compressor case separated, the fan assembly separated, and the fuel supply line in the leading edge of the pylon fractured. Manufacturer's data show that, with the tank fuel pump "on," the fuel flow through the 2-inch fuel line is between 150 and 160 gallons per minute. Calculations based on the flight data recorder and the motion picture taken from the cockpit during takeoff and rollout, indicated that 15 seconds elapsed from the 6,400-foot point on the runway to the point where the fuel shutoff was actuated. Therefore, about 40 gallons of fuel would have been expelled, and the aircraft would have traveled about 3,800 feet. After the fuel was shut off, sufficient fuel remained between the shutoff valve and the break in the fuel line to support combustion until the aircraft came to rest.

The fire rescue forces were on scene within 1 minute. However, flammable cargo (tires, spray cans of paint, and other flammable material) and the fuel which had leaked into the storm drain hampered firefighters' efforts; the fire was not extinguished until about 36 hours after the accident. Although firefighters were not aware of the contents of the baggage compartment, they were able to extinguish the cargo fire with dry chemical fire extinguisher when they identified the material that was burning. Large amounts of foam and water had previously been applied to the fire without success.

1.15 Survival Aspects

This was a survivable accident. The occupiable area of the aircraft was intact; the only danger to occupants was fire and smoke; decelerative forces experienced by the occupants were minor and well within human tolerance.

1.16 Tests and Research

To analyze the factors involved in the engine breakup, the manufacturer conducted tests and research programs to attempt to understand the failure and to provide information on which to base corrective action.

The effects of fan drag torque (torsional loading) versus fan rotor imbalance as a result of bird ingestion or foreign object damage were examined both analytically and by component testing.

Tests conducted by the manufacturer were designed to simulate the effects of a 122,000 gram-inch fan rotor assembly imbalance at takeoff thrust. The results of these tests and associated component tests eliminated fan drag torque as a cause of the HPC case failure.

The manufacturer also examined the extreme overpressures developed in the engine as the result of a bird strike.

Calculations were made to determine the pressures required to cause the internal deformations found in the No. 3 engine. The calculations were made using the material properties for steady-state loading at the material's operating temperature. The results were expressed in terms of the differential pressure across the section. These pressures would have to be applied as a high-rate impulse. (See Appendix E.)

The combustion characteristics of various abradable rub shroud materials were investigated in laboratory tests. Two of the test devices used in these studies were patterned after a "Hartmann tube," which was developed by the U.S. Bureau of Mines for dust cloud explosion investigations. A third test device was a flame tunnel with a combustor section and flowing air stream. The results of the "Hartmann tube" and flame tunnel tests showed that the P6TF1 phenolic microballoon epoxy abradable rub shroud material installed in the CF6 engine had greater combustibility characteristics at lower operating temperatures than other abradable rub shroud materials. The material's pressure-rate rise during combustion was also significantly greater than other comparable abradable rub shroud materials.

Typically, powdered P6TF1 abradable rub shroud material autoignited when introduced into a flame tunnel test environment of 215 psi and 1,000°F and caused a pressure rise of 720 psi/second with an increase in pressure and temperature of 48 psi and 680°F, respectively. The same material when subjected to "Hartmann tube" tests showed a maximum rise in the pressure rate of 2,750 psi/second.

A silicon rubber-based abradable rub shroud material used in other engines of similar thrust ratings exhibited autoignition characteristics similar to those exhibited by the P6TF1 material. The results of these tests also demonstrated that aluminum rub shroud material did not autoignite after being exposed to tempertures up to 1,100°F in the flame tunnel tests.

In an effort to reproduce the failure of the No. 3 engine, three diagnostic engine tests and two fan rotor assembly imbalance tests were conducted in a test cell. The first three tests were designed to determine the cause(s) of compressor case separations and to demonstrate corrective actions.

The three diagnostic tests demonstrated that the HPC case separations were caused by a critical degree of fan-rotor assembly imbalance. The fan rotor assembly imbalance caused rubbing, powdering, and subsequent autoigniting of the P6TF1 fan-booster-stage abradable rub shroud material. As a result of this finding, the booster shroud for CF6-6 and CF6-50 series engines is being modified. The P6TF1 shroud material will be removed and replaced with aluminum shroud material.

The fourth and fifth engine tests were tests to prove structural integrity; these tests were conducted under conditions of severe fan ingestion damage which resulted from an induced fan-blade failure.

During the fourth test, a CF6-50 engine was subjected to a fan rotor assembly imbalance of 122,000 [4] gram-inches. The test engine was a standard configuration. The attaching bolts installed in the compressor case were current field configuration type. Open-cell aluminum honeycomb rub shrouds replaced the P6TF1 rub shroud material in the fan stator assembly tip shrouds and the interstage seals. Solid first stage fan blades were installed in the engine. During the test, two first stage fan blade panels were separated explosively 4 1/2 inches below the part-span shroud; the fan blade panels were separated by five unfailed blades. The blade panels were targeted to release at a fan speed of 4,000 rpm. Normal fan rotor speed at takeoff conditions for this model engine is 109.73 percent, or 3,766 rpm; this is based on normal engine bleed and standard day conditions. At 4,000 rpm, both the fan and core compressor stalled during the tests. The stall initiated between compressor stages 6 and 9. The engine began to decelerate before the blades released.

4/ Equivalent to the fan rotor assembly imbalance measured during disassembly of the No. 3 engine.

The fan blade panels released at 3,368 rpm--well above "critical" [5/] engine rotor speed of 2,800 rpm. The engine stalled seven times before the fan blades released and once after the blades released. The maximum deceleration rate measured for the engine was 2,500 rpm per second, which corresponded to a possible seizure torque of approximately 400,000 inch-lbs.

The test data indicated that the compressor had minimum stall margin at the targeted fan-rotor-speed conditions of the test. Operating the cowled engine at the unusually high fan-rotor speed in the static test stand without inlet ram air available to simulate aircraft takeoff forward velocity also probably contributed to this condition. Ground wind gusts and ground vortices were observed at the time of the test; these conditions caused a fan inlet airflow disturbance, which could result in dynamic pressure fluctuations of the core compressor inlet. A weak compressor could be affected by these conditions.

Since the compressor recovered momentarily from each of the seven stall pulses, there was no internal self-inflicted damage caused by rubs or blade failures, or both. The fan debris appeared to have entered the compressor through the booster stages or the open bleed doors. The fan debris apparently damaged the core compressor, which degraded the blade airfoil and which finally culminated in a stall. When the blades broke, metallic particles caused severe wedging-type blade tip rubs. This condition can cause a titanium fire. An internal titanium fire erupted about 40 milliseconds after the blades were released. The fire burned through the bleed air extraction manifolds; the compressor's rotor spool remained intact. The fire burned through the oil lines under the engine and adjacent to the manifold, which caused fluid to be released and feed the external fire. An engine system resonance of 24 Hz, independent of the rapidly dropping compressor rpm, was observed. Such a pulsation is possibly set off by the high-energy release of the titanium fire. The 4-foot long, 24-Hz pulsation column between the compressor inlet and the high pressure turbine nozzle caused a sound wave velocity of 2,400 fps. An average gas temperature of 2,400°F. is required for a sound wave velocity of this magnitude.

During the fifth test, a CF6-6D engine was subjected to the same test described for the fourth test. This engine was also a standard production configuration, with current field configuration compressor case attaching bolts. The honeycomb material was removed from the fan booster stage. The engine incorporated first stage fan blades that had been drilled. The engine maintained its structural integrity after two fan-blade panels had been released. It did not stall, no titanium fires erupted, and there was neither high-pressure compressor damage nor impending failure of the compressor cases' horizontal split line flanges.

5/ Engine operating speed at which maximum radial loads are absorbed by the No. 1 bearing.

The results of these tests demonstrated no flow path overpressure and no loss of structural integrity as a result of massive fan imbalance, including a maximum load during deceleration through engine system resonance.

No consideration was given by the FAA's certificating officer or the General Electric Company as to the possible effects of a compressor rotor imbalance upon the epoxy shroud or the secondary effects of epoxy shroud pulverization.

Accordingly, on April 1, 1976, the Safety Board submitted recommendations to the FAA indicating the need for retesting the General Electric CF6 engine to demonstrate compliance with the complete bird ingestion criteria of AC-33-1A. Subsequent diagnostic testing of CF6 engines, critical evaluation of CF6 service history related to foreign object ingestion incidents, and, finally, testing of CF6 engines with mechanically induced rotor imbalance conditions with modified fan booster shroud assemblies disclosed that the proposed modifications to the engine would adequately protect against conditions resulting from foreign object ingestions which were, heretofore, not considered in certification tests.

While the overpressure demonstrated by the tests did not duplicate exactly the pressure distortions in the combustor and HPT regions of the accident engine, the tests did demonstrate that changing the booster shroud material to aluminum honeycomb would effectively prevent the engine overpressure caused by ingestion and combustion of powdered phenolic microballoon epoxy material.

1.17 Other Information

1.17.1 Certification of CF6-6 and CF6-50 Engines

Application for type certification for the CF6 engine was filed on July 3, 1968. Type Inspection Authorization (TIA) project No. CJ2210EA-D was issued by the FAA on April 2, 1970, and provided authority for certification testing of the CF6-6 engine under criteria in 14 CFR 33 and amendments 1, 2, and 3. The regulation was effective on February 1, 1965. When the General Electric Company applied to the FAA to test the CF6-6 engine, it submitted a test plan "CF6 Ice Slab, Hailstone and Bird Ingestion Certification Test." Subsequent to the application, FAA issued the TIA.

The test plan submitted specified procedures and methods for conducting certain tests and the means for complying with applicable regulations. 6/

6/ 14 CFR 33.13, in effect at the time application was made for the GE CF-6 type certificate, required: "The engine may not have design features that experience had shown to be hazardous or unreliable. The suitability of each questionable design detail or part must be established by tests."

The purpose of the test was to demonstrate that the CF6 engine was capable of ingesting birds, hailstones, and ice slabs at typical aircraft velocities without indication of imminent engine failure, need for immediate engine shutdown, and engine power recovery to 75 percent at stabilized operation. Such demonstration would satisfy FAA test requirements in AC-33-1A. [7] For large birds, no specific power recovery was defined, although a useful power was desired.

For testing, AC-33-1A specified bird sizes, weights, and quantities based on bird ingestion experience. When the circular was issued on June 19, 1968, there was no experience relative to the ingestion characteristics of large, by-pass type turbofan engines such as the CF6. Therefore, the advisory circular did not stress or identify the critical areas of the engines which were to be tested for effects of bird ingestion. The General Electric proposal submitted in lieu of AC-33-1A considered such critical areas.

On April 10, 1970, General Electric's test program was accepted by the FAA certificating office and found to be in compliance with 14 CFR 33.13 and 33.19. On July 8, 1970, and on January 19, 1971, General Electric submitted the test results to the FAA; the FAA accepted the results for certification of the CF6-6 engine.

Because of the design similarities between components of the CF6-50 and CF6-6 engines, analysis based on similarity was chosen as a technically valid basis for determining the structural requirements to contain the CF6-50 engine. To that end, the kinetic energy of the rotor blades as it relates to the structure's capability to contain them was analyzed. Where this relationship failed to show containment capability equivalent to that of the CF6-6, the containment structures were strengthened appropriately. Because of the similarities between the two engines, FAA required no additional ingestion tests for the CF6-50 engine. (See Appendix F.)

1.17.2 Port Authority Bird Control Program

The Port Authority Aeronautical Services Division (ASD) was responsible for the control of the bird hazard at JFK Airport. Implementation of the program rests primarily with the airport's duty supervisor and construction supervisor. Before November 1, 1975, the number of personnel and vehicles actively engaged in bird dispersal ranged from one to six vehicles and up to seven personnel. Except for one individual,

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7/ Advisory Circular AC-33-1A provides guidance and acceptable means, but not the sole means, by which compliance may be shown with the design and construction requirements of 14 CFR 33.

these personnel were not employed exclusively for bird control duties. They were assigned various other duties with bird control as an additional duty. Airport personnel in Airport Operations and Construction had radio contact with the JFK tower when on duty and would coordinate bird-dispersal activities with the tower. Port Authority personnel indicated that all employees of the airport were requested to observe and report bird loafing and related activities to appropriate airport personnel.

The bird dispersal program consisted, in part, of the following measures:

(1) On the day of the accident seven carbide cannons were in service along the first 5,000 feet of runway 13R.

(2) One vehicle had the capability of transmitting tape recorded stress cries of birds.

(3) Shotguns and bird patrols were used.

(4) Vegetation, rodent life, water ponds, and food sources are to be removed from the airport.

(5) Efforts were made to reduce the attraction to birds presented by dumps. The efforts were being made by the Environmental Protection Agency (EPA), the FAA, the Port Authority, and the New York City Sanitation Department.

FAA monitored the bird problem at JFK Airport and found that there were more bird strikes in 1975 than in the same period for 1974. In March 1975, a series of meetings began to discuss solutions to the bird hazard. The meetings were attended regularly by the FAA Airports Division, Port Authority of New York and New Jersey, and seven other local and Federal agencies.

The FAA Airports Division stated that the purpose of the FAA's effort had been to cause the Port Authority to implement a more aggressive bird reduction program. They further indicated that they had received no correspondence from the Air Transport Association, Air Line Pilots Association, or individual air carriers regarding the bird problem at JFK Airport.

On July 15, 1975, a 30-day bird reduction test program was implemented. A 7-day-per-week bird patrol was established using a Port Authority employee and a police officer with a shotgun. This patrol operated from 1200 to 2000 hours.

From August 15 to September 15, 1975, the bird patrol continued from 1200 to 2000 hours, 5 to 7 days per week. A police officer with a shotgun was available upon request. After September 15, 1975, the bird patrol was accomplished daily from 1200 to 2000 5 days a week by a Port Authority police officer with a shotgun.

An officer was available upon request at other times. The use of shotguns was restricted to certain areas of the airport; cracker shells were used instead of live ammunition.

The number of serious bird strikes increased from one in July, two in August, and one in September, to seven in October. The seven strikes occurred on large air carrier jets, and resulted in five engine changes. This increased bird-strike activity caused the Port Authority to expand the bird control measures on November 1, 1975, as follows:

0600 to 1000 - One vehicle with police officer and shotgun
1000 to 1400 - Two vehicles with police officers and shotguns
1400 to dusk - One vehicle with police officer and shotgun

In addition, more vehicles were scheduled to be equipped with tapes. One such vehicle was in use on the day of the accident.

1.17.3 Calculated Aircraft Stopping Distances

The accelerate-stop distance for this aircraft under normal circumstances on a dry runway is about 10,000 feet. The Safety Board was unable to establish a calculated stopping distance for the circumstances of the accident because of a lack of evidence regarding the timing and sequence of tire and wheel failures, the actual coefficient of friction on the runway, and the amount of wheel braking available.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

There was no evidence of any malfunction of the aircraft or its flight control system, wheels, brakes, tires, or propulsion systems before it encountered the sea gulls. The aircraft had been maintained in accordance with FAA-approved procedures, was certified properly, and was equipped properly for the flight.

The crewmembers were qualified to perform their assigned duties. There was no evidence that flightcrew or cabin crew performance or that any medical factor played a part in this accident.

The ingestion of many 3- to 5-lb sea gulls into the No. 3 engine initiated the overall failure sequence. At that time, the No. 3 engine was operating at takeoff power. The ingestion caused massive fan blade damage and, ultimately, fan rotor imbalance.

When the fan rotor assembly became unbalanced, the P6TF1 phenolic microballoon epoxy abradable rub shroud began to pulverize. The pulverized rub shroud material entered the high-pressure and high-temperature environment of the HPC, where ignition and explosive burning occurred. The resultant overpressure within the compressor section caused the compressor cases to separate and structural integrity of the engine to be lost.

The HPC rotor assembly, the fan midshaft, and the fan module separated as a direct consequence of the loss of the engine's structural integrity. Compressor stalls were not associated with the separation of the HPC case.

High fan drag torque resulted from the large fan rotor assembly imbalance forces which were transmitted through the fan case to the HPC case. These loads affected the HPC case's circumferential flanges and bolts, and the horizontal split line flanges and bolts; however, these forces were not large enough to cause the primary failure of the case assembly. This was demonstrated by static engine component tests and two factory-development engines with modified booster-stage rub shroud material. These engines were able to retain their structural integrity after being subjected to an induced fan rotor assembly imbalance of about 122,000 gram-inches.

An evaluation of the failure mechanism involved in the accident engine suggests that the engine would not have disintegrated if either a smaller or larger degree of rotor imbalance had existed after the foreign objects were ingested. Service experience and diagnostic testing have demonstrated that the amount of rotor imbalance must be of a specific magnitude to produce the precise fuel-air ratio of powdered epoxy microballoon material and HPC air and temperature to create an explosion.

The above evaluation is supported by a review of CF6 engine service history. This review disclosed that incidents of massive fan rotor imbalance have occurred without resultant HPC case opening, distortion, or separation. The review showed that parts of tires, engine core cowling sections which weighed more than 100 lbs, and blade sections have been ingested without resultant separation of the HPC case.

The final structural proof test conducted by General Electric consisted of operating a CF6-6 engine at takeoff power with two fan blades, 5 blades apart, intentionally separated 4.5 inches below the midspan shroud. The epoxy microballoon material had been removed from the fan booster shroud.

Inspection after this test disclosed that the separated fan blades were contained and that all of the engine's structural members remained intact. The compressor discharge pressure shutdown tube, which is designed to terminate engine operation in cases of major failures, functioned and shut the engine down. The HPC case flanges remained intact. There was no evidence of internal overpressure or any indication of external fire.

The secondary compressor damage in all test cases appeared to be of equal severity to that observed in the No. 3 engine of N1032F. Although rotor imbalance conditions were certainly encountered during initial certification testing, the epoxy microballoon rub problem was of such proportions that no fire or secondary explosions occurred. It is also apparent that neither the FAA nor General Electric knew or considered the possible effects of the pulverization of the epoxy microballoon material.

The Safety Board believes that these tests identified the problem area sufficiently so that corrective action can be taken to prevent recurrence of a similar failure.

The results of the engine diagnostic test and component tests, which were conducted over a period of several months, eliminated fan drag torque as a cause of the HPC compressor case separations. (See Appendix E.)

A detailed review of the CF6-6 engine certification program, particularly the bird ingestion test portion of the program, disclosed that when the engine was certificated relatively little or no experience was available in the industry as far as large high bypass turbofan engines without inlet guide vanes were concerned.

Consequently, the Advisory Circulars 33-1 and 33-1A were based on experience and testing of smaller turbine and turbofan engines which incorporate inlet guide vanes.

The acceptance of the test plan for the bird ingestion portion of the CF6-6 certification program appeared to be based on the certificating officer's knowledge and past experience in the field of turbine engine design, operation, and certification requirements.

Although the National Transportation Safety Board believes that the test guidelines set forth in Advisory Circular 33-1A were more stringent than those actually used by General Electric during initial certification, the Safety Board finds that there was no regulatory requirement which could have made the guidelines of AC-33-1A mandatory.

On the contrary, the Advisory Circular could not be properly used for other than guidance, if, in the opinion and judgment of the Administrator's representative, the intent of the applicable regulatory material was satisfied.

The Safety Board found that the CF6-6 certification tests conducted by General Electric and accepted by the FAA were in accordance with applicable provisions of 14 CFR 33, and that analytical data were accepted because of the similarity between the CF6-6 and CF6-50 as a basis for certification of the CF6-50.

After the engine failed, the flight engineer immediately alerted the captain that the No. 2 brake system had failed, as evidenced by a zero brake pressure reading. The No. 1 system, however, appeared to be operational and, thus, adequate braking should have existed for that system.

Although 14 CFR 25 requires a single brake system to be capable of stopping the aircraft under all normal conditions, the Safety Board concludes that in this accident the loss of one system did not prevent the aircraft from stopping on the runway. Even if all tires had remained intact, the antiskid system would have made application of 100 percent of available brake torque impossible because of the wet runway. With up to three of the wheels damaged, there was no means to utilize all available braking power to stop the aircraft; consequently, it could not be stopped on the wet runway. Under normal conditions, on a dry runway, the aircraft could have been stopped in about 10,000 feet from the start of the takeoff roll.

The Safety Board concludes that the crew performed exceptionally well during the emergency. The entire rejected-takeoff checklist was accomplished without delay. When the crew completed these procedures, they expected the aircraft to be stopped normally on the runway. The loss of braking ability, however, was further compounded by the loss of reverse thrust on the No. 3 engine, the inability to deploy No. 3 spoiler panels on each wing, and standing puddles of water on the runway. The crew was acutely aware of the deteriorating rate of deceleration, but could do nothing to stop the aircraft beyond what had already been accomplished. Finally, the blast fence at the departure end of the runway forced the captain to attempt a relatively high speed turn on to the last taxiway.

Based on available evidence, the Safety Board concludes that fire erupted as the engine separated. The most probable ignition source was the raw fuel which was released from the main fuel line onto the hot engine at a rate of 150 to 160 gallons per minute. The fire was fed by fuel from either failure of the high pressure manifold, which surrounds the compressor rear frame, or failure of the fuel supply line at the leading edge of the pylon.

As the aircraft was turned onto taxiway Z, the fire continued to burn in the area of No. 3 engine. After the failure of the right main landing gear, structural loads were transferred to the right wing when the wing hit the ground. This transfer resulted in an overload failure of the right rear spar and skin at wing station 622 in the area of the No. 3 fuel tank. Fuel released from the wing tank fracture area, flowed down to, and pooled against, the fuselage, and continued to feed the fire at the No. 3 pylon location.

Simultaneous with the right main landing gear and wing failures, the No. 3 pylon structure also hit the ground and was displaced inboard, which allowed the remaining parts of No. 3 engine to penetrate the lower wing skin at the No. 2 fuel tank location; this penetration allowed additional fuel to be added to the fire.

Although firefighters were on scene within 1 minute, they were not able to extinguish the fire for about 36 hours because of the fuel accumulation in the storm drain.

This was a survivable accident. The occupiable area of the aircraft was totally intact. The rapid and successful egress of all the occupants may be partially attributed to the fact that nearly all passengers were trained crewmembers and all were airline employees with knowledge of the aircraft, evacuation procedures, and facilities. Serious evacuation problems could have been experienced had this been a routine passenger flight with untrained airline passengers.

The Safety Board found that the bird hazard reduction program at JFK Airport was under routine FAA surveillance as a regular function of the Airport Certification Inspection. To assist the inspectors, 14 CFR 139.67 states that the operator "must show that it has established instructions and procedures for the prevention or removal of factors on the airport that attract or may attract birds." While this appears to give the inspector much latitude, the chief of the FAA Eastern Region Airport Certification Program stated that 14 CFR 139 was adequate to implement viable bird hazard reduction programs. Considering the wide range of variables which could affect a bird control program, it is not practical to attempt to make the rule more definitive.

The Safety Board concludes that the complexity of controlling bird populations on or around airports requires ecological and ornithological studies before an effective program can be formulated. An airport certification inspector, who is aeronautically oriented, can determine that birds represent a serious problem at an airport, but he cannot evaluate the technical aspects of the problem to determine which bird reduction program will be effective.

The Safety Board believes that the measures adopted at JFK after the accident represent a strong bird control program and can deal effectively with the immediate problem of birds at the airport.

2.2 CONCLUSIONS

a. Findings

1. The takeoff operation was normal until the sea gulls struck the aircraft.

2. The bird strikes damaged the fan blades in the No. 3 engine.

3. Damage to No. 3 engine's fan assembly resulted in rotor imbalance. As a result of the imbalance, the fan-booster stage blades rubbed on the epoxy microballoon shroud material.

4. Pulverized epoxy microballoon material entered into the No. 3 engine's HPC area, ignited, and caused the compressor case to separate.

5. The FAA and General Electric Company failed to consider the effects of rotor imbalance on the abradable epoxy shroud material during certification.

6. The structural integrity of the No. 3 engine was lost after the compressor case separated.

7. Fire erupted in the right wing and pylon simultaneously with the breakup of No. 3 engine.

8. Deceleration was impaired by loss of tires on the right main landing gear, loss of No. 3 hydraulic system, inability to deploy No. 3 spoiler panels, a wet runway surface, and unavailability of reverse thrust on the No. 3 engine.

9. The aircraft could not be stopped on the runway.

10. The aircraft sustained major structural damage after it left the runway surface.

11. Massive quantities of fuel were released into the fire when the right wing fuel tank was fractured.

12. The flammable material on the aircraft and the aircraft's position near a fuel-saturated storm drain made it virtually impossible to control the fire.

13. The CF6-6 engine was certificated in accordance with existing regulations.

14. The CF6-6 engine certification bird ingestion tests were conducted in compliance with existing regulations. The FAA accepted CF6-6 engine certification data for the certification of the CF6-50 engine.

15. FAA Advisory Circular AC-33-1A contained guidelines for the conduct of bird ingestion tests.

16. The engine manufacturer did not follow the guidelines regarding sizes and numbers of large birds to be used during ingestion tests, as outlined in AC-33-1A, but used alternate procedures using fewer birds, which were approved by FAA.

17. Two factory development engines configured with modified rub shroud material retained their total structural integrity when subjected to fan rotor assembly imbalance of 122,000 gram-inches.

18. The postaccident tests performed by the manufacturer were more demanding and more stringent than any in-service bird strikes to date.

19. A bird control system was in effect at JFK Airport.

20. The bird control system did not assure that runway 13R was clear of birds before the takeoff of N1032F.

b. Probable Cause

The National Transportation Safety Board determined that the probable cause of the accident was the disintegration and subsequent fire in the No. 3 engine when it ingested a large number of sea gulls. Following the disintegration, the aircraft failed to decelerate effectively because: (1) The No. 3 hydraulic system was inoperative, which caused the loss of the No. 2 brake system and braking torque to be reduced 50 percent; (2) the No. 3 engine for thrust reverser was inoperative; (3) at least three tires disintegrated; (4) the No. 3 system spoiler panels on each wing could not deploy; and (5) the runway surface was wet.

The following factors contributed to the accident: (1) The bird-control program at John F. Kennedy Airport did not effectively control the bird hazard on the airport; and (2) the Federal Aviation Administration and the General Electric Company failed to consider the effects of rotor imbalance on the abradable epoxy shroud material when the engine was tested for certification.

3. RECOMMENDATIONS

As a result of the accident, on April 1, 1976, the Safety Board submitted the following recommendations to the Administrator, Federal Aviation Administration:

"1. Require immediate retest of the General Electric CF6 engine to demonstrate its compliance with the complete bird ingestion criteria of AC 33-1A. (Class I--Urgent followup.) (A-76-59.)

"2. Require that any engine modifications necessary to comply with the bird ingestion criteria of AC 33-1A be incorporated into all newly manufactured CF6 engines. (Class II--Priority followup.) (A-76-60.)

"3. Require that any engine modifications necessary to comply with the bird ingestion criteria of AC 33-1A be incorporated into all CF6 engines in service. (Class II--Priority followup.) (A-76-61.)

"4. Until the CF6 engine is modified, require that a bird patrol sweep runways at all airports which have recognized bird problems and are served by CF6-powered aircraft. The sweep should be made before a runway is put into operation for CF6-powered aircraft and at sufficient intervals thereafter to assure that a bird hazard does not exist. (Class I--Urgent followup.) (A-76-62.)

"5. Advise all operators, domestic and foreign, of CF-6 engines of the catastrophic consequences of foreign objects damage and the need for appropriate caution to avoid such damage. (Class I--Urgent followup.) (A-76-63.)

"6. Amend 14 CFR 33.77 to increase the maximum number of birds in the various size categories required to be ingested into turbine engines with large inlets. These increased numbers and sizes should be consistent with the birds ingested during service experience of these engines. (Class III--Longer-Term followup.) (A-76-64.)"

Earlier recommendations were made to the Administrator, Federal Aviation Administration as a result of this accident; these recommendations were issued, on March 8, 1976.

"1. In coordination and cooperation with the Port Authority of New York and New Jersey, expedite the following actions:

   (a) Determine the weather conditions, ocean tide conditions, seasonal factors, migratory patterns, and daily movement patterns which could be used to forecast periods of greatest bird hazards at the Port Authority of New York and New Jersey airports and take effective actions to disperse the birds before use of the affected runways is permitted.

   (b) Remove the abandoned runway 7-25 pier at JFK.

   (c) Remove the bird attraction to the beach adjacent to the south and east boundaries of the airport by eliminating the beach through gravel fill, dredging, a seawall or other appropriate means.

   (d) Drain the Chapel Pond at JFK. (Class II-Priority followup.) (A-76-8.)

"2. Require a physical inspection of a runway and adjacent areas at each controlled airport certificated under 14 CFR 139, which has a recognized bird-hazard problem on each occasion before:

(a) Designating that runway as the active runway, or

(b) Allowing takeoffs from other than the active runway. (Class II-Priority followup.) (A-76-9.)

"3. Frequently review the operations manual for each airport certificated under 14 CFR 139 which has a recognized bird hazard problem to assure that the provisions of their bird-hazard reduction program are adequate. (Class II-Priority followup.) (A-76-10.)

"4. Require that a specially trained, staffed, and equipped bird-dispersal organization be established at each controlled certificated airport with a recognized bird-hazard problem. (Class III-Longer-Term followup.) (A-76-11.)

"5. Amend 14 CFR 139.67 to require that, where the Administrator finds that a bird hazard exists, an ecological study be conducted to determine the measures necessary for an effective bird-hazard reduction program. (Class III-Longer-Term followup.) (A-76-12.)

"6. Revise FAA Form 5280-3, Airport Certification Safety Inspection, to include more detailed criteria for use by airport certification specialists to evaluate the bird hazard potential at an airport. These criteria should include, but not be limited to, migratory patterns, local attractants, and airport features likely to attract birds. (Class III-Longer-Term followup.) (A-76-13.)

"7. Assist and encourage the Port Authority to implement the recommendations contained in the previous ecological studies of Port Authroity airports. Specifically, these studies offered the following remedial measures:

(a) For John F. Kennedy International Airport:

(1) Eliminate the two dumps and several sewer outlets which attract gulls.

(2) Drain or fill the several small marshes and ponds on the airport.

(3) Dredge mudflats or cover them with gravel to eliminate shore bird concentrations.

(4) Remove the wire fence at the southeast end of the airport.

(5) Dispose of food-bearing plants such as bayberry, tall stands of phragmites, and other dense growths of vegetation used for roosting purposes. This may be done by burning, cutting, bulldozing or with herbicides.

(6) Shoot or trap rodents and rabbits which attract birds of prey.

(7) Employ a well supervised shotgun patrol to repel birds from critical airport areas. The patrols should use shell crackers, and to a limited extend, live ammunition.

(b) For LaGuardia Airport:

(1) Consider the appointment to the New York Airports of an environmental specialist to coordinate the programs of bird control.

(2) Fill temporary water areas, and alter habitat in the headland area by bulldozing or the use of herbicides.

(3) Continue a shotgun patrol and the use of scare devices.

(4) Communicate with the New York City Department of Public Works to explore possibilities for minimizing gull access to domestic waste. Elimination of food sources will substantially reduce the local gull population.

(c) For Newark International Airport:

(1) Bird and other wildlife habitat at the airport be altered by drainage, cutting, bulldozing, or use of herbicides.

(2) Grasshoppers be controlled by applying either insecticides, or through agricultural practices.

(3) Newly constructed areas not be landscaped with ornamental trees, shrubs, or brush.

(4) A shotgun and scare devise patrol be continued.

(5) A collection of bird/plane and near-miss data be continued.

(6) A man be appointed full-time to eliminate bird hazards.

(7) The Port of New York Authority influence the termination of the Oak Island and Elizabeth Dumps, and prohibit the development of proposed sites near the airport. (Class II-Priority followup.) (A-76-14.)"

Also on March 8, 1976, the Safety Board recommended that the Federal Aviation Administration:

"1. Rescind the Technical Standard Order (TSO) approving the American Safety, Inc., dual retractor restraint system until it is modified so that the seatbelt cannot release inadvertently. (Class I-Urgent followup.) (A-76-15.)

"2. Issue an AD to prohibit the use of all rearward-facing flight attendant seats on DC-10 aircraft until the deficiencies of the restraint systems are corrected or until a suitable alternate restraint system is installed. (Class I-Urgent followup.) (A-76-16.)"

As a result of an earlier special investigation concerning the CF6 engine, the Safety Board issued the following recommendations to the Administrator, Federal Aviation Administration, on March 25, 1975.

"1. Require that certification demonstration of engine anti-icing provisions be performed in a test facility which can aerodynamically simulate in-flight icing conditions.

"2. Warn all operators of aircraft equipped with CF6-50 engines that engine damage could result when ice is shed from the fan spinner after prolonged exposure to moderate or severe icing condition at a holding pattern power setting.

"3. Gather accurate engine performance information from selected in-service cases of bird ingestion by large turbo fan engines which resulted in engine shutdown, serious thrust loss, or excessive vibration. This information, in combination with the most recent ornithological data and advances in engine technology, should be used to evaluate the adequacy of bird ingestion criteria for large turbo fan engines."

FAA responses to recommendations are shown in Appendix G.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ WEBSTER B. TODD, JR.
Chairman

/s/ KAY BAILEY
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ WILLIAM R. HALEY
Member

December 16, 1976

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

At 1315 e.s.t., on November 12, 1975, the National Transportation Safety Board was notified of the accident by the FAA Communications Center in Washington, D.C.

An investigation team was dispatched immediately to John F. Kennedy International Airport, Jamaica, New York. Working groups were established for operations, airports, human factors, structures, systems, powerplants, aircraft records, metallurgy, flight data recorder, and cockpit voice recorder.

The FAA, General Electric Co., Overseas National Airways, Air Line Pilots Association, Association of Flight Attendants, McDonnell Douglas Aircraft Co., Port Authority of New York and New Jersey, and U.S. Department of Interior's Fish and Wildlife Service participated in the investigation.

2. Hearing

A public hearing was held in Jamaica, New York, from March 9 through March 11, 1976. Parties to the hearing included the FAA, Overseas National Airways, Air Line Pilots Association, Association of Flight Attendants, McDonnell Douglas Aircraft Co., General Electric Co., and the Port Authority of New York and New Jersey.

Depositions were taken from additional FAA and General Electric Co. witnesses on May 18 and May 19, 1976.

APPENDIX B

AIRMEN INFORMATION

Captain Harry R. Davis

Captain Harry R. Davis, 55, was first employed by Overseas National Airways on May 21, 1951. His initial employment was as a captain with the company. He completed the DC-10 captain's transition course and was qualified as a DC-10 captain on March 2, 1973.

Captain Davis held Airline Transport Pilot Certificate No. 173240, issued March 1, 1973, with an airplane multiengine land rating. He held type ratings in the DC-4/DC-6/DC-7/DC-8/DC-10. He had commercial privileges for airplane single engine land and sea. His first-class medical certificate, issued November 4, 1975, had the following limitation: "Holder shall wear and shall possess glasses for distant and near vision while exercising the privileges of his airman's certificate." An electrocardiogram was performed in May 1975.

Captain Davis had accumulated about 25,000 flight-hours, 2,000 hours of which were as captain, DC-10. In the past 90 days he had recorded 142 flight-hours. He had not flown in the previous 30 days.

Captain Davis completed a proficiency check on February 22, 1975. An FAA inspector observed the check. This training included simulator and aircraft periods. He completed a simulator proficiency check on October 1, 1975. Each simulator proficiency period covered heavy takeoffs (550,000 pounds), rejected takeoff and takeoffs with simulated engine failure.

Captain Davis received line checks on April 20, 1975, and March 22, 1974. He completed DC-10 pilot recurrent ground school on February 6, 1974, and DC-10 captain refresher training on February 2, 1975. He successfully completed the Overseas National home study courses on March 30, 1975, and June 28, 1975.

First Officer Raymond A. Carrier

First Officer (F/O) Raymond A. Carrier, 52, was first employed by Overseas National Airways on March 18, 1968. He served as a DC-9 captain until February 19, 1975, when he completed DC-10 First Officer transition. He completed a DC-10 proficiency check on March 1, 1975. This training included simulator and aircraft periods. He completed recurrent training during the DC-10 transition training in February 1975. He completed Overseas National home study courses November 12, 1975, and July 29, 1975. As a DC-9 captain, F/O Carrier had recurrent training on May 8, 1974 and DC-9 proficiency checks May 10, 1974, and November 12, 1973.

F/O Carrier held Airline Transport Certificate No. 527690, issued June 6, 1969. He had a rating for airplane multiengine land, Douglas DC-9 and Lockheed L-188. He had commercial privileges for airplane single engine land and Douglas DC-3/A-26. His second-class medical certificate was dated October 25, 1975, with the following limitation: "Holder shall possess correcting glasses for near vision while exercising the privileges of his airman certificate."

F/O Carrier had accumulated about 14,500 flight-hours, 450 hours which were in the DC-10. He had flown 26 hours in the past 30 days and 136 hours in the last 90 days.

Flight Engineer Jack A. Holland

F/E Jack A. Holland, 44, was first employed by Overseas National Airways on May 19, 1959, as a flight engineer. He held Flight Engineer Certificate No. 1374312, issued January 11, 1967, with ratings for reciprocating engine-powered and turbojet-powered aircraft. He also held Mechanic Certificate No. 1353167, issued September 13, 1956, with airframe and powerplant ratings. His second-class medical certificate, dated May 19, 1975, had the following limitation: "Holder shall possess correcting glasses for near vision while exercising the privileges of his airman certificate."

F/E Holland completed DC-10 flight engineer transition on April 2, 1973. He completed flight engineer proficiency checks on February 27, 1975, and February 4, 1974. These checks were accomplished in a simulator. His last line checks were June 27, 1975, and June 22, 1974. F/E Holland completed recurrent training February 26, 1975, and February 1, 1974. His last home study course was completed September 15, 1975.

F/E Holland has accumulated about 12,000 flight-hours, all as a flight engineer, about 2,000 hours of which were in DC-10 aircraft. He had not flown in the previous 30 days, but had recorded 117 hours in the last 90 days.

None of the crewmembers logged any flight time in the 24 hours before the accident. The arrived at the ONA dispatch office about 1000 on the day of the accident for the scheduled 1230 departure.

APPENDIX C

AIRCRAFT INFORMATION

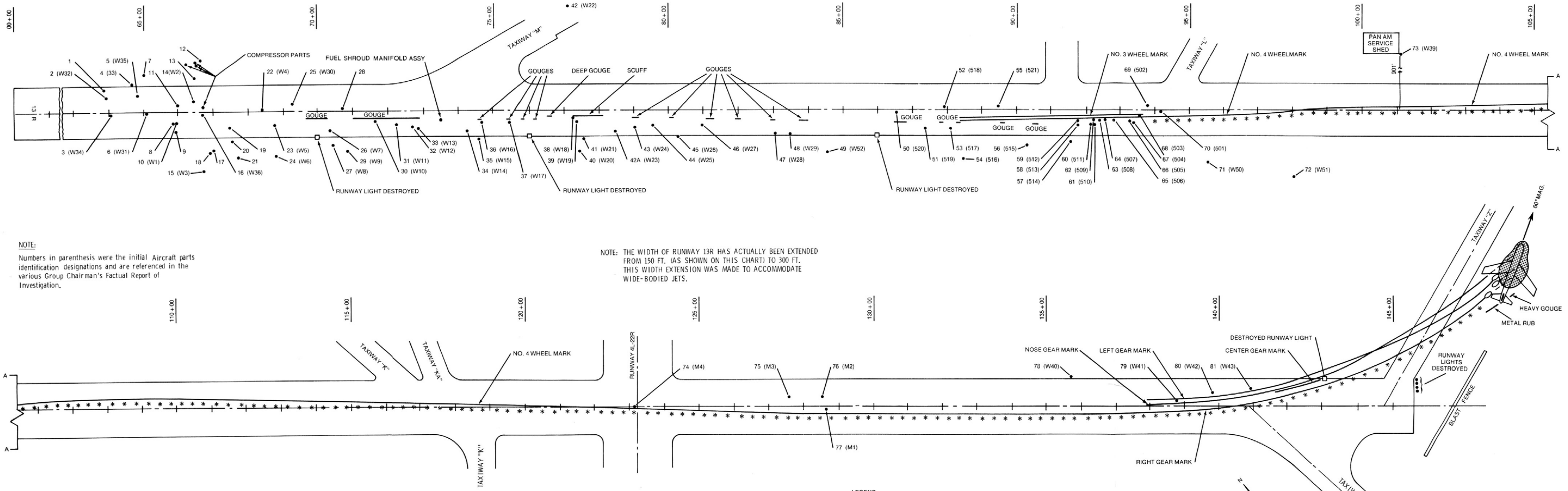
The aircraft, a Douglas DC-10-30F, United States registry N1032F, serial No. 46826, was manufactured on June 29, 1973, and accepted by Overseas National Airways, Inc. on the same day. The airplane had accumulated a total of 8,193:13 flight-hours.

The aircraft was certificated and maintained in accordance with existing Government regulations and company procedures. There were no open or uncorrected safety of flight items listed in the aircraft's log when it was released for flight on November 12, 1975.

The latest "C" check was completed on July 10, 1975, when the aircraft had a total of 6,922:0 flight-hours. A review of the maintenance records since that date disclosed no evidence of any pre-existing maintenance problems which could be associated with the accident.

The aircraft was equipped with three General Electric Co. CF6-50A high bypass ratio, turbo fan engines:

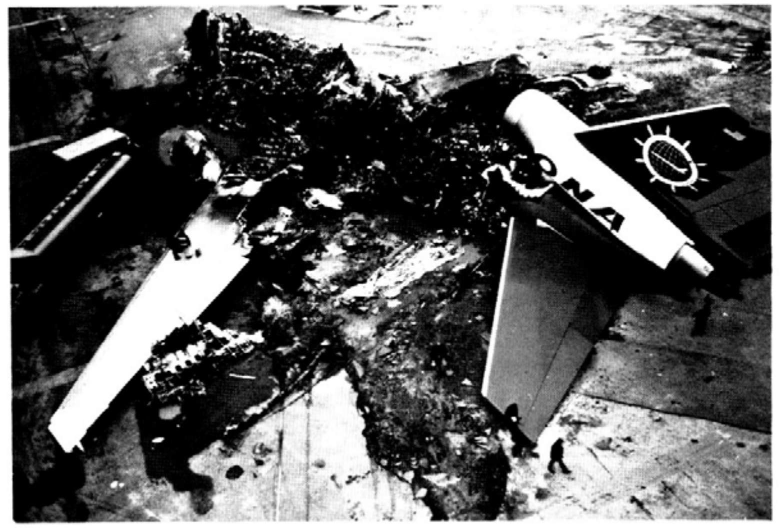
Engine Position	No. 1	No. 2	No. 3
Serial No:	455-153	455-122	455-219
Total Time:	5,607:03	7,708:38	6,257:01
Total Cycles:	1,334	1,776	1,376
Hours since repair/last shop visit:	245:41	3437:49	2405:09
Date Installed:	10/10/75	10/9/74	3/12/75
Hours Since Installation:	245:41	3437:49	2405:09
Cycles Since Installation:	67	731	515



NOTE:

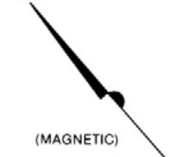
Numbers in parenthesis were the initial Aircraft parts identification designations and are referenced in the various Group Chairman's Factual Report of Investigation.

NOTE: THE WIDTH OF RUNWAY 13R HAS ACTUALLY BEEN EXTENDED FROM 150 FT. (AS SHOWN ON THIS CHART) TO 300 FT. THIS WIDTH EXTENSION WAS MADE TO ACCOMMODATE WIDE-BODIED JETS.



LEGEND

1.		SEA GULL
2.	(W32)	COMPRESSOR PART
3.	(W34)	OVERBD. BLEED FITTING ON LH REVERSER
4.	(W33)	ENGINE FIRE SEAL BLOWOUT DOOR
5.	(W35)	NO. 1 SENSOR SHIM
6.	(W31)	COMPRESSOR PART
7.		SEA GULL
8.		SEA GULL
9.		SEA GULL
10.	(W1)	REVERSER TO PYLON STRIP
11.		SEA GULL
12.		SEA GULL
13.		SEA GULL
14.	(W2)	PIECE OF COWLING
15.	(W3)	RH CORE COWL
16.	(W36)	COMPRESSOR PART IMBEDDED IN ACOUSTIC MATERIAL
17.		SEA GULL
18.		SEA GULL
19.		SEA GULL
20.		SEA GULL
21.		SEA GULL
22.	(W4)	PIECE OF LH CORE COWLING
23.	(W5)	ACCESS BLOWOUT DOOR/FAN REVERSER
24.	(W6)	LH FAN COWLING
25.	(W30)	INNER COMPRESSOR BLEED DOOR
26.	(W7)	PIECE OF TIRE
27.	(W8)	PIECE OF TIRE
28.		SEA GULL
29.	(W9)	RH REVERSER FAN AIR BLEED DUCT
30.	(W10)	RH CENTERLINE GEAR DOOR
31.	(W11)	PIECE OF RH FAN COWLING W/COMPRESSOR PARTS IMBEDDED
32.	(W12)	RH FAN REVERSER
33.	(W13)	RH FAN COWLING
34.	(W14)	LH INNER FAN REVERSER COWLING
35.	(W15)	LH FAN COWL (LWR FWD CORNER)
36.	(W16)	PART OF PNEUMATIC PRESSURE REGULATOR VALVE
37.	(W17)	LH FAN COWL (W/FUEL LINE STOWAGE COMPARTMENT AND PRESSURE RELIEF DOOR)
38.	(W18)	NOSE COWLING - OUTER SKIN
39.	(W19)	NOSE COWLING - OUTER SKIN
40.	(W20)	FAN REVERSER - LESS INNER DUCT
41.	(W21)	ENGINE PART
42.	(W22)	NOSE COWLING ASSY
42A.	(W23)	LH FAN COWL FWD. HOLD - OPEN ROD W/ROD STOW BRACKET ATTACHED
43.	(W24)	LARGE PIECE OF TIRE
44.	(W25)	INLET COWL ANTI-ICE VALVE
45.	(W26)	LWR HALF HP COMPRESSOR CASE
46.	(W27)	TYPE OF ROD
47.	(W28)	FAN SPEED SENSOR
48.	(W29)	ANTI-ICE VALVE W/BUTTERFLY VALVE BODY AND 51 INCHES OF TUBING ATTACHED
49.	(W52)	STAGE 2 COMPRESSOR DISK
50.	(520)	NOSE COWLING FIRE SEAL W/OUTLET PORTION OF ANTI-ICE TUBING AND VALVE ATTACHED
51.	(519)	STAGE 1 DISK (HP COMPRESSOR)
52.	(518)	PIECE OF TIRE
53.	(517)	FUEL PUMP
54.	(516)	SECTION OF MAIN ENGINE FUEL CONTROL
55.	(521)	FUEL FILTER
56.	(515)	OIL TANK
57.	(514)	PIECE OF TIRE
58.	(513)	FUEL TUBING
59.	(512)	INBD. ENGINE DRIVEN HYD. PUMP
60.	(511)	LEFT HALF OF ACCESSORY GEAR BOX W/ENGINE DRIVEN HYD. PUMP ATTACHED
61.	(510)	STARTER VALVE
62.	(509)	GEARS - SPEED SENSOR
63.	(508)	LARGE PIECE OF TIRE
64.	(507)	TRANSMITTER FUEL FLOW
65.	(506)	SUPPORT - IDLER CRANK THROTTLE SYSTEM
66.	(505)	TRANSFER GEAR BOX
67.	(504)	ENGINE DRAIN MODULE W/TUBING P/N ASL0268-1
68.	(503)	NO. 3 ENGINE FAN CASE
69.	(502)	AC GENERATOR
70.	(501)	TRANSMISSION
71.	(W50)	LP TURBINE MID SHAFT
72.	(W51)	PIECE OF WHEEL
73.	(W39)	HP COMPRESSOR ROTOR (PAN AM SERVICE SHED)
74.	(M4)	PIECE OF TIRE
75.	(M3)	PIECE OF TIRE
76.	(M2)	PIECE OF TIRE
77.	(M1)	PIECE OF TIRE
78.	(W40)	PIECE OF TIRE
79.	(W41)	PIECE OF TIRE
80.	(W42)	PIECE OF TIRE
81.	(W43)	PIECE OF TIRE



SYMBOL KEY

*****	INTERMITTENT METAL SPLATTERS
▨	BURNED-OUT AREA

1. AVERAGE ELEVATION OF RUNWAY
   ℄ 11.8 M.S.L.
2. COORDINATES
   LAT. 40°38'28.8"N
   LONG. 73°46'41.4"W
3. 100 0 100 200
   SCALE (FEET)

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D.C.

WRECKAGE DISTRIBUTION CHART

OVERSEAS NATIONAL AIRWAYS

MCDONNELL-DOUGLAS DC-10-30, N1032F

JOHN F. KENNEDY INTERNATIONAL AIRPORT
JAMAICA, NEW YORK

NOVEMBER 12, 1975

APPENDIX E

ENGINEERING STUDY OF DYNAMIC LOADS CAUSED BY SUDDEN CHANGES IN FAN ROTOR BALANCE

The investigation initially considered that the compressor case separations resulted from extremely high torsional forces generated in the fan case by fan blade damage caused by foreign object ingestion. This damage and metal particles caused heavy rub between the fan blades and fan case (fan drag torque), and subsequent fan rotor assembly imbalance. In addition to these torsional forces, large bending forces occurred as a result of fan rotor assembly imbalance. These loads produced forces on the compressor case bolts. The torque forces produced direct shear loads. The bending forces produced both indirect shear and tensile loads with the shear-type loading being more predominant. As a result of these forces, the compressor case's horizontal split line flanges began to slip relative to each other. Since torque forces applied to the cases were greater than the clamping force of the bolts, a shear load was received by the body-bound bolts. (Four of these bolts are located in the front compressor case and two are located in the rear compressor case.) The body bound bolts then failed in shear. The compressor case's horizontal split line flanges continued to slip. The nonbody-bound bolts then failed.

A detailed engineering study of the dynamic loads which result from sudden changes in fan rotor balance due to blade damages was conducted by the engine manufacturer.

The engineering study assumed an instantaneous increase in fan imbalance to 122,800 gram inches, at 3,741 rpm. The vibration amplitude required very little time to build up. In the process of the vibration buildup, the fan blade tips rubbed the fan shroud material and the containment ring; this resulted in a radial interference load and concurrent tangential load caused by friction. This loading would also be increased if blade fragments were wedged at the blade tips. These loads occurred at a point on the rotor lagging the rotor heavy spot by 90°. The effective coefficient of friction between the fan blade tips and the fan case was not known. For the study, a coefficient of friction of 0.3 was assumed.

The buildup in radial and tangential loads resulted in a concurrent buildup of torque which tended to decelerate the fan rotor. The torque-rise time was about 0.06 seconds, which is about one-half the fundamental torsional mode period of the installed engine. This sudden application of torque resulted in a dynamic amplification, and a peak torque in the compressor case of 1,100,000 inch-lbs and occurred at about 0.12 seconds, or at about 3,500 rpm. At the same time, compressor case loads imposed by engine bending occurred and produced additional shear loads in the compressor case's horizontal split line. These loads occurred simultaneously with the corresponding operational torque, thrust loads, static loads, and pressure loads.

APPENDIX E

The study concluded that there were two conditions when the combined loading peaked--at 3,400 to 3,500 fan rpm's when the predominant loading was torque, and at 3,000 fan rpm's when predominant loadings were either torque or transverse shear. There are, of course, many amplifying factors, such as a lack of any support from the cowling and fan thrust reverser and the effective friction coefficient between the fan blade tips and the fan case. When the HPC bolts failed because of either of the two peak load combinations, the largest component of bolt loading at the compressor case's horizontal split lines would be shear. The bolts that had been installed in the split line locations on the accident engine showed some indications of shear deformation, but the bolts failed primarily in tension bending.

Several component tests were conducted to demonstrate the above theory. These tests included a full scale static engine test to provide a structural simulation of the maximum load conditions necessary to induce HPC case yield. Tests revealed that field failures of compressor cases could not be duplicated by the above torque-failure theory. The nearest degree of correlation to the accident case was demonstrated by inducing a hoop tension load in the compressor cases, in order to produce essentially a tensile loading in the compressor case bolts, and subjecting the case to a shock load.

A full-scale static engine structure was subjected to loads which simulated engine operating torque, internal operating pressures, bending moments resultant from an approximate 150,000 gram-inch fan rotor assembly imbalance (equivalent to the separation of two blades below the part span shroud), and engine thrust. Thus, the engine was subjected to a total static torque of approximately 4.72 by 10^6 inch-lbs, which represented a summation of the above loads. At these loads, the fan frame buckled; the compressor cases also yielded by becoming elongated around the variable stator vane bores. However, the compressor bolts and mounting flanges did not break.

Three operational diagnostic tests were performed on a factory development engine in the manufacturers test cell. The initial test consisted of artificially inducing a 25,000 gram-inch fan rotor assembly imbalance by an explosive bolt release of a weight which was installed in a fixture that was located in the fan disc bore. The engine was inspected after release of the weight; the engine did not display any evidence of overpressure. The engine was not damaged except that approximately 1 1/2 lbs of fan booster stage phenolic microballoon epoxy rub shroud material was rubbed out. This engine was a standard CF6-50 configuration except for the installation of stronger compressor case bolts.

A second test was conducted on the same engine using the same configuration of compressor case bolts. A weight commensurate with 50,000 gram-inches of fan rotor assembly imbalance was released in the same manner as cited above. In this instance, the left side of the compressor case separated between stages 4 through 8. Seizure torques between 300,000 to 500,000 psi were demonstrated, which represented about 10 percent of the maximum torque load condition required to induce HPC case yield. The engine also bore evidence of stall. Approximately 2.5 lbs of rub shroud material was ground away.

Evaluation of the test results showed that within 55 milliseconds after weight release, the HPC case flange split open within four fan revolutions. Fan rotation speed dropped from 4,000 rpm to 3,600 rpm within 120 milliseconds, or within seven fan revolutions. Pressure rate increases in excess of 35,000 psi/second were recorded during this excursion. The peak rate increased approximately 1 millisecond before the case split. In 5 milliseconds, the temperature rose from 1,000°F. to 1,500°F. Maximum differential overpressure was approximately 225 psi. The pressure peaked for 0.6 milliseconds. Within 1 millisecond, the pressure again rose to about 235 psi.

A third diagnostic test was conducted on a second factory development engine. This engine was the same configuration as the first engine except that the abradable fan booster stage shroud rub material was removed and was replaced by aluminum honeycomb shroud material. The engine was also subjected to an induced fan rotor assembly imbalance of 50,000 gram-inches. With the aluminum honeycomb shroud material installed and 50,000 gram-inches of induced imbalance, the engine functioned normally. Test data showed no evidence of abnormal pressure activity or indications of overpressure. The compressor cases remained intact, and there was no evidence of stall. The compressor case bolts used for this engine were typical of those used in field service.

Deformation Locations and Results of Calculations

Numerous deformations which were not associated with any mechanical loadings were observed in the combustion and turbine areas of No. 3 engine. None of these deformations have been observed or reported on any other General Electric field or factory engine. The locations of the deformations are keyed on the engine cross section drawing on page 39.

Results of Calculations

1. Diffuser extension in flowpath
   Buckled radially inward
   Normal differential pressure is negligible
   Pressure required for buckling is between 160 and 245 psi
     differential pressure

APPENDIX E

2. Mini-Nozzle bolts
   Tensile fracture in threaded section
   Normal differential pressure is 223 psi
   Pressure required for bolt fracture is 430 PSI differential pressure

3. Turbine Nozzle Support Cone
   Pressure buckling - 18 node
   Normal differential pressure is 223 PSI
   Pressure required for 18 node buckling is 472 PSI differential pressure

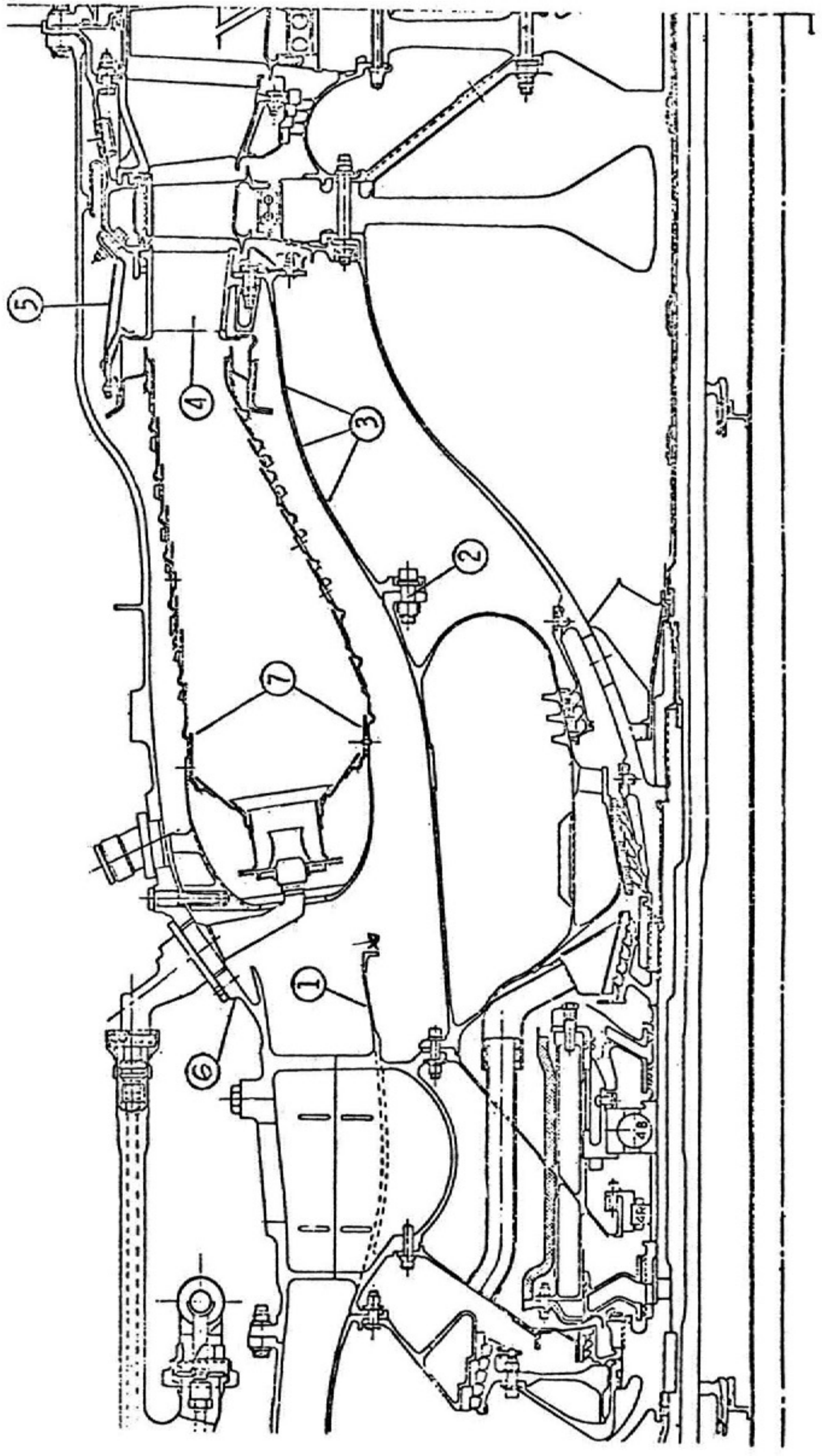
4. Stage 1 High Pressure Turbine Nozzle Vanes
   Pressure side bulge
   Normal differential pressure is 15 PSI
   Pressure required for bulges is 350 PSI differential pressure

5. Nozzle Screen Support
   Radial inward buckling
   Normal differential pressure is 6.7 PSI
   Pressure required for buckling is 50 to 80 PSI differential pressure

6. Fuel Nozzle Mounting Flange
   Permanent outward deformation
   Normal differential pressure is 430 PSI
   Pressure required for permanent deformation is 600 PSI differential pressure

7. Combustor Liner
   Inward and aft buckling of shell
   Normal differential pressure is 15 PSI
   Pressure required for buckling is 192 PSI differential pressure

DEFORMATION LOCATION



APPENDIX F

Design Similarities/Differences Between CF6-6D and CF6-50 [8]

(a) Stage 1 Fan Blade

The CF6-50 fan blade is identical to that of the CF6-6. The maximum fan speed of the CF6-50 is 4,180 rpm whereas the CF6-6 containment test speed was 3,950 rpm. This difference in speed represents approximately 12 percent greater energy for the CF6-50: 156,300 ft. lbs. vs. 139,600 ft. lbs. The fan casings and containment structural geometry are the same for these two engines. Consequently, the CF6-50 containment structure thickness was increased by an amount proportional to the square root of the energy.

(b) Low Pressure Compressor (Booster)

The three booster stages of the CF6-50 are compared to the single booster stage of the CF6-6. The kinetic energy levels of the CF6-50 booster blades at 4,180 rpm are: Stage 2-4,070 ft-lbs, Stage 3-3,560 ft-lbs, and Stage 4-2,775 ft-lbs. This compares to an energy level of 2,360 ft-lbs for the single CF6-6 booster stage at 3,950 rpm. The casing and shroud structure over each booster stage had been analyzed and found to be adequate to insure blade containment.

(c) High Pressure Compressor

The compressor blading of the CF6-50 was essentially identical, except for material changes, to that of the CF6-6. The maximum compressor speed of the CF6-50 is 10,670 rpm compared to 9,900 rpm for the CF6-6, which represents a speed increase of approximately 8 percent. It has been determined by analysis that the increased strength of the titanium casing was sufficient to absorb the additional energy present in the CF6-50 and provided adequate containment.

(d) High Pressure Turbine (HP)

The CF6-50 HP turbine has, as has the HP Turbine of the CF6-6, a substantial containment margin due to the multiple layers of heavy engine structure surrounding both turbine stages. This margin was demonstrated by containment of failed blades on TF 39 and CF6-6 engines. Analyses indicated that the kinetic energy of the Stage 1 and 2 blades was 28 percent and 18 percent, respectively, of the energy required to penetrate the surrounding structure.

8/ This data was extracted from CF6-50 certification data "Containment" FAR 33.19, Report No. R70AEG457, December 31, 1970.

APPENDIX F

(e) Low Pressure Turbine (LP)

The first three stages of the CF6-50 LP turbine have lighter blades than the TF39 and CF6-6 engines. This offsets the effect of higher CF6-50 speed and consequently results in equal or lower kinetic energy levels. Therefore, similar casing thicknesses on the CF6-50 and the CF6-6 provides equivalent containment. The CF6-50 Stage 4 blade, however, because of the higher rpm, represents about 15 percent higher energy than stage 5 of the CF6-6. For equivalent containment capability, the Stage 4 containment structure of the CF6-50 is greater by an appropriate amount than CF6-6 Stage 5 to absorb the additional energy.

APPENDIX G

DEPARTMENT OF T .NSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20591

OFFICE OF
THE ADMINISTRATOR

RECEIVED
APR - 2, 1976
Notation 1749B

Honorable Webster B. Todd, Jr.
Chairman, National Transportation Safety Board
800 Independence Avenue, S. W.
Washington, D. C. 20594

Dear Mr. Chairman:

This refers to your Safety Recommendations Numbers A-76-59 through 64 issued April 1 covering the General Electric Company Model CF6 engine.

We have reviewed these recommendations and offer the following comments. You will note that some of the actions reflected will require further development on our part and we will keep you apprised.

Recommendation No. 1. Require immediate retest of the General Electric CF6 engine to demonstrate its compliance with the complete bird ingestion criteria of AC 33-1A.

Comment. General Electric is conducting an in-depth investigation aimed specifically at determining the cause of the compressor case failure and identifying corrective action that may be needed. The test program is being run on an expedited basis and we will keep you advised of the schedule and findings.

Recommendation No. 2. Require that any engine modifications necessary to comply with the bird ingestion criteria of AC 33-1A be incorporated into all newly manufactured CF6 engines.

Comment. The test results will be assessed and used as the basis for substantiating any required modifications for newly produced engines.

Recommendation No. 3. Require that any engine modifications necessary to comply with the bird ingestion criteria of AC 33-1A be incorporated into all CF6 engines in service.

Comment. We will give careful attention to the inservice engines and, based on the program now in process, will develop appropriate corrective measures.

Recommendation No. 4. Until the CF6 engine is modified, require that a bird patrol sweep runways at all airports which have recognized bird problems and are served by CF6-powered aircraft. The sweep should be made before a runway is put into operation for CF6-powered aircraft and at sufficient intervals thereafter to assure that a bird hazard does not exist.

Comment. The FAA has a current, on-going program to identify those airports having bird problems and to seek the most viable means of reducing or eliminating any associated hazards. A special agency task force was established March 12 to pursue this program. A series of meetings are planned with airport operators, the Air Transport Association, the Airport Operators Council International, and the airlines to review bird problems experienced in the past and to solicit recommendations for future actions. The FAA will determine which techniques appear to be the most effective and feasible and will develop a national plan of implementation.

Recommendation No. 5. Advise all operators, domestic and foreign, of CF6 engines of the catastrophic consequences of foreign object damage and the need for appropriate caution to avoid such damage.

Comment. We will advise all operators of CF6 engines within seven days of this recommendation.

Recommendation No. 6. Amend 14 CFR 33.77 to increase the maximum number of birds in the various size categories required to be ingested into turbine engines with large inlets. These increased numbers and sizes should be consistent with the birds ingested during service experience of these engines.

Comment. Consistent with your recommendation, the Agency is in the process of scheduling a regulatory review with all interested parties to identify areas needing possible revision in FAR 33. Special attention to FAR 33.77 will be given.

Sincerely,

John L. McLucas
Administrator

APPENDIX G

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D.C. 20591

OFFICE OF
THE ADMINISTRATOR

RECEIVED
APR 28. 1976
Notation 1749B

April 26, 1976

Honorable Webster B. Todd, Jr.
Chairman, National Transportation Safety Board
800 Independence Avenue, S. W.
Washington, D. C. 20594

Dear Mr. Chairman:

This is to keep you apprised of developments with regard to your Safety Recommendations A-76-59 through 64, as requested in your letter of April 9.

As you know, General Electric is planning to continue testing of the CF6 engine to validate the use of an aluminum honeycomb fan booster compressor shroud rub strip. One or more tests are planned. The first test, using a CF6 engine, is scheduled for the end of April. Further testing may be scheduled depending on the results of this test. Any decision by the Federal Aviation Administration with respect to actual bird ingestion tests will be made only after analysis of all test results.

Concurrently, the FAA is actively pursuing the problem of airport bird hazards. The special task force, formed on March 12, has now visited John F. Kennedy Airport in New York, Dulles Airport, Washington, D. C., Peachtree-DeKalb Airport in Atlanta, Georgia, Tallahassee and Jacksonville Airports in Florida, and Charleston Airport, South Carolina. These visits served to provide the task force with valuable information to be used in developing a national program of bird hazard reporting and alleviation.

As a first step, a General Notice (GENOT - an FAA internal telegraphic message) was developed and transmitted to all regions to implement a 60-day special emphasis program designed to identify airports having bird problems and to initiate action directed at alleviating the hazards at these airports. The GENOT included a list of available publications to assist field personnel in the formulation of local programs. A copy of this GENOT is enclosed.

We will keep you informed of further developments.

Sincerely,

J W Cochran

J. W. Cochran
Acting Administrator

Enclosure

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D.C. 20591

OFFICE OF
THE ADMINISTRATOR

June 15, 1976

Notation 1749A

Honorable Webster B. Todd, Jr.
Chairman, National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, D.C. 20594

Dear Mr. Chairman:

This is in response to NTSB Safety Recommendations A-76-15 and 16.

Recommendation No. 1. Rescind the Technical Standard Order (TSO) approving the American Safety, Inc., dual retractor restraint system until it is modified so that the seatbelt cannot release inadvertently.

Comment. We consider Technical Standard Order (TSO) C-22 satisfactory. The American Safety dual retractor system fully complies with the minimum standards of the TSO.

Recommendation No. 2. Issue an AD to prohibit the use of all rearward-facing flight attendant seats on DC-10 aircraft until the deficiencies of the restraint systems are corrected or until a suitable alternate restraint system is installed.

Comment. Investigation of the DC-10 dual retractor restraint system indicates that nonrestraint condition could occur if system is incorrectly used. An All Operators Letter, AOL-10-1033, was issued by McDonnell Douglas on April 6 advising DC-10 operators of correct fastening/adjustment procedures of flight attendant seatbelts. The Federal Aviation Administration (FAA) issued a message to all DC-10 Principal Operations Inspectors on March 10 to assure that operators disseminate this information to all flight attendants as an interim measure. The FAA is initiating a Notice of Proposed Rule Making AD to have the restraint systems corrected.

Sincerely,

J. W. Cochran

J. W. Cochran
Acting Deputy Administrator

APPENDIX G

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20591

OFFICE OF
THE ADMINISTRATOR

JUN 16 1976

Honorable Webster B. Todd, Jr.
Chairman, National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, D.C. 20594

Dear Mr. Chairman: Notation 1749

This is in response to NTSB Safety Recommendations A-76-8 through 14.

1. The Federal Aviation Administration (FAA) requested that the Port Authority of New York and New Jersey advise concerning the plan to implement the four recommendations. The Port Authority has responded. The reply was not considered completely satisfactory. As a result, a meeting was held May 20 between the Eastern Region of the FAA and the U.S. Fish and Wildlife Service.

With the concurrence of the U.S. Fish and Wildlife Service we have made the following conclusions with respect to Items (a) through (d).

(a) Additional work needs to be accomplished.

(b) We concur with the Port Authority that removal of the pier is not necessary provided a modification which will prevent roosting or resting by birds is made.

(c) We also concur with the Port Authority that the beaches adjacent to the south and east boundaries of the airport do not cause a bird problem.

(d) The balloons flying above the Chapel Pond are not effective. The pool should be drained.

We are transmitting the above conclusions to the Port Authority. We will request that the Port Authority report on Items (a) and (d) within 30 days.

2. The determination of what constitutes a "recognized bird hazard problem" is a complex, variable science to which no definitive set of standards or criteria can be developed for all airports. We have, however, initiated a study to identify those certificated airports having large concentrations of birds which could be a hazard. Analysis of the results of the study should provide direction for action. We expect the study to be completed in nine months.

3. A detailed review of the Airport Operations Manual is made during each annual inspection of an airport. Consideration is being given to several possible revisions to Operations Manuals in the area. The results expected from the studies underway and contemplated should define and ensure compliance with manual contents and indicate the frequency of reviews necessary on a case by case basis. We anticipate that the above actions will be completed within one year.

4. When the study identified in Item 2 is completed, we will determine the type of specialized expertise needed within each jurisdictional area.

5. The study and subsequent analyses described in Item 2 may indicate a necessity for formal ecological studies to determine the fact of any existing hazardous conditions and methods for hazard reduction. Any expansion of our current undertaking or efforts to regulate are limited by economic impact, Federal financial assistance capability, and available FAA resources.

6. Concurrently with studies initiated on bird hazards we will revise FAA Form 5280-3, Airport Certification Safety Inspection, to provide guidance to certification inspectors on bird hazards. We expect to complete the revision concurrent with the study identified in Item 2.

7. Our comments on Item 1 include the areas of concern in this recommendation. The FAA is working hand in hand with the New York and New Jersey Port Authority to develop measures for the control of these problems.

Sincerely,

John Mc Lucas
John L. McLucas
Administrator

APPENDIX G

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D.C. 20591

OFFICE OF
THE ADMINISTRATOR

JUL 26 1976

Notation 1749B

Honorable Webster B. Todd, Jr.
Chairman, National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, D.C. 20594

Dear Mr. Chairman:

This supplements our April 2 and 26 responses to NTSB Safety Recommendations A-76-59 through 64.

The General Electric Company, through full-scale controlled engine failure testing, has been able to reproduce the mode of compressor failure experienced by the Overseas National Airlines DC-10 on November 12, 1975.

The failure was achieved on a CF6-50 engine at the Peebles test facility in Peebles, Ohio, on February 29 by instantaneous unbalance of the rotor in the region of the mid-span shroud to create a 50,000 gram inch unbalance. The unbalance generated causes sufficient interference to occur between the three booster stage fan blades and the epoxy shroud material to provide a fine powder which permitted auto-ignition under elevated temperature and pressures. Subsequent laboratory material tests on scale models supported the failure mode experienced on the full-scale engine tests.

In order to further confirm that the abradable epoxy material was the cause of the ONA engine failure, CF6-6 and CF6-50 engines were built up with the epoxy eliminated on the CF6-6 engine and replaced with an abradable aluminum honeycomb material on the CF6-50 engine. Both engines were configured to incorporate the modifications which were being considered for service release and field modification.

At this point, considerable thought was given to whether the engine failure should be induced by bird ingestion or through controlled fan blade failure to produce a controlled engine rotor system unbalance.

On the basis of operational experience as well as certification tests where bird ingestion damage was encountered, it appeared highly improbable that the bird ingestion would produce enough unbalance and subsequent damage to create the service failure mode. It was, therefore, considered most appropriate to simulate a bird strike by controlled fan blade failure to a degree exceeding the most severe unbalance conditions encountered to date. It was also considered important to unbalance conditions with the abradable epoxy removed and with the abradable epoxy replaced with aluminum honeycomb material.

The tests on the CF6-50 engine were completed April 29 and on the CF6-6 engine on May 6. No indications of over pressure of the high compressor case or case separation at the bolted flanges were encountered.

The Federal Aviation Administration participated in the above test program planning and concurs that the controlled unbalance tests were more severe than could be encountered by inservice bird strikes and that a viable field modification program to the engine has been proposed by General Electric to eliminate future high pressure compressor case failures.

Notices of Proposed Rule Making (NPRMs) have been issued specifying that the modification of inservice engines commence immediately with a scheduled completion date of June 1, 1977, for CF6-50 model and July 1, 1977, for the CF6-6 model engines. The modification is being incorporated in all new production engines.

We believe that the action described above satisfies the intent of the recommendations.

Sincerely,

John McLucas

John L. McLucas
Administrator

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