Uncontained engine failure, National Airlines, Inc., DC-10-10, N60NA, Near Albuquerque, New Mexico, November 3, 1973

Micro-summary: **This McDonnell Douglas DC-10-10 experienced an uncontained engine failure in cruise, with components penetrating the fuselate.**

Event Date: **1973-11-03 at 1640 MST**

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

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

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FILE NO. 1-0043

AIRCRAFT ACCIDENT REPORT

NATIONAL AIRLINES, INC.
DC-10-10, N60NA
NEAR ALBUQUERQUE, NEW MEXICO
NOVEMBER 3, 1973

ADOPTED: JANUARY 15, 1975

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D.C. 20591
REPORT NUMBER: NTSB-AAR-75-2

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C. 20591

AIRCRAFT ACCIDENT REPORT

Adopted: January 15, 1975

National Airlines, Inc.
DC-10-10, N60NA
Near Albuquerque, New Mexico
November 3, 1973

SYNOPSIS

On November 3, 1973, National Airlines, Inc., Flight 27 was operating as a scheduled passenger flight between Miami, Florida, and San Francisco, California, with intermediate stops at New Orleans, Louisiana, Houston, Texas, and Las Vegas, Nevada. About 1640 m.s.t. while the aircraft was cruising at 39,000 feet 65 nmi southwest of Albuquerque, New Mexico, the No. 3 engine fan assembly disintegrated and its fragments penetrated the fuselage, the Nos. 1 and 2 engine nacelles, and the right wing area. The resultant damage caused decompression of the aircraft cabin and the loss of certain electrical and hydraulic services. One cabin window, which was struck by a fragment of the fan assembly, separated from the fuselage, and the passenger who was sitting next to that window was forced through the opening and ejected from the aircraft.

The flightcrew initiated an emergency descent, and the aircraft was landed safely at Albuquerque International Airport 19 minutes after the engine failed. The 115 passengers and 12 crewmembers exited the aircraft by using the emergency slides.

As a result of the accident, 1 passenger died and 24 persons were treated for smoke inhalation, ear problems, and minor abrasions.

The National Transportation Safety Board determines that the probable cause of this accident was the disintegration of the No. 3 engine fan assembly as a result of an interaction between the fan blade tips and the fan case. The fan-tip rub condition was caused by the acceleration of the engine to an abnormally high fan speed which initiated a multiwave, vibratory resonance within the fan section of the engine. The precise reason or reasons for the acceleration and the onset of the destructive vibration could not be determined conclusively.

As a result of this accident, the Safety Board has made nine recommendations to the Federal Aviation Administration (FAA).

1. INVESTIGATION

1.1 History of the Flight

On November 3, 1973, National Airlines, Inc., Flight 27, N60NA, was a scheduled passenger flight from Miami, Florida, to San Francisco, California, with intermediate stops at New Orleans, Louisiana, Houston, Texas, and Las Vegas, Nevada.

The flight from Miami to Houston was uneventful. At 1440 1/ the flight departed Houston for Las Vegas on an instrument flight rules (IFR) clearance. The flight was to cruise at 39,000 feet 2/ and arrive at Las Vegas in 2 hours 49 minutes. There were 116 passengers and 12 crewmembers on board.

The climb to 39,000 feet was conducted with the use of the autopilot and autothrottle systems. The aircraft was leveled off at 39,000 feet and when the desired cruising speed of .82 MACH (257 knots indicated airspeed (KIAS)) was attained, the autothrottle was disengaged and the power was reset manually to maintain the speed.

According to the captain, at about 1640, when the aircraft was in the vicinity of Socorro, New Mexico, he engaged the autothrottle system in the airspeed mode with a target airspeed of 257 KIAS. After the airspeed stabilized at 257 KIAS, and following a discussion with the flight engineer about the operation of the engine N_1 (first stage fan) tachometers, the flight engineer pulled the N_1 circuit breakers, and the target airspeed was reduced about 5 kn. on the speed indicator. The captain stated that when the throttles retarded slightly, he disengaged the autothrottles and remarked to the flight engineer that he was satisfied with the function.

At this time, the crew heard and felt an explosion, and the aircraft began to buffet severely. The pilots immediately initiated an emergency descent. The Albuquerque Air Route Traffic Control Center was alerted by means of the emergency code on the transponder that an emergency was in progress.

At 1645 radio contact was established with Albuquerque Approach Control, and the flight was cleared to descend to 8,000 feet and vectored for an approach to runway 26 at the Albuquerque International Airport. At 1659, the flight landed safely.

The emergency equipment was available when the aircraft landed. The passengers and crew evacuated the aircraft via the emergency evacuation slides.

At the National Transportation Safety Board's public hearing concerning the accident, the captain testified that he had detected no discrepancies before the explosion. Just before the explosion, he and the flight engineer had discussed the electronic interrelationship between the autothrottle system and the associated N_1 tachometers. As a result of their

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1/ All times herein are mountain standard, based on the 24-hour clock.
2/ All altitudes herein are mean sea level, unless otherwise indicated.

discussion, it was decided to check certain functions of the system. The captain stated that, "The flight engineer and I were speculating about where the automatic throttle system gets its various inputs, whether it came from, for example, the tachometer, itself, the N_1 tachometer, or from the tachometer generator. So we set up the aircraft in the autopilot and in the airspeed (autothrottle) mode. . . . allowed the airspeed to stabilize (at the preselected 257 KIAS) then selectively, successively pulled the N_1 circuit breakers on 1, 2, 3 engine." He further stated, "We retained a speed mode on the enunciator. I was satisfied at that point that the pick up came at some other point than the gage itself, but to check further, I retarded the speed bug on the airspeed indicator slightly . . . I merely wanted to check to see if the throttle followed the speed bug. I backed up the speed bug approximately 5 knots, and noticed that the throttles were retarding slightly. I reached in and disengaged the autothrottles and turned to the engineer and made some remark to him that I was satisfied with this function and at that point the explosion took place."

The flight engineer stated that after he had pulled the three N_1 circuit breakers, he saw the captain engage the autothrottles and noted that the throttles responded to the resetting of the speed bug. He stated that the captain then disconnected the autothrottle and that he (the flight engineer) reached up and reset the N_1 circuit breakers. He believed that the captain was going to reset the power at this point but could not remember if the throttles had been advanced when the explosion occurred.

Following the explosion, the flight engineer saw the fire warning light in the No. 3 engine fuel shutoff handle and observed that other instruments on his panel indicated various systems failures. He was unable to move the No. 3 fuel shutoff handle. After several unsuccessful attempts, the flight engineer activated the firewall shutoff handle and discharged two fire extinguisher bottles into the No. 3 engine.

He stated that he realized the cabin was depressurizing so he closed the cabin outflow valve and activated the release switch for the passengers' oxygen masks. The first officer, who had been back in the passenger cabin, returned to the cockpit. While the door was open, the flight engineer noticed that the cabin was filling with smoke. He also noted that warning lights on his panel were indicating a failure of the No. 3 AC generator, No. 3 AC bus, and the No. 3 DC bus. He stated that all attempts to restore power on these lines were unsuccessful. He also noted failure indications for the No. 1 generator and the left emergency AC bus. The oil pressure and the hydraulic quantity for the No. 1 engine were low. According to the flight engineer, the captain switched on the emergency power, which restored his flight instruments, and subsequently electrical power was restored to the No. 1 AC and DC buses. He stated that during the approach, the wing slats and flaps operated normally, but that the landing gear had to be extended by means of the emergency extension lever. Although the No. 1 engine's oil pressure and hydraulic quantity continued to deteriorate during the descent and approach, both the engine and the system remained operational throughout the emergency.

It was reported to the crew following the landing that a male passenger, located in seat 17H, had been forced through a cabin window after it had been dislodged from its frame by fragments from the disintegrated No. 3 engine fan assembly. None of the flight attendants stationed in the passenger cabin witnessed this event nor were they made aware that it had occurred until after the emergency landing.

Statements from the flight attendants who were in the passenger cabin and in the lower galley during the engine disintegration indicated that the explosion was followed by blue-grey smoke in the cabin which became progressively more dense toward the rear of the aircraft. They also reported that shortly after the explosion, passenger oxygen masks were presented automatically in the midsection of the cabin, but that in other sections of the cabin, it was almost 3 minutes before the masks dropped. In the rear left side of the cabin, the masks did not deploy at all. Passengers seated in these sections had either to pry the oxygen containers open, or to move to other seats to obtain oxygen masks.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other
Fatal	0	1	0
Nonfatal	4	20	0
None	8	95	

1.3 Damage to Aircraft

The aircraft was damaged substantially when the No. 3 engine fan rotor assembly disintegrated. Pieces of the fan penetrated the lower fuselage, the Nos. 1 and 2 engine nacelles, and the right wing area. One passenger window was struck by a fan fragment and separated from the aircraft.

1.4 Other Damage

None.

1.5 Crew Information

The captain, first officer, and flight engineer were certificated for the flight. (See Appendix B.)

1.6 Aircraft Information

N60NA, a Douglas DC-10-10, was registered to National Airlines, Inc. The aircraft was certificated and maintained according to FAA procedures.

1.7 Meteorological Information

The weather in the area of the accident was reported as: 10,000 feet scattered clouds with a broken cloud ceiling of 25,000 feet. The visibility at the surface was 60 miles, and the wind was from 280° at 18 kn. with gusts to 20 kn. The altimeter setting at Albuquerque International Airport was 30 in.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

Radio communications between the flight and the Albuquerque Center were lost temporarily after the engine disintegrated; however, transmissions between the flight and the Center were relayed by another National Airlines flight which was in the area. Radio communications were reestablished with Albuquerque Approach Control shortly thereafter and were satisfactory throughout the remainder of the approach and landing.

1.10 Aerodrome and Ground Facilities

Runway 26 at Albuquerque International Airport is 13,373 feet long, 300 feet wide, and is concrete surfaced. The field elevation is 5,352 feet.

1.11 Flight Recorders

The aircraft was equipped with a Lockheed Aircraft Service (LAS) Model 209 digital flight data recorder (DFDR) serial No. 135. The recorder was undamaged in the accident. However, despite extensive readout efforts using electronic readout equipment, no meaningful data could be retrieved from the tape. A new tape was then placed into the recorder, and test data were recorded and retrieved successfully.

Although other tests and examinations were conducted using the original DFDR tape, no information was obtained.

Testing of the flight data acquisition unit (FDAU) which was installed in N60NA showed that despite some minor discrepancies, this unit was capable of satisfactory operation.

Both the DFDR and the FDAU were reinstalled on N60NA and ground tested. The engine N_1 self-test parameters and the acceleration parameters were recorded, and the readout indicated satisfactory operation of the system.

NAL maintenance procedures required that the DFDR system be tested for satisfactory operation every 2,000 hours of operation. Records for the DFDR on N60NA indicate that the last test on the system was performed on July 30, 1973. Results of that test as indicated on the applicable maintenance record were as follows:

> "Failed test. Pg. 5 of 11 failed accelerometer chs (checks) other chs unreliable pg. 5 thru pg. 10"

There was no record that these discrepancies had been corrected.

Testimony from NAL maintenance personnel indicated that the DFDR and the FDAU were last tested using electronic testing equipment. When the system did not pass the test, the DFDR and FDAU were replaced with other stock units, and these units were tested. When these units also failed, it was assumed that the test equipment was faulty and the original units were again installed in N60NA. Reportedly, the self-test feature of the system was tested, and it indicated that the system was operating satisfactorily. These same DFDR components remained in N60NA until after the accident.

The aircraft was equipped with a Sundstrand (VCOD) Model V-557 cockpit voice recorder (CVR). The final 22:45.5 minutes of the tape were transcribed.

The following excerpt from the transcript begins 48 seconds before the engine failure and continues for about 2 minutes 22 seconds thereafter:

LEGEND

CAM	Cockpit Area Microphone
-1	Voice Identified as Captain
-3	Voice Identified as Flight Engineer

INTRA-COCKPIT

TIME & SOURCE	CONTENT
00:00.0 CAM-3	Wonder ---, wonder if you pull the N_1, tach will that, --- autothrottle respond to N_1?

00:11.5 CAM-1	Gee, I don't know
00:12.0 CAM- (1 or 3)	You want to try it and see?
00:14.0 CAM- (1)	Yeah, let's see here
00:24.0 CAM-3	You're on speed right now though
CAM- (1)	Yeah
00:28.0 CAM-1	You know what I mean if your annunciated speed --- if you got, ---
CAM- ?	Still got 'em
CAM-1	Well --- --- haven't got it ---
00:36.0 CAM-1	There it is
00:38.0 CAM-1 or 3	I guess it does
00:47.0 CAM-1	Yea, I guess it does -- right on the nose
00:48.0 CAM	Sound of explosion ((simultaneous with word "nose" above))
00:48.0 CAM	Ratcheting sound begins
00:49.5 CAM-1	# (Goldy) what was that?
00:55.5 CAM-?	# #
00:57.5 CAM	Ratcheting sound ends
00:57.5 CAM	Sound similar to rush of air begins

00:59.5 CAM-3	Okay, that's it
CAM	Sound of several clicks
02:34.5 CAM	Sound similar to rush of air flow ceases.

1.12 Aircraft Wreckage

Examination of the aircraft at Albuquerque revealed that the No. 3 powerplant disintegrated substantially at the first stage fan assembly. (See Appendix D., -- Photographs of aircraft and engine.) The major components which separated in flight included the nose cowl, the fan blade containment ring, and 32 of the 38 first stage fan blades. The bulk of these parts were recovered in the desert area near Socorro and were returned to Albuquerque for examination. From Albuquerque, they were shipped to the engine manufacturer's facility (General Electric Company) for detailed inspection and evaluation by the Safety Board.

The nose cowl (inlet duct) was intact. It had broken away along the aft attach area, and the aft portion had been crushed on ground impact. Numerous blade fragments had penetrated through the inner barrel of the cowl. The outer barrel was punctured in eight locations.

The porous sheet from the first acoustic panel, extending from 12:00 3/ to 4:00, was missing from the nose cowl. It had been torn lengthwise at 12:30. A piece of this porous skin, about 230 square inches in area, was found resting against the fan outlet guide vanes.

The fan blade containment ring was recovered in an opened-up and twisted configuration. It separated at the 7:00 position, and the entire ring appeared torn and distorted, with considerable abrasion along the inner surface of the ring. Of the 12 bolts that attach the nose cowl to the containment ring, only portions of 5 bolts were recovered. The fracture surfaces of the bolts showed evidence of failure in shear. The 12 attachment bolt holes had deformed in various directions. The predominant forces, however, as shown on both the nose cowl and the containment ring, were in the direction of engine rotation.

Twenty-four fan blade root sections, each with a different amount of blade remaining, including the six blades which remained in the fan disk, were recovered. Damage to the blade roots and fan disk showed forward movement past the blade restraining devides and out of the slot for each of the 18 blades which had departed the engine. For each of

3/ All locations herein designated in reference to block positions are as viewed from the rear of the powerplant looking forward toward the front of the aircraft.

the six blades that remained in the disk, the damage indicated some rearward movement in the slot.

The N_1 shaft had a spiral fracture near the forward end and was bent slightly in the crack area.

Main bearings Nos. 1, 4, 5, 6, and 7 were found in near serviceable condition. The Nos. 2 and 3 main bearings had disintegrated. There was no evidence of prefailure distress in the engine mounts, in the high pressure compressor, or in either of the turbine assemblies. The fuel nozzles and the combustion area showed no abnormalities. The fuel control unit was bench tested and was capable of normal operation.

Examination of the No. 1 engine revealed that it had been struck by fragments from the No. 3 engine fan assembly. One fan blade section had punctured through and protruded out of, the far side of the engine oil tank. Electrical wiring from the No. 1 generator constant speed drive (CSD) unit was severed. One fan blade tip section was found in the bottom of the cowling in this area.

The torque values on the cowl to containment ring bolts were measured to determine if they were within 336 to 384 inch-pounds, the prescribed torque range. Only 1 of the 12 bolts was found to be within these tolerances. Three bolts were above the torque range, while the remaining eight were below. When all the bolts were retorqued to 336 inch-pounds, the overhang on 10 bolts was more than the prescribed maximum.

Examination of the No. 2 engine revealed that it also had been struck by fragments from the No. 3 fan assembly and had been abraded in the area of the fan blade shroud. There was also leading edge damage to two fan blades, and there was a small piece of the fan blade embedded in the front section of the nose cowl. Engine interior inspection by borescope revealed a stage compressor blade with one small nick and a stage 7 blade with two small nicks.

The aircraft structure exhibited numerous punctures and tears in the lower fuselage skin, primarily in the area of the No. 3 engine. The lower fuselage skin had been punctured in six areas, each ranging between 170 and 540 square inches. Other small punctures and skin damage were found in the right wing along the inboard leading edge and the fuselage fillet area. One puncture on the underside of the right wing extended into the inboard fuel tank.

A window panel, located at station 1129, was missing. The outer pahel, inner panel, window seal acoustic panel, and seal had separated from the aircraft. The anacoustic seal support was cracked along the forward edge of the window, from above the horizontal centerline to the lower edge vertical centerline. Three of the eight window panel retaining clips, two on the upper forward side, one on the lower forward side, were broken at or near the end of their adjusting slots. All adjusting screws were tight and in place. There was also a depressed skin tear in the outer landing at the window centerline.

The hydraulic lines for the No. 3 system, located in the right hand wing fillet area, were torn and severed. The slat extend line from hydraulic system No. 1 was dented and slightly crushed. The Nos. 1 and 3 system hydraulic reservoirs were empty. The No. 2 hydraulic reservoir was found at its normal (full) level.

The control cables for right elevator "up" and rudder trim "nose left" were severed and inoperable.

Examination of cockpit circuit breaker panels and electrical control panel showed that all circuit breakers (C/B's) were set, except for the DC bus 1 C/B which was in the "tripped" position. The three AC bus tie relay switches on the flight engineer's panel were in the "norm" position. No lockouts were found on the corresponding bus-tie relays and all were in the "closed" position. The three DC bus tie switches were found in the "open" position. Because of the damage to the generator feeder cables on the No. 3 engine, the ferry flight from Albuquerque to Long Beach was conducted without having the No. 3 generator connected. All systems operated normally off the AC tie bus to the No. 3 AC bus and to the right emergency bus during this flight and in the subsequent ground tests that were conducted at the Douglas Aircraft Company.

Power for electrical deployment of passenger oxygen masks is obtained from the three AC electrical buses. The No. 1 bus powers all masks forward of fuselage station 816; No. 2 bus powers the masks for the midcabin and the right-hand seats forward of fuselage station 1281. All other passenger mask positions are powered from the No. 3 bus.

Inspection of the passenger cabin at Albuquerque showed that the right aft cabin, midcabin, and forward cabin masks had deployed. The left aft cabin masks had not deployed. When the No. 3 bus was powered during ground checks, these masks deployed satisfactorily.

The pneumatic duct from the No. 3 engine to the center accessory compartment was severed in the right-hand wing fillet area. Two holes, each about 4 square inches, were found in the pneumatic duct in the center accessory compartment leading to the No. 3 air conditioning pack. Three holes, each between 2 and 3 square inches, were found in the pneumatic duct in the center accessory compartment leading to the No. 1 air-conditioning pack.

Before the examination of the aircraft at Albuquerque, the battery was removed. It was not determined whether DC electrical power was applied to the battery bus before or during the removal of the battery.

Wiring in the No. 3 engine nacelle had separated or had torn loose at the AC generator. Also at the forward part of the right wing fillet area, four of the six No. 3 generator feeder cables and the wiring to the differential current transformer were severed. Additionally, wiring between the No. 3 engine fuel flow transmitter and its associated fuel flow electronics unit was severed.

Wiring was also damaged in the No. 1 engine nacelle. The lead between the No. 1 engine fuel flow transmitter and the fuel flow electronics unit was severed.

The No. 3 AC generator bus tie relay switch was in the "norm" position and the relay was closed. The No. 3 DC bus tie relay switch was in the "open" position, and the relay was open.

Instrument Readings

Several photographs of the instrument panel and the flight engineer's panel were taken during the inspection of the aircraft at Albuquerque. Examination of these photographs revealed the following instrument displays:

Pilot's Instrument Panel

True Airspeed/Static Air Temperature

TAS 473 kn.
SAT - 59^{o} C

Copilot's Instrument Panel

Mach/Airspeed Indicator

Mach .824
IAS 250 kn.

Center Instrument Panel

Engine No. 1 Pressure Ratio and Fuel Flow

EPR 7.07
FF 6,640 lbs./hr.

Engine No. 2 Pressure Ratio and Fuel Flow

EPR 6.93
FF Not indicated.

Engine No. 3 Pressure Ratio and Fuel Flow

EPR 6.93
FF 6,420 lbs./hr.

Flight Engineer's Panel

Engine No. 1 fuel used-14,040 lbs.
Engine No. 2 fuel used-12,930 lbs.
Engine No. 3 fuel used-10,400 lbs.

Total Fuel Quantity	00,400 lbs.
Gross Weight	349,000 lbs.

1.13 Medical and Pathological Information

Five persons reported that they become unconscious after the decompression. Three of the five were standing and were active. The remaining two were seated in the lower galley area and lost consciousness when they stood up to obtain supplemental oxygen.

Twenty passengers and four crewmembers were examined at the military hospital at Kirtland Air Force Base. Ten persons were treated for smoke inhalation, and ten were treated for barotrauma.

1.14 Fire

Not applicable.

1.15 Survival Aspects

The missing passenger was forced through the cabin window near seat location 17H. The window opening was 16 1/8- by 10 5/8 in. with curved corners of 4 1/2 in. radius. Although the seatbelt was fastened, about 8 inches of slack existed when it was fastened around a person of the weight and build of the missing passenger. According to a witness, the occupant of the seat was partially forced through the window opening and was temporarily retained in this position by his seatbelt. Efforts to pull the passenger back into the airplane by another passenger were unsuccessful, and the occupant of seat 17H was subsequently forced entirely through the cabin window.

The New Mexico State Police and local organizations searched extensively for the missing passenger. A computer analysis was made of the possible falling trajectories which narrowed the search pattern. However, the search effort was unsuccessful, and the body of the passenger was not recovered.

To the passengers, the cabin decompression sounded like a loud explosion. The cabin filled with a blue-grey smoke, which became progressively more dense toward the rear of the cabin. The DC-10 is equipped with emergency supplemental oxygen for all cabin occupants. Oxygen generating units and appropriate dispensing equipment generally are located in compartments in one of the seatbacks of each double seat unit. The other seatbacks contain storage space for lifevests. Oxygen units are also located in compartment divider partitions and at each flight attendant station. In the galley, lavatories, and above some first row seats the units are installed in ceiling compartments.

The oxygen generators produce oxygen through the thermal decomposition of sodium chlorate by chemical reaction. When a lanyard, attached to the oxygen mask, is pulled, a pin at the end of the lanyard frees a spring-loaded striker on the oxygen generator which in turn ignites the sodium chlorate core and thereby generates heat and produces oxygen. The oxygen is routed through a filter and a supply hose into a reservoir bag which is attached to an inhalation valve on the face of the oxygen mask. For storage purposes, the reservoir bag is folded inside the mask and the supply tubing is coiled on top of the bag. The entire mask assembly is held in place on the inside of the oxygen compartment door by a wire holder. The compartment doors are held closed by electromagnetic latching devices which operate on a single-phase, 118 volts AC, 400-cycle electrical signal. Various sections of the passenger cabin are supplied this AC electrical power, separately and independently, by one of the three AC buses which comprise the AC electrical system. The compartment door latching mechanism may also be operated manually by inserting a small diameter object into an opening in the bottom edge of the door.

Statements from the flight attendants and passengers indicated that the passenger oxygen masks were not all presented simultaneously. Depending on the cabin location, the time lapse between the start of the decompression and the presentation of masks ranged from a few seconds to over 3 minutes. Several flight attendants and some of the passengers forced open the oxygen compartment doors to obtain oxygen.

Some of the passengers reported that they did not know how to use the equipment. Some removed the mask from the compartment door, and leaned forward toward the mask, rather than pulling the masks toward them. This prevented the lanyard from being pulled, and consequently the unit was not activated. Other passengers stopped using the masks, either because they could not discern oxygen flow or the reservoir bags did not inflate, or both, which caused them to believe that the equipment was defective.

At three seat locations, the oxygen generators were pulled from their mountings and the hot cylinders (as high as 547° F.) severely scorched seat upholstery. One flight attendant attempted to pick up one of these cylinders from a seat, and her fingers were burned severely.

Most flight attendants circulated throughout the cabin to aid passengers with their oxygen equipment and to prepare them for a possible emergency landing. Despite the heavy irritating smoke in the cabin, none of the attendants used the portable oxygen equipment. A few attendants reported that they would occasionally take oxygen at individual seats by using passengers' masks.

In the lower galley, two flight attendants were seated in the jumpseat facing the elevators when they heard the explosion. They immediately felt a surge of air and saw napkins and pot holders fly through the air toward the rear of the galley. The doors to the storage and serving cart areas opened, and some of the serving carts moved partially into the galley area. The personnel lift dropped to the lower galley position, and the lift access door opened. The flight attendants noticed that the overhead oxygen compartment was still closed, and they stood up to obtain the portable oxygen equipment which was stored behind the escape ladder. Both flight attendants became unconscious before they could reach the equipment. One of them regained consciousness shortly afterward and was able to get up to the passenger cabin by means of the cart lift.

All passengers were instructed about the bracing position in preparation for an emergency landing at Albuquerque. The landing was relatively uneventful, and after the aircraft stopped, the flight attendants opened the exits and deployed the evacuation slides.

The slide pack at the left forward door fell to the floor of the cabin, and the flight attendant at that position threw it out of the door. She noted that the slide did not inflate, whereupon she followed the instructions printed on the flap which covers the girt ditching release handle. The instructions on the flap read:

1. LIFT FLAP
2. PULL HANDLE

Immediately above this flap are printed the words:

"FOR DITCHING ONLY"

and a red handle labeled "PULL" is situated to the left side of these words. When the flap is pulled up, the words "TO RELEASE SLIDE" become visible and a white handle, labeled "PULL" is situated directly below these words. Also, "TO INFLATE" is printed below the red handle.

The flight attendant stated that she did not see the red inflation handle and therefore followed the instructions on the girt flap, lifted the flap, and pulled the handle. The slide was consequently jettisoned from the door sill. The red inflation handle is not immediately visible to flight attendants on an uninflated emergency slide because it is located beyond the door sill.

The emergency slide at the right forward door deployed normally but did not inflate. The flight attendant at that door pulled the manual inflation handle, and the slide inflated properly. All other emergency slides deployed and inflated automatically. However, the slide at the right overwing exit did not deploy across the engine pylon but remained on top of the wing and was useless. The aircraft was evacuated without major difficulties in about 60 seconds through six of the eight cabin exits.

1.16 Test and Research

1.16.1 Autothrottle System Study

Postaccident examination of the aircraft CVR and testimony given at the public hearing indicate that the crew was using the automatic throttle system for thrust control at or shortly before the engine failed. The evidence further disclosed that the captain and the flight engineer, after speculating about the effects of interrupting certain electrical circuits upon autothrottle system operation, pulled the circuit breakers to observe the results. The circuit breakers were subsequently reset. The exact time sequence of resetting the circuit breakers and the disintegration of the engine fan assembly was not established.

The DC-10 aircraft has two independent autothrottle/speed control systems which are usually engaged separately. When operating in the autoland mode, both systems are engaged and operate to provide the required degree of redundancy.

The autothrottle system is designed to automatically position the throttles to maintain either a selected airspeed or a thrust-level schedule based on the engine low-pressure compressor rotational speed (N_1). The heart of the system is the autothrottle/speed control (AT/SC) computer. This unit accepts inputs from the central air data computer (CADC), the thrust rating computer (TRC), engine speed sensors, aircraft attitude and acceleration sensors, control surface position sensors, and other significant parameter transducers and provides the proper output to an electrical servo which drives the throttles. The pilot engages either or both systems and selects the desired operating mode, i.e., N_1 or airspeed from an autothrottle control panel located on the instrument panel glare shield. The desired airspeed is also selected on this panel.

The TRC accepts pertinent air data and generates a signal which corresponds to the maximum engine N_1 limit allowable for a particular operating mode selected by the pilot, i.e., takeoff, climb, cruise, maximum continuous thrust, or go-around. This N1 limit established by the TRC controls the upper limit of the AT/SC authority. A selected airspeed which would require thrust in excess of that developed at the appropriate N_1 limit will cause the throttles to advance only to the position which corresponds to the established N_1 limit.

Thus, in speed mode operation, the AT/SC system drives the throttles to a position which nulls out the error between the selected airspeed and the CADC airspeed input. As the throttles advance, an engine N_1 signal generated by the N_1 fan speed sensor through the N_1 RPM indicator, is compared with the signal which corresponds to the TRC N_1 limit. When this error reaches null, the throttle stops advancing regardless of the existing airspeed error. When operating in the N_1 mode, the AT/SC system drives the throttles to a position where engine N_1 is maintained at the TRC N_1 limit.

The automatic throttle speed control system was examined theoretically to determine the effects on system operation produced when the crew pulled accessible circuit breakers.

The examination revealed that the autothrottle system can move the throttle levers to a maximum throttle quadrant position under certain conditions. The conditions vary depending on the autothrottle operating mode selected. If the N_1 mode is in use and the circuit breakers for all three N_1 tach indicators are opened, the throttles will advance to the mechanical stop. If the speed mode is selected and the three N_1 circuit breakers are opened, the throttles can advance without limit, if an airspeed error is sensed which would require thrust application.

These N_1 tach circuit breakers are accessible to the flightcrew, since they are located on the flight compartment overhead panel. Basically, these circuits provide the signal proportionate to engine speed, which is compared with the N_1 limiting signal established by the TRC to control autothrottle system authority. When these circuits are opened, the N_1 error signal cannot be nulled and the limiting authority is removed.

The rate at which the throttles will advance in response to autothrottle system command was also studied. In the N_1 mode, the throttles advance at an angular rate measured at the control pedestal quadrant of 3°/sec. In the speed mode, a saturated speed error of 16 kn. causes the throttles to move forward at 6°/sec. A speed error signal of less magnitude produces slower throttle motion. If the throttles' positions correspond to the maximum limit established by the thrust rating computer for cruise, i.e., 98.5 percent N_1 when the three circuits are opened, a saturated speed error would cause the throttles to move to the forward stop within 2 seconds.

1.16.2 Engine Operating Parameters and Limitations

The limits approved by the FAA for continuous operation of the GE CF6-6D engine with Service Bulletin 31-7 incorporated, under all environmental conditions, specify the maximum low-pressure compressor speed (N_1) as 111 percent of the reference rating, and the maximum high-pressure compressor speed (N_2) as 101 percent of the reference rating.

The engine limits normally imposed upon autothrottle authority as established by the TRC for 39,000 feet pressure altitude and a total air temperature (TAT) of -30° C were obtained for the selectable operating modes. These limits are as follows:

Takeoff -	102.8 percent N_1
Go Around -	101.8 percent N_1
Max Continuous -	100.8 percent N_1
Climb -	100.6 percent N_1
Cruise -	98.5 percent N_1

The -30° C TAT corresponds to a static air temperature (SAT) of -59° C with an indicated airspeed of 255 kn.

The engine parameters shown on the DC-10-10 cruise control tables for the No. 3 engine, long range cruise operation at 39,000 feet, a standard day SAT of -56.5° C and an aircraft weight of 300,000 lbs. are as follows:

Mach N_1	.819
IAS	255 kn.
N_1	96.2 percent
MCR	99.1 percent
N_2	89.3 percent
EPR	5.25
Fuel Flow	4,104 lbs./hr.
EGT	687° C
TAT	27.4° C
TAS	470 kn.

Those values for fuel flow and engine pressure ratio which were evident on the instrument photos were examined to determine compatibility and to establish a relationship with the specified limits. The estimated parameters listed below were based on an extrapolation of GE CF6-6D engine data for the 39,000 feet pressure altitude, -59° C SAT, and 473 kn. TAS condition.

Other engine parameters estimated to correspond with fuel flow values:

Engine 1	Engine 2	Engine 3
N_1 - 108.7 percent	-	N_1 - 107.7 percent
N_2 - 97.8 percent	-	N_2 - 97.1 percent
EGT - 824° C	-	EGT - 812° C
EPR - 7.39	-	EPR - 7.23

Other engine parameters estimated to correspond with EPR values:

Engine 1	Engine 2	Engine 3
N_1 - 106.9 percent	N_1 - 106.5 percent	N_1 - 106.0 percent
N_2 - 96.5 percent	N_2 - 96.2 percent	N_2 - 95.8 percent
EGT - 803° C	EGT - 797° C	EGT - 793° C
FF - 6,243 lbs./hr.	FF - 6,117 lbs./hr.	FF - 6,033 lbs./hr.

1.16.3 General Electric Company Analysis of CVR Tape

At the request of the Safety Board, the General Electric Company conducted a sound spectral examination of the recorded sounds on the CVR tape from N60NA. Because of difficulties in matching the recorder head spacing of the original CVR tape to the laboratory recording equipment, the Safety Board recorded the cockpit area microphone (CAM) channel data onto a standard 1/4-in. tape at 3 1/2 IPS. This tape was used for the study.

Through a process of sound filtration and special photographic methods, predominant resonances were identified for the time base being examined. The identity of the No. 3 engine was established through an engine sound signature frequency that was picked up during the beginning of the explosive sounds and which terminated shortly thereafter. Two additional engine sounds could subsequently be detected but could not be identified individually by engine position. The three engine sounds were traced back to time 00:00 (all times correspond to the times listed in the CVR transcript) by visually tracking their resonance traces.

The General Electric report states: "This study does not purport to have extreme accuracy and there could be variations of a small magnitude resulting from interpretation and possible CVR speed variations and tape flutter . . . . A summarization of the results of this study are as follows:

"At time 00:00, the speed line of the No. 3 engine is at 97% N_1, and another speed line, believed to be the superimposed speeds of the Nos. 1 and 2 engines, is at 96.5% N_1. These frequencies remain stable and constant until time 00:24, commensurate with the voice on the CVR 'you're right on speed right now though'. At this time the speed lines increase in parallel with the No. 3 engine, which is the higher, reaching 100% N_1.

"The next activity starts at time 00:31 when both speed lines decrease in parallel about 3%. The No. 3 engine then, almost immediately, starts a series of random oscillations of speed between 94% and 100% N_1 with smoothness reappearing at about 00:44. During this period of random oscillation of the No. 3 engine, the No. 1 and No. 2 engines' speed line remains stable.

"The No. 3 engine's speed line starts another oscillation at time 00:47 reaching a speed of 99% N_1 at the start of the first bang at time 00:48. The acceleration of the engine is linear and reaches about 110% N_1 at time 00:49.42 whereupon the No. 3 engine N_1 can no longer be detected.

"The other two engine sounds appear to evolve out of the lower speed line as previously discussed as a probable superimposition of these two frequencies. The first of these engines appears to start its acceleration during the period relative quiet following the first bang and at time 00:49.42 has achieved a speed of about 100% N_1. Acceleration appears to be complete in about seven seconds of elapsed time with the speed stabilizing at approximately 100.5% N_1. The other of the remaining engines appears to start accelerating at time 00:50.2 and reaches stabilization in about eight seconds at about 107% N_1. The two remaining engines continue to operate at these speeds until time 01:14.6 whereupon a substantial speed reduction is made and the engine sounds are no longer discernible.

"The acceleration rate (maximum slope) was calculated for each engine from measurement of time and frequency change. These are as follows: Engine No. 3 - 266 rev/min/sec; the faster engine (of the remaining two) - 129 rev/min/sec; and the slower engine - 96 rev/min/sec."

According to the General Electric study, a maximum acceleration rate of 238 rev/min/sec had been achieved as a result of a complete fan stall. The acceleration rate of the other two engines corresponds to a value slightly less than that calculated for a 3^{o}/sec. throttle advance. The condition required to achieve the acceleration rate of the No. 3 engine is to unload or block the fan air flow.

The supplemental conclusions listed in the report are summarized as follows:

1. The speed of the No. 3 engine was 99 percent N_1 at the time of the initial explosive sound.

2. The No. 3 engine accelerated following the initial explosive sound at a rate of 266 rev/min/sec., which requires a severe restriction of the engine fan air flow in order to be achieved.

3. The two remaining engines were accelerated to a high power setting very shortly after initial explosive sound and remained at this high power until 26.6 seconds after the initial explosive sound.

4. The No. 3 engine exhibited random speed fluctuations of 6 percent N_1 before the initial explosive sound.

5. The No. 3 engine gearbox and electrical system were disabled 7 seconds after the initial explosive sound.

6. Engines No. 1 and No. 2 did not exceed the limit speed of 111 percent N_1. The speed of engine No. 3 was no longer discernible after achieving 110 percent N_1 during acceleration, hence the maximum speed attained could not be determined.

1.16.4 Douglas Aircraft Company Analysis of CVR Area Microphone Signals

The Douglas Aircraft Company conducted an indepth study of the sounds found on the cockpit area microphone to analyze and interpret these signals. The stated objectives of the study were: (1) Establish the characteristics of the CAM/CVR and, in turn, the characteristics or limitations of the system in providing engine related evidence, and (2) determine engine speeds, character of the massive failure sounds, and the nature of other sounds relative to the No. 3 engine failure.

The source of the N60NA CVR/CAM signals was a 2-channel, 1/4-in. recording tape which was re-recorded from the original CVR tape by the National Transportation Safety Board. Two analysis tapes were prepared from this tape and were used in the processing displaying techniques employed in this study.

Several supplementary tests were conducted during the study to acquire comparative data from which to establish CAM/CVR installation characteristics and performance and to determine the type and level of engine-related tones in the cockpit during flight and ground operation. Most of these tests utilized multiple cockpit acoustic recording systems.

The significant conclusions outlined in the Douglas study are as follows:

1. The large value of observed tape speed variation of the CAM/CVR system limits the capability of the system to reproduce any type of discrete frequency tones. The narrow acoustic frequency range of the system further limits the tone capacility related to engine speeds during cruise flight.

2. Engine-speed-related tones cannot be detected in the cockpit during high-altitude cruise flight with the CAM/CVR, or

even with precision flight test acoustic recording/reproducing systems, coupled with advanced spectral analysis systems. This is because a 1 engine speed tone levels are much lower than the background noise levels. Engine-speed-related tones were detected during low-altitude low-Mach flight testing.

3. The major portion of acoustic energy, during the massive failure period, occurred in the first 200 milliseconds and was the only time of sustained high-level noise in the first 10 seconds of the failure period.

4. The cockpit vibratory noise (ratcheting sounds), 4 to 6 seconds after the start of the massive failure period, corresponds with cockpit equipment noises during heavy cockpit vibration. The vibratory frequency corresponds to excited modes of the wing/pylon and fuselage excited by a steadily-decreasing-frequency source from 22 to 16 Hz.

5. The cockpit flow noise, which began about 10 seconds after the start of the massive failure, is similar to the noise made by cockpit pressure-demand oxygen masks discharging automatically in the 100 percent oxygen mode. This identification is substantiated with a cabin decompression calculation.

1.16.5 Previous CF6 Engine Failures

Two previous CF6 engine fan failures were brought to the attention of the Safety Board during its investigation. Both of these failures occurred during test-cell operation, but the similarities between the failure modes found in these engines and the failure mode of the No. 3 engine installed on N60NA are valuable for comparison purposes.

The first failure occurred during test-cell operation of a CF6-6 engine, S/N 451-141, at the American Airlines Tulsa Maintenance Base on November 15, 1972. The engine had been removed from service on November 2, 1972, because of a number of maintenance writeups concerning high vibration. At the time of removal, it had a time since new of 2,045 hours.

At the time of the failure, the engine was undergoing test for trim balance of the fan rotor. The engine was set at maximum continuous power with an N_1 fan speed of 3,308 RPM, core speed 9,200 RPM, and fan vibration of 7.1 mils. After 3 minutes of these conditions, a loud explosion was heard, and it was found that the inlet and exhaust cone had separated from the engine and that all fan blades had been released from the fan disk. The engine and the test cell were damaged considerably.

This failure was investigated by representatives of American Airlines, Douglas Aircraft Company, and General Electric. It was found that

5 of the 11 bolts used to attach the inlet bellmouth to the engine became fatigued over 15 to 50 percent of their cross-sections. These bolts, located over the upper half of the bellmouth-to-engine attach sector, then failed, and the other bolts failed by tension/bending. The bell-mouth pivoted about the 7:00 location forward and down to the left, and then fell to the test cell floor.

It was further determined that the disturbed airflow into the fan caused dynamic activity to the fan blades. The dovetail, shank, and platform regions of all 38 blades were recovered essentially intact, together with substantially all other portions of the blades. There was evidence of severe blade tip rub and shingling of fan blade midspan shrouds. Also, there was evidence of axial racking of the fan blades in their dovetail slots.

These activities caused forward motion of the fan blades, shearing of axial retention hooks, excessive axial load against the rotor spinner, and finally, sufficient forward axial displacement of the blades for blade and disk dovetail tangs to shear, allowing all 38 blades to leave the rotor.

The rotor unbalance from the initial release of the fan blades over-loaded the No. 1 bearing and its outer race failed. Multiple impacts of fan blades burst the containment casing and tore it from the engine. Debris from the fan area was ingested by the core compressor and caused damage throughout.

The second test-cell failure occurred on January 12, 1973, to a model CF6-50 production engine, S/N 455-201. The purpose of the special engineering test was to investigate the cause of fan blade shingling which occurred previously during the original production engine run. Special vibration instrumentation, a high speed movie camera, TV camera, sound recording equipment, and stroboscopic light equipment were in-stalled to aid in studying fan-blade behavior. For this test, the original hardware had been returned to the engine.

Engine operation was normal to the point where failure had occurred. The investigation report showed that the failure occurred during an at-tempted acceleration to 3,983 N_1 RPM. Disintegration occurred at 3,742 RPM. The failure was initiated by the rubbing between the fan rotor and casing. Vibratory response of the rotor was substantially synchronized with the casing so that the rubbing action fed rotor energy into both rotor and stator. The coincident excitation which fed energy into the blade system produced high blade-tip forces, which pushed the blade out of its dovetail fitting and led to the ultimate failure. The entire fan rotor separated from the engine; the fan stator, case, and bellmouth also separated from the engine.

The probable failure sequence was summarized in part, as follows:

- Fan tips rubbed the abradable shroud.

- Fan case vibration response was a 6-wave mode traveling at 1/2 fan speed in the direction of fan rotation.

- Vibratory response of the rotor was substantially synchronous with the stator so that rubbing action fed rotor energy into both the rotor and stator, resulting in a rapid increase in amplitude in both rotor and stator.

- Amplitude of rotor and stator response continued to build up. High blade tip forces generated by the rubbing action, together with fore-and-aft rocking of the blades in the dovetail, forced the blades forward against blade hooks and bulletnose.

- First fan blades left the disk, causing a large unbalance, which failed bolts attaching No. 1 bearing unbalance, which failed bolts attaching No. 1 bearing to bearing support cone.

1.16.6 Evacuation Slide Study

A study was conducted to determine the reasons for the failure of the two forward door slides to inflate automatically and for the failure of the right overwing escape slide to track properly across the engine pylon.

It was determined that the deployment straps on the forward left door container were not rigged properly and that one of the slides on the forward doors had an improper firing handle assembly. The right overwing slide did not incorporate an optional modification (PICO Service Bulletin 25-35) which recommended the installation of a length of velcro tape for improved slide tracking during deployment.

National Airlines maintenance records showed that evacuation slide AA002 had been installed on the right forward door while slide AA007 was installed on the left forward door. Examination of these slides showed that slide AA007 had been used extensively by evacuating passengers and that slide AA002 had not been used. Since the left forward door had not been used during the evacuation, it was concluded that these two slides had been reversed during initial installation or while maintenance had been performed on them. The maintenance records showed that repairs had been made on slide AA007 which included repair of multiple holes in the fabric and the installation of a new air bottle. There were no repairs indicated for slide AA002. The repairs on slide AA007 may, therefore, account for the installation of an improper firing handle assembly.

1.17 Other Information

The procedures to be followed in the event of a generator bus failure are contained in the emergency and abnormal procedures manual carried on the aircraft. The applicable procedures outlined in this manual are as follows:

"GENERATOR BUS FAILURE

NOTE: If Captain's instruments are inoperative, utilize First Officer's and standby instruments.

During critical phase of flight,
EMER PWR Sw . . . . ON

CAUTION: With emergency power sw ON, airplane battery cannot be relied upon for more than thirty minutes.

NOTE: If Captain's flight instruments and engine instruments are not restored, move emergency power sw to OFF and operate without affected bus.

CONDITION 1

GENERATOR BUS HAD BEEN OR SHOULD BE POWERED BY ASSOCIATED GENERATOR

DC TIE Sw(s) . . . . Close

GEN Control Sw . . . . RESET/ON

RESET Sw . . . . GEN RLY/BUS TIE RLY LOCKOUT

- IF AC BUS OFF LT IS NOW OFF or there is other evidence that power has been restored to the generator bus:
  Continue this procedure.

- IF AC BUS OFF LT IS ON and failed generator bus had not been restored:
  Continue flight with affected circuits inoperative.

NOTES: If generator bus 1 is not restored, move fuel quantity indicator power switch to ALTN.

If generator bus 2 is not restored, move fuel system 2 forward tank pump sw to ON and right aft tank pump sw to OFF.

If generator bus 3 is not restored, select fuel system tank pumps as required.

GEN OFF Lt . . . . OFF

AC Load Meters . . . . NORMAL

- IF ASSOCIATED GENERATOR IS NOW SUPPLYING RESTORED GENERATOR BUS:

  Continue this procedure.

- IF ASSOCIATED GENERATOR IS NOT SUPPLYING RESTORED GENERATOR BUS:

  Continue flight with generator off. Restore dc tie sws as required.

PARALLEL GENS Button . . . . PUSH

If generator paralleling system is inoperative, confirm preferential circuit. Verify AC bus tie sw for affected channel is in NORM. Move ac bus tie sw(s) (associated with other operating engines) to ISOL. Return ac bus tie sw(s) to NORM.

AC BUS TIE ISOL LT

- IF AC BUS TIE ISOL Lt REMAINS ON:

  Continue this procedure.

- IF AC BUS TIE ISOL Lt IS OFF:

  The ac channel has been restored. Restore dc tie sws as required.

ELEC SYS RESET Sw . . . . BUS FAULT

PARALLEL GENS Button . . . . PUSH

If generator paralleling system is inoperative, disregard this step. Restore dc tie sws as required.

AC BUS TIE ISOL Lt . . . . OFF

If ac bus tie isol lt remains on, continue flight with generator out of parallel.

DC TIE Sws . . . . AS REQD.

CONDITION 3

GENERATOR BUS HAD BEEN OR SHOULD BE POWERED BY AC TIE BUS

DC TIE Sw(s) . . . . CLOSE

ELEC SYS RESET Sw . . . . BUS RLY/BUS TIE RLY LOCKOUT

AC BUS OFF Lt . . . . OFF

- o IF AC BUS OFF LT REMAINS ON:

  Continue this procedure.

- o IF AC BUS OFF Lt AND AC BUS TIE ISOL LT ARE OFF:

  Restore dc tie sws as required.

ELECT SYS RESET Sw . . . . BUS FAULT

AC BUS OFF Lt . . . . OFF

- o IF AC BUS OFF LT AND AC BUS TIE ISOL LTS ARE OFF:

  Restore dc tie sws as required.

- o IF AC BUS OFF LT AND AC BUS TIE ISOL LTS REMAIN ON:

  Continue flight with affected circuits inoperative."

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

Fan Tip Rub

The reports of the two test-cell engine failures assisted the Safety Board's understanding of the failure of the No. 3 engine on N60NA. In each of these failures, all of the fan blades were displaced from their fan disk slots. Other similarities between the two cases were: (1) All blades were lost in rapid succession. (2) The blades moved forward under sufficient driving force to shear blade retainers and the rotor spinner and to overcome dovetail friction. (3) There was evidence of blade rocking motion during the forward displacement. (4) Individual blade failure in every instance resulted from impact with surrounding structures after separation. (5) Disintegration occurred simultaneously with a rapid acceleration of the engine.

In both test-cell failures, the mechanism which allowed loss of the fan blade was the same--the interaction of the fan rotor and the fan case during resonance between the two during multiwave vibrations. The basic difference between the two failure sequences was the action that preceded the severe rub between the fan blade tip and the fan case, which in turn, initiated the destructive interaction. If the second test-cell failure, (S/N 455-201) the rub occurred "spontaneously" during an acceleration under unusual test conditions (including intentionally reduced blade tip clearance). In the first test-cell failure, (S/N 454-141) the fan was also accelerated, but was precipitated by a severe fan stall caused by loss of the test cell bellmouth from the engine. The consequent rapid fan acceleration and axial excursion of the fan blade tips caused the rub and the ensuing loss of blades.

Regardless of the triggering element in the overall failure sequence after this type of rotor/case vibration begins, the vibratory forces and their destructive effects take place rapidly. In the failure analysis of engine 455-201, about 0.24 sec. elapsed between initiation of the rotor/case vibration and loss of the first fan blade. All remaining blades were lost within 3 revolutions, or 0.05 sec. later.

From the above data, GE calculated a time sequence of failure applicable to the S/N 454-141 test-cell failure. Their analysis indicated that all fan blades were released about 0.92 sec. after the bellmouth had separated at the top sufficiently to stall the fan. Some engine parts from the disintegration reached the floor before the bellmouth did.

Examination of N60NA's No. 3 engine revealed no indication of failure or malfunction within the engine section or fan assembly which could have caused the disintegration. The only damage to the engine was attributable to the force effects of the 32 fan blades when they exited their disk slots.

Examination of the fan blades and disk and fan-blade retention devices revealed that the blades were forced out of their slots by extremely high dynamic forces. However, there was no evidence of a mechanical failure which could have caused the fan blades to exit the disk slots in such a manner. Moreover, a mechanical failure alone could not have caused the type of blade release exhibited. Without the high vibratory effects acting to reduce the extremely high centrifugal forces on the fan blades and increasing the forward axial loading on the blades, the fan blades could not have exited their slots. In this respect, the mechanism of the blade loss was the same as the mechanism in the two test-cell failures.

Thus, from the test-cell experience and from a theoretical standpoint, a rapid fan acceleration together with a consequent fan-tip rub condition and a multiwave-vibratory condition would be necessary in order for the 32 fan blades to exit as they did. The vibrations, involving the interaction between the fan rotor and the fan case are necessary to provide the fan blade "unloading." Without the interaction, a blade operating at high power could not move forward and out of its disk slot. The frictional "grip" of the blade against the radially outward surfaces of its slot, which results from the centrifugal force of about 113,000 pounds, would normally be greater than any force attempting to move the blade forward in its slot. Thus, in order for the blade to move forward and past its three mechanical retainers, a unique interaction, during which a very rapid blade vibratory force (loading/unloading) must take place. The reason, or reasons, for the onset of these vibrations, then, would constitute the primary cause of the engine disintegration.

The aircraft was in level flight at 39,000 feet when the No. 3 engine fan assembly disintegrated. Shortly before the disintegration, the captain had engaged the automatic throttle speed control system, and he and the flight engineer had speculated about the effect that pulling the three N_1 tachometer C/B's would have on the ATS operation.

According to the captain and flight engineer, the airspeed mode was selected on the autothrottle control panel and the cruise mode was selected on the TRC. After the airspeed stabilized, the flight engineer pulled the three N_1 tachometer C/B's, which are located on the flight compartment overhead emergency circuit breaker panel. The captain stated that he retarded the speed bug to decrease speed 5 kn. in order to determine whether the throttle would respond to such a command; after watching the throttle levers retard, he disengaged the autothrottle system. Both crewmembers testified that the engine failure occurred immediately after disengagement of the autothrottle system. The flight engineer reset the N_1 tachometer circuit breakers; the exact sequence of his action with engine failure could not be determined.

It is difficult to relate the procedures described by the crew with the engine failure. It must be assumed that the aircraft was reasonably stable and maintaining an airspeed close to the commanded airspeed when the flight engineer pulled the N_1 C/B's. Although this action would have removed the limiting authority imposed on the autothrottle system by the TRC circuitry, the throttle levers would move forward only if an airspeed error existed which would require additional thrust. If such an error did exist, the throttle levers would have moved at a rate which is determined by the magnitude of the error.

Since the captain and flight engineer were interested in determining throttle response with the circuit breakers pulled, they probably would have observed and acted to prevent an undesirable thrust increase. The captain's action to retard the speed bug should have produced a retarding motion of the throttle levers.

It is, therefore, hard to rationalize engine operation outside of the normal cruise envelope. The engine instrumentation does, however, imply that such a condition occurred. After the flight, the operation of the engine-pressure ratio and fuel-flow indicators was examined with respect to the wiring damage. The digital readout on the engine-pressure-ratio indicators remained in the last position attained before removal of electrical power. Since all three indicators are powered from the No. 3 AC generator bus, a loss of bus power would effectively freeze the EPR indication when power was lost. The Safety Board believes that the No. 3 AC generator power was lost as a result of wiring damage inflicted when the fan disintegrated. Therefore, EPR reading noted during the aircraft examination after the accident should have been valid at the instant of engine failure. These readings were 7.07, 6.99 and 6.93 for the Nos. 1, 2, and 3 engines, respectively. Furthermore, if the wires between the fuel flow transmitter and fuel electronics unit were severed, the digital counter of the fuel flow indicator will freeze at the last indicated reading. Such wiring damage was evident in both the Nos. 1 and 3 engine nacelles. The fuel flow indications of 6,640 lbs./hr. and 6,420 lbs./hr. for the Nos. 1 and 3 engines, respectively, are compatible with the corresponding engine pressure ratios indicated for these engines. This compatibility, along with the similarity of the values for the three engines, appears to be more than coincidental. Thus, it is strongly indicated that the engines were operating at an abnormally high power setting at the time of failure.

<u>Possible Triggering Mechanisms</u>

Possibly, the captain inadvertently advanced the levers beyond the required settings while manually resetting the throttle levers without the N_1 tachometer or, the autothrottle system may still have been in operation and the target airspeed was at a higher setting than the prevailing airspeed, which caused a signal for increased thrust. Because of the lack of evidence to support either of these postulations, no positive determination can be assessed.

It is most important, however, that the indicated power setting, although higher than that required for the cruise condition and beyond the normal autothrottle system limits, was still within the certificated maximum allowable operating limits specified for the CF6-6D engine. Furthermore, at 39,000 feet, under a normal cruising environment, it is difficult to conceive of any condition under which engine limits can be exceeded, even with maximum throttle lever travel. Therefore, to apply particular significance to the engine power setting with regard to the fan disintegration would be pure conjecture.

One must question whether operation at an engine speed greater than encountered normally but less than specified limits is explored adequately during the aircraft certification process. The possibility of untested vibratory modes caused by the interface between the engine and the airframe must, therefore, be considered as a triggering device for such failure. To determine other possible triggering devices of the engine disintegration, the CVR sound spectral analyses developed by G.E. and Douglas were studied.

In the G.E. analysis, basic time coincided with the initial 00:00.0 time as presented in the CVR transcript, at which point the flight engineer stated, ". . . wonder if you pull the N_1 tach (C/B) will that, autothrottle respond to N_1?" At this same time the analysis shows the No. 3 engine speed to be 97 percent N_1. This engine speed would have been almost normal for the cruise flight conditions at that time. Twenty-four sec. later, the N_1 speed increases to 100 percent, and the other two engines increase parallel to this speed. The most obvious explanation for this general increase in engine power is that it resulted from the autothrottle system.

The analysis also shows that between times 00:31 and 00:44 sec. the No. 3 engine N_1 speed oscillated at random between 94 and 100 percent. The other two engines maintained N_1 stability. At 00:48, when the explosion sounded, the No. 3 engine speed was 99 percent N_1 and accelerated to almost 110 percent N_1 at 00:49.42, after which this engine sound is no longer detectable. The other two engines accelerated to high power settings (109.5 percent and 107 percent N_1) shortly after the initial explosion and remained at this setting for 26.6 sec.

Again, the acceleration of the engine to these high power settings would suggest that the autothrottle system was still operational, but without the benefit of the thrust-limiting feature. However, the pilot could have set the throttles manually beyond the required thrust position. However, the captain did not testify that he manually advanced the Nos. 1 and 2 power levers immediately after the explosion, and it is inconceivable that he would have elected to increase power under those conditions.

It cannot be determined what effect the unrestrained N_1 acceleration had on the No. 3 disintegration; however, it is highly coincidental that both test-cell failures occurred during rapid accelerations. Moreover, the January 1973 test-cell failure occurred at an N_1 speed of about 109 percent--the same approximate N_1 speed as the subject engine at the time of failure. The Safety Board does not imply that these fan speeds are hazardous. The prescribed N_1 operational limitation is 111 percent, although the assembly is designed to withstand much greater speeds. In this case, the nominal N_1 speed of the No. 3 engine was most probably exceeded because of the combination of a vibration or some other extremely rare condition.

For example, the G.E. sound spectral analysis indicates random oscillations of the No. 3 engine, which began about 17 sec. before the explosion. These oscillations suggest an inlet air disturbance or turbulence effect, which in turn caused the N_1 cycling. As was noted during the examination of the nose cowl, a large portion of the inner perforated liner (between the 12:00 and 4:00 positions) had been torn away and was found in the engine against the outlet guide vanes. One theory is that the inner liner worked loose, disrupted airflow into the fan, and initiated the failure. The acceleration rate, as calculated for that engine which showed a 266 rev/min/sec. maximum slope between the time of the initial explosion and the loss of discernible sounds from the engine, support this theory. According to supplementary data supplied by G.E., a maximum acceleration rate of 238 rev/min/sec. could be expected from a complete fan stall, but to achieve the 266-rev/min/sec. rate, airflow to the fan would have to be restricted severely.

To further support the theory, the G.E. sound spectrograph shows that the explosive sound of the engine failure was actually composed of two separate and different explosive sounds and within a close time relationship to each other. The first sound could conceivably be the missing piece of inlet duct acoustic liner tearing loose and allowing the fan to accelerate suddenly as a result of airflow disruption. However, extensive examination of the recovered portions of this liner indicates that the failure of the bonding was caused by shear and not by tension. This, then, would indicate that the liner was sheared from its bonding by fragments of the disintegrating fan and not torn loose before fan-blade release. Moreover, the fragment damage to the honeycomb material where the liner is missing appears to have been made while the liner was still in place, which would also tend to refute the possiblity that the liner separated before the engine disintegrated.

In addition, the Douglas sound spectral analysis shows that the major portion of acoustic energy occurred in the first 200 milliseconds and was the only time of sustained high-level noise in the first 10 seconds of the failure. Thus, the massive failure occurred instantaneously and was not preceded by a separate explosive sound.

A second theory was the possibility that the nose cowl separated or began to separate from its engine mounting before the engine disintegrated. Such a condition would explain the triggering device of the failure and would be similar to that of the first test-cell engine, since the loss of a nose cowl in flight would have results similar to the loss of the bellmouth in the test cell. Conceivably, the first explosive sound could have been the nose cowl tearing away from the engine. The nose cowl had, in fact, separated in flight and was relatively undamaged except for impact crushing on the aft, or attachment, end and fragment punctures scattered throughout the barrel. There was evidence of fretting or working found on all of the attachment fitting surfaces, which would indicate that there was at least some looseness between the cowl and its mounting surface. However, the deformed bolt holes at the 12 attachment fittings indicate that all of the bolts were in place when the cowl separated from the containment ring. The deformations also indicate that the containment ring rotated in the direction of fan rotation, probably as a result of the sudden fan blade strike which sheared the attach bolts. Examination of the five recovered bolts supports this evaluation. Therefore, it is concluded that the loss of the nose cowl did not precede the disintegration of the fan.

In summary, the catastrophic failure of the No. 3 engine must have been precipitated by a blade-tip rub condition which produced the blade exiting sequence. The two most prominent theories as to the initiating mechanism of the blade tip rub, as based on the evidence available, are: (1) An acceleration of the engine to an abnormally high N_1 speed, either by an unrestricted throttle advance by the autothrottle system or a manual throttle advance by the pilot, which created a resonant frequency and subsequent destructive vibratory mode. (2) A piece of inner acoustic panel from the inlet duct separated from its honeycomb bonding and restricted airflow into the engine resulting in a very rapid fan acceleration and a destructive vibratory mode.

Regardless of the cause of the high fan speed at the time of the fan failure, the Safety Board is concerned that the flightcrew was, in effect, performing an untested failure analysis on this system. This type of experimentation, without the benefit of training or specific guidelines, should never be performed during passenger flight operations.

Electrical System Difficulties

The flight engineer stated that he saw the failure warning lights on his panel illuminate, which indicated a failure of the No. 3 AC generator, No. 3 DC generator, No. 3 AC generator bus, and the No. 3 DC bus. Postaccident examination of the aircraft disclosed that the wiring in the No. 3 nacelle had been severed. The wiring damage was such that an apparent bus fault would have been detected by logic circuitry and, thereby, would have caused the No. 3 AC bus tie relay to open. Power on both the No. 3 AC generator bus, the No. 3 DC bus, and the right emergency bus would have been lost. An analysis of the readings of the cockpit instrumentation after the flight substantiated the loss and nonrestoration of power on these buses.

Postaccident examination also disclosed that power could have been restored to all buses by normal procedures required during completion of the emergency checklist; specifically, activation of the bus reset switch on the flight engineer's panel to the "bus fault" position would have caused the bus tie relay to close. DC power alone was restorable by positioning the DC bus tie switch to the "closed" position.

The flight engineer did not complete these checklist items, probably because of his heavy workload of coping with the critical aspects of the emergency. Partial loss of electrical power had only one significant effect on the system performance--the depressurization warning system and the automatic oxygen deployment system are powered from the right emergency bus and were, therefore, deactivated. The flight engineer activated the manual oxygen deployment switch properly and thereby released all of the passenger seatback oxygen generating canisters, except for the 24 units which are released through the No. 3 bus.

Although the first officer's instrumentation was affected, the captain's was not. The operation of essential navigation and communication equipment, which is powered by the left emergency bus, remained normal. The Safety Board therefore believes that the failures experienced during this accident demonstrate the value of redundant systems in the design of modern aircraft.

Extent of Decompression

Decompression curves were calculated in order to determine the extent of the decompression which took place in the cabin and the pressure altitudes to which the aircraft occupants were exposed. The decompression profile indicated that the aircraft decompressed to about 34,000 feet in 26 sec. The calculation is based on the assumption that the aircraft descended 5,000 f/min. beginning 6 sec. after the explosion. Calculations further indicated that aircraft occupants were exposed to altitudes above 30,000 feet for about 1 minute and to altitudes above 25,000 feet for more than 2 minutes. Though the average time of useful consciousness is about 60 sec. at 30,000 feet for persons without supplemental oxygen and less than 2 minutes at 25,000 feet, the lack of physical activity could explain why more hypoxia symptoms were not encountered by more of the passengers.

The loss of a passenger through a cabin window opening indicates the extent and immediacy of the decompression. A differential pressure of about 8.7 p.s.i. existed in the cabin at the time the window at seat location 17H was dislodged. The sudden opening in the pressure hull of about 160 square inches created by the loss of this window resulted in an immediate loss of cabin pressure as it attempted to equalize with the atmospheric pressure at 39,000 feet. The flow of air thus created by the pressure differential would have reached its highest velocity at the window opening exerting a wind blast effect on anything in its path. Although no tests have been performed in large volume aircraft concerning the size of an opening in a pressure hull relative to ejection potential, decompression tests 4/ have been performed on small pressurized aircraft at various pressure differentials and pressure hull opening areas. These tests have shown that even with small volume cabins at pressure differentials as low as 5.2 p.s.i., the danger of ejection exists. It was found that the relative ejection potential depends on the size of the opening and the distance of the object or person from that opening.

4/ Reference: John J. Swearingen, M.S., "Evaluation of Potential Decompression Hazards in Small Pressurized Aircraft" Aerospace Medicine, Vol. 38, No. 10, October 1967.

Evidence also indicates that a significant pressure differential existed between the passenger cabin and the lower galley. The decompression profile for the lower galley could have been significantly steeper and thus would have exposed the two galley occupants to an altitude above 35,000 feet. The fact that both flight attendants stationed in this area lost consciousness shortly after the explosion lends credence to this possibility.

Overall, the extensive compartmentalization of the aircraft and its intricate interconnections may account, in part, for the disparity between the expected physiological effects on the aircraft occupants and those actually encountered.

2.2 Conclusions

a. Findings

1. The crew was qualified and certificated for the operation.

2. The aircraft was certificated and maintained in accordance with applicable regulations.

3. About 36 sec. before the initial explosion, the flightcrew pulled the N_1 tachometer circuit breakers to determine how this disconnection would affect the automatic throttle system's operation. The system circuitry is such that with these circuit breakers pulled, the autothrottle system's N_1 limiting authority is cancelled.

4. If the N_1 circuit breaker were disengaged with the autothrottle system in use, the throttle could advance beyond normal authority limits.

5. The flightcrew was, in effect, performing an untested failure analysis on the autothrottle system.

6. At the time of the failure, the three engines were operating at a power setting above that specified for normal operation, but below the approved maximum continuous operating limits of the engines.

7. There was no evidence of any failure or malfunction within the engine which would have caused the fan disintegration.

8. Thirty-two of the 38 fan blades exited in a forward direction out of their fan disk slots.

9. The damage to the No. 3 engine which resulted from the rubbing of the fan blade tips and the exiting of the fan blades

was similar to the damage found in the two test-cell engine failures, the triggering mechanism of which was interaction between the fan rotor and the fan case during resonance between the two at a multiwave, vibratory mode.

10. A portion of the inlet duct inner liner was missing from the duct. A piece of this liner was found lodged against the fan outlet guide vanes.

11. Fragments of the No. 3 engine fan assembly penetrated the fuselage, the Nos. 1 and 3 engine nacelles, and the right wing area. A cabin window was struck by a fragment and separated from the aircraft.

12. As a result of the loss of a cabin window and cabin decompression, a passenger was forced out of the window and was lost.

13. Damage to the wiring in the No. 3 engine nacelle caused a partial electrical power loss which affected various aircraft systems.

14. Electrical power could have been restored to all systems through completion of the emergency checklist procedures.

b. Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the disintegration of the No. 3 engine fan assembly as a result of an interaction between the fan blade tips and the fan case. The fan-tip rub condition was caused by the acceleration of the engine to an abnormally high fan speed which initiated a multiwave, vibratory resonance within the fan section of the engine. The precise reason or reasons for the acceleration and the onset of the destructive vibration could not be determined conclusively.

3. RECOMMENDATIONS

As a result of this accident, the Safety Board submitted 9 recommendations to the Administrator, FAA. Three of these recommendations (A-73-116, 117, and 118) pertain to the inspection and maintenance of digital flight data recorders, and five (A-74-7 through 11) concern the passenger and portable oxygen systems installed in the DC-10. The final recommendation (A-74-18) pertains to assessment of aircraft damage by flightcrews during in-flight emergencies. (Copies of these recommendations and the Administrator's response are contained in Appendix E.)

Because of the prompt and effective actions taken by the FAA, General Electric, Douglas Aircraft Co., and airlines flying the DC-10, no recommendations were necessary concerning the engine installation. Immediately following the accident, the FAA issued a telegraphic Airworthiness Directive applicable to all DC-10 aircraft to require inspection of the engine nose cowl mounting integrity and to correct any possible defiencies in that area. Also, it was recognized early that fan-tip rub was a necessary condition in the sequence of events that brought about the loss of the fan blades. As a preventative measure against the recurrence of this type of condition, the fan blade tip-to-shroud clearances were increased. Further, as backup for the possibility of blade-tip rub even after the tip clearance was modified, an extensive development, testing, and production program was established to increase the capabilities of the blade retention devices. One of the primary retaining devices has been redesigned to provide each blade with a rearward retaining capability of 60,000 pounds as compared to the 18,000-pound capability of the accident engine. These modified blade-retaining devices have now been incorporated in all of the in-service engines.

With regard to the flightcrew's performing an untested failure analysis of the autothrottle/speed control system, the Safety Board stresses that the operator and the pilot-in-command should be fully cognizant of their operational responsibilities to conduct the flight in a professional manner and not to conduct experiments to aircraft systems in which they have not received specific training or instruction.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

January 15, 1975

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified of the accident at 1700 m.s.t. on November 3, 1973, and air safety investigators were dispatched to the scene. Working groups were established for operations and air traffic control, powerplants, structures, systems, human factors, maintenance records, autoflight systems, digital flight data recorder, and cockpit voice recorder. Parties to the investigation included: National Airlines, Inc., the Federal Aviation Administration, Douglas Aircraft Company, General Electric Company, Air Line Pilots Association (ALPA), and Flight Engineers International Association (FEIA).

2. Hearing

A public hearing was held by the Safety Board in Miami, Florida, on December 10, 11, and 12, 1973, and on February 12, 13, and 14, 1974.

APPENDIX B

CREW INFORMATION

Captain William R. Broocke

Captain William R. Broocke, 54, was employed by National Airlines, Inc., in May 1946. He holds Airline Transport Pilot Certificate No. 503900, with type ratings in C-46, Lockheed Lodestar, Convair-340 and 440, DC-6, DC-7, Lockheed Electra, Boeing 727, and DC-10 aircraft. He was upgraded to captain in the DC-10 on May 13, 1972.

Captain Broocke's last proficiency check was May 2, 1973. His last line check was on August 3, 1973. He passed both checks satisfactorily. As of the date of the accident, Captain Broocke had 21,853 flight-hours, 801 hours of which were in DC-10 equipment. Captain Broocke had 2 days' rest before the flight.

First Officer Eddie H. Saunders

First Officer Eddie H. Saunders, 33, was employed by National Airlines, Inc., in September 1965. He holds a Commercial Certificate with single engine, multi-engine, and instrument ratings. He completed his DC-10 training in September 1972, and requalified for the DC-10 in April 1973 after which he was assigned as a DC-10 first officer.

First Officer Saunders had accumulated 7,086 flight-hours as of the date of this accident, 445 hours of which were in the DC-10. He passed his last proficiency check satisfactorily on September 25, 1973. He had a 17-hour rest period before this flight.

Flight Engineer Golden W. Hanks

Flight Engineer Golden W. Hanks, 55, was employed by National Airlines, Inc., in June 1950. He holds an Airplane/Powerplant Mechanic Certificate, Flight Engineer Certificate, and Commercial Pilot Single-Engine Certificate with an instrument rating. He completed his DC-10 training and passed his original qualification and line check on January 28, 1972.

Flight Engineer Hanks had accumulated 17,814 flight-hours, 1,252 hours of which were in the DC-10. His last proficiency check was accomplished on August 29, 1973. He had 2 days' rest before the flight.

Flight Attendants

The nine flight attendants assigned to this flight were qualified and had received adequate rest before the flight.

APPENDIX C

AIRCRAFT INFORMATION

Aircraft Data

Aircraft N60NA is a McDonnell-Douglas DC-10-10, serial No. 46700. It was manufactured on November 1, 1971, and registered to National Airlines, Inc. A standard airworthiness certificate was issued for the aircraft in November 1971. The aircraft had accumulated 5,954 hours at the time of the accident.

A review of aircraft and component records revealed that all inspections and item changes had been made within the prescribed time limits and that the aircraft had been maintained in accordance with all company procedures and FAA Regulations. As of November 3, 1973, all applicable airworthiness directives had been complied with.

The aircraft was equipped with three General Electric CF-6-60 engines. The No. 1 engine, serial No. 451146, had 4,130 hours. It had not been overhauled. The No. 2 engine, serial No. 451341, had 2,660 hours. It had not been overhauled.

History of the No. 3 Engine

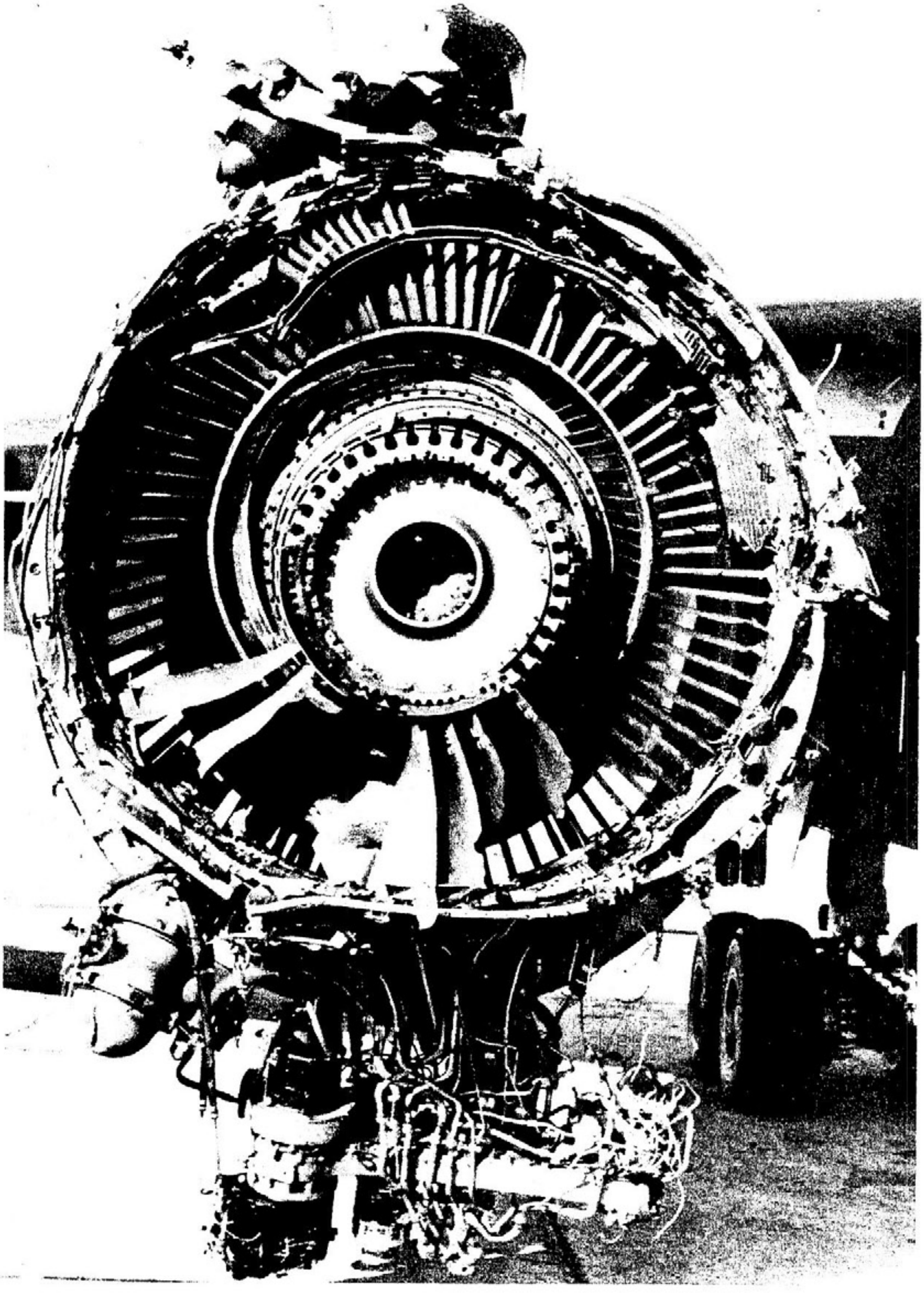
The No. 3 engine had 5089.23 hours since new and 2,779 cycles. The engine was originally installed on DC-10, N61NA on November 17, 1971, with a time since new (TSN) of 0:00. It was removed on July 31, 1972, for threshold inspection at Southwest Airmotive Company. Total time was 2,231 hours with 1,123 cycles. It was installed on N62NA on October 21, 1972, only to be removed 8 days later for a compressor discharge pressure leak. It was repaired at the Miami facility of National Airlines, Inc. Total time on the engine was 2,267 hours with 1,153 cycles. On March 23, 1973, the engine was removed from N62NA and returned to Southwest Airmotive Company because of performance deterioration and vane and 10th-stage blade failure. Total time on the engine was 3,513 hours with 1,866 cycles. On April 21, 1973, the engine was installed on N65NA. On August 25, 1973, the engine was removed, modified and replaced on the aircraft the following day. The total time of the engine at this time was 4,632 hours with 2,486 cycles. On September 13, 1973, the engine was again removed from N65NA for turbine damage and combustion failure. Metal was found in the tail pipe assembly. The total time on the engine was 4,790 hours with 2,589 cycles. The engine was installed on N60NA on September 23, 1973. The engine remained on N60NA and in the No. 3 position until the accident on November 3, 1973, when the fan disintegrated.

The fan rotor assembly, serial No. 21X91102, was received new in March 1973. This fan assembly was installed on engine S/N 451151 on

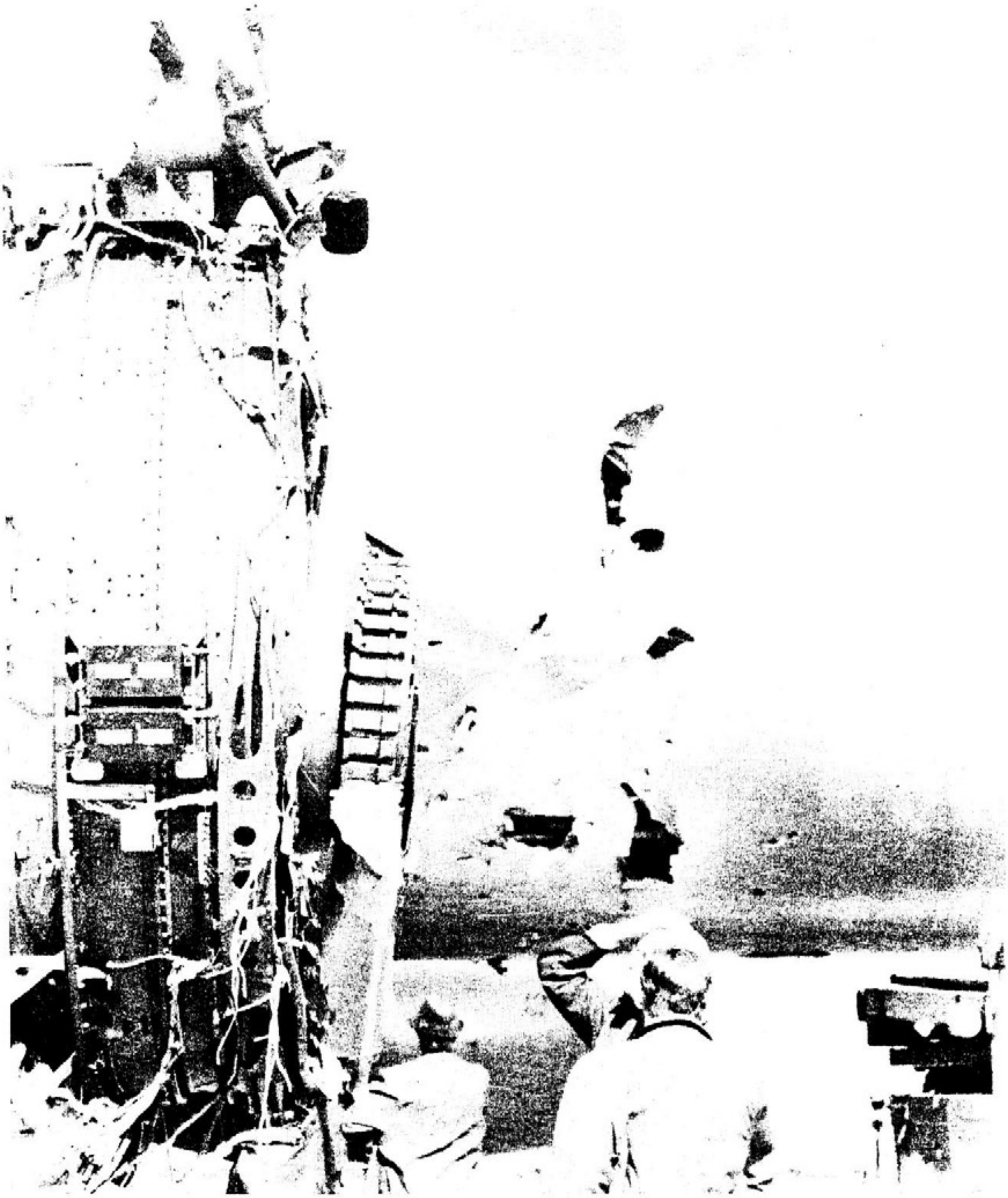
August 27, 1973. Time on the fan rotor assembly at this time was 617 hours with 337 cycles and 3 modifications, Q-7230-03, -22, and -21, had been completed. The engine and fan assembly were installed in the No. 3 position of N60NA on September 23, 1973.

The engine nose cowl was installed new on engine S/N 451146 on March 10, 1973, and removed on August 24, 1973. Total time since new was 1,473 hours. The nose cowl was installed on engine S/N 451151 on September 23, 1973, and was retained in this position until the accident.

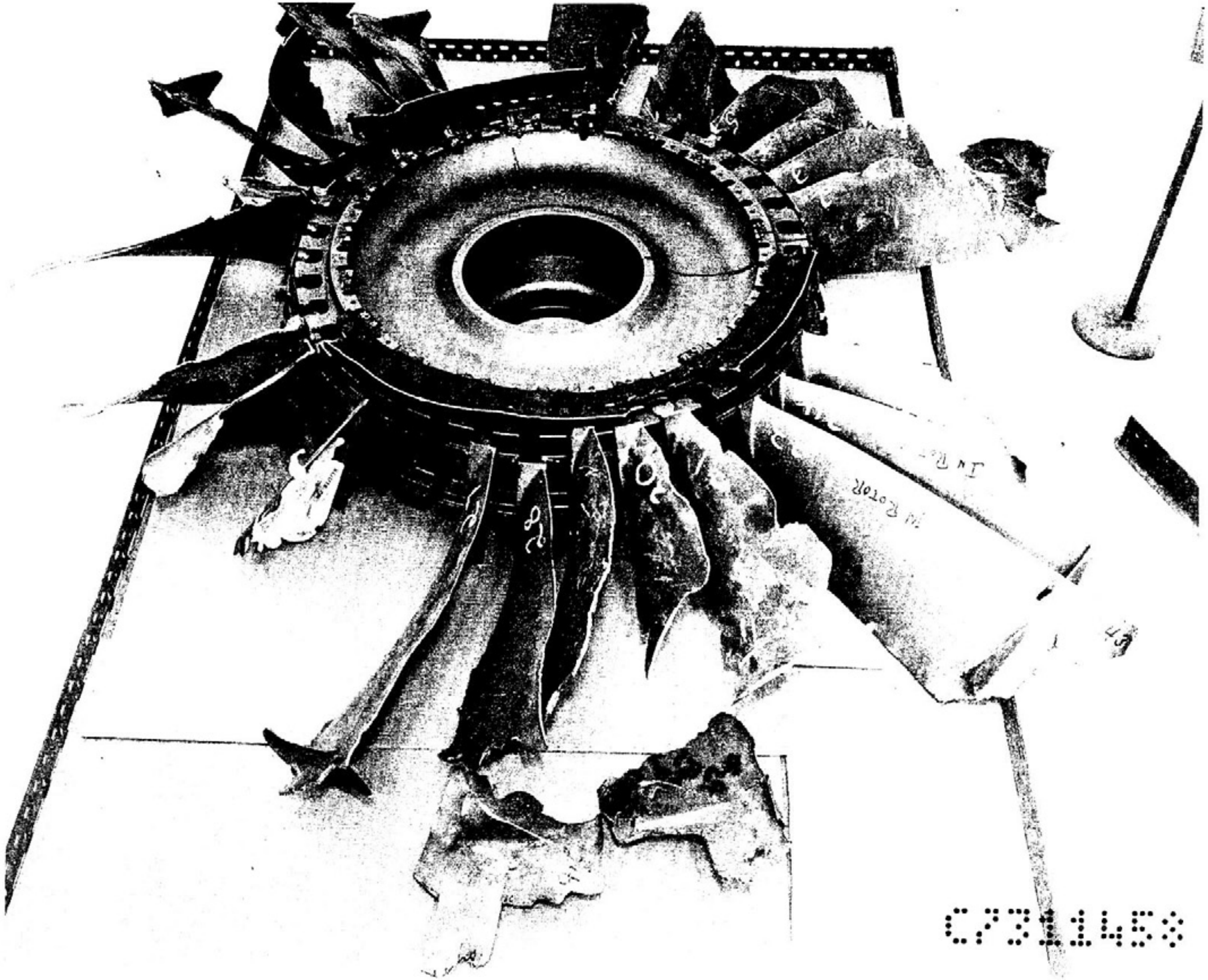
APPENDIX D



Front View No. 3 Engine



Right side view showing damage to No. 3 engine, fragment damage and missing window.



Fan disk with recovered blade portions and spinner attachment flange segments.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

APPENDIX E

ISSUED: January 22, 1974

Forwarded to:
Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20590

SAFETY RECOMMENDATION(S)

A-73-116 thru 118

(revised)

The National Transportation Safety Board's investigation of a National Airlines Douglas DC-10 accident, which occurred in flight near Albuquerque, New Mexico, on November 3, 1973, disclosed a malfunction in the digital flight data recorder (DFDR). This malfunction precluded recovery of any data related to the accident. The Board is very much concerned about this type of failure, because it is not detectable by the test equipment aboard the aircraft and, therefore, might exist on a large number of aircraft equipped with the new DFDR.

National Airlines subsequently performed readouts of the DFDR throughout their entire fleet of wide-bodied aircraft to assess the extent of similar undetected malfunctions. Testimony at the Safety Board's public hearing held in Miami, Florida, on December 10-12, 1973, and subsequent readout examinations disclosed that, of 13 wide-bodied jets in the fleet, 7 had been operating with undetected malfunctions which would have precluded recovery of acceptable data for some parameters required under 14 CFR 121.343(a)(2).

In meetings with your staff, the Board's staff has discussed the preliminary findings of the survey of DFDR's conducted under GENOT 8000.92. In the Board's opinion, these preliminary findings also indicate that the current 2,000- to 3,000-hour inspection intervals are unrealistic and should be adjusted to be commensurate with the mean-time-between-failure (MTBF) rates that these recording systems have been experiencing during this early period of operation.

Therefore, to insure that recorders in the current fleet of wide-bodied jets are operating in an approved manner, as specified under 14 CFR 121.343 (a)(1), (2), and Appendix B, the National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Require, within the next 100 flight hours, a readout of data recorded in flight on the digital flight data recorders, as required under 14 CFR 121.343(a)(2), and take action to insure that the parameters required are being recorded within the ranges, accuracies, and recording intervals specified in Appendix B thereof.

2. Require repetitive readout inspections, as specified above, at 500-hour intervals, until the reliability of these recorder systems improves.

3. Require retention by the operators of the data received in the two most recent readout inspections.

Personnel from our Bureau of Aviation Safety offices will be made available if any further information or assistance is desired.

REED, Chairman, McADAMS, BURGESS, and HALEY, Members, concurred in the above recommendations. THAYER, Member, was absent, not voting.

By John H. Reed
Chairman

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

FEB 8 1974

Honorable John H. Reed
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D.C. 20591

Dear Mr. Chairman: Notation 1230

This is in reply to your Safety Recommendations A-73-116 thru 118 issued January 22, 1974, concerning your recommendations on digital flight data recorders relative to the National Airlines DC-10 accident of November 3, 1973. In addition, your release identified National Airlines operating with seven of 13 digital flight data recorders with undetected malfunctions.

The FAA has already initiated appropriate corrective action with regard to the National Airlines readout deficiencies which were cited in your letter.

Several other actions have been taken by the FAA. Immediately following the accident we initiated a national survey regarding the performance of all installed digital flight data recorders. Our accumulated data is sufficiently conclusive that a rule or regulation change at this time is not necessary. We have determined that the present maintenance programs with certain adjustments are adequate. We have also initiated a related maintenance bulletin to be released soon to all maintenance personnel which recommends corrective action in those cases where mean-time-between-failure (MTBF) and inspection frequencies are not deemed sufficient to properly service and maintain the digital flight data recorder.

The equipment combination involved in the National Airlines DC-10 accident is peculiar only to National Airlines. We believe the actions taken are appropriate and that our present rules are adequate. To apply your stringent recommendations based on a single accident would be inappropriate and would not serve the best interests of the aviation industry.

Sincerely,

Alexander P. Butterfield

Alexander P. Butterfield
Administrator

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: February 7, 1974

Forwarded to:

Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATION(S)

A-74-7 thru 11

The National Transportation Safety Board's continuing investigation of the National Airlines DC-10 accident near Albuquerque, New Mexico, on November 3, 1973, has disclosed unsafe conditions in the passenger oxygen system, portable oxygen system, and cabin pressurization system. The Board believes that these unsafe conditions merit your immediate attention and the attentions of all air carriers which operate aircraft with this equipment.

When the aircraft lost a cabin window and the passenger cabin decompressed, many of the passenger's oxygen-generating units were activated. Three oxygen canisters came out of their mountings in the seatback oxygen compartment and fell onto passenger seat cushions. Two of these canisters, which become very hot when operating, scorched the cushions and burned fingers when seat occupants tried to remove them. The third reportedly caused a small fire. The canisters came out of their mounting brackets because of the pulling force exerted on either the initiation lanyard of the canisters or the oxygen supply hose. The Safety Board believes that these canisters constitute a potential fire and injury hazard when they are not retained properly in their mountings.

A subsequent inspection of a similar DC-10 aircraft at National Airlines' maintenance base in Miami, Florida, also revealed improperly mounted canisters. The improper mountings were a result of a slight distortion of the base plate and short mounting studs on the canister. Also, some of the oxygen supply hoses and the masks were improperly packaged. The Board found that shortcomings exist in both the design of the mounts of these oxygen units and related maintenance and servicing practices.

Another unsafe condition exists in the storage and availability of the portable oxygen equipment aboard the DC-10 aircraft. Portable oxygen bottles are contained in enclosed cabinets near the cabin attendants' stations. The regulator assemblies were covered with cellophane-type wrapping which was held by an elastic band. K-S disposable oxygen masks and supply tubing were sealed separately in plastic bags and stored with, or near, the portable oxygen bottles.

Paragraph (4) of 14 CFR 25.1447 "Equipment Standards for Oxygen Dispensing Units" requires that portable oxygen equipment be immediately available for each cabin attendant. The Board questions the "immediate availability" of such equipment when it must be unwrapped and assembled before it can be used, considering the reduced time of useful consciousness at flight level altitudes.

A third condition which the Board believes merits your attention is the distinct possibility that separate pressure losses of different magnitudes may occur on the DC-10. Preliminary estimates suggest that the lower lobe galley and the adjacent cargo compartment of the subject aircraft decompressed faster than the main passenger cabin or the cockpit area. This theory is reinforced by the fact that the two cabin attendants in the lower lobe galley lost consciousness almost immediately after the decompression.

The Board's concern about the third unsafe condition is twofold:

1. The aneroid device, which detects unacceptable cabin pressure altitudes in the aircraft and causes the oxygen dispensing units to be deployed automatically in such cases, is located in the ceiling of the forward passenger cabin. It controls the deployment of oxygen masks in the entire aircraft. Therefore, if decompression occurred in the lower lobe of the aircraft, it might not be sensed by the aneroid device in the passenger cabin, and supplemental oxygen would not be available to the

Honorable Alexander P. Butterfield (3)

occupants in the lower galley. This apparently occurred in the subject accident, and both cabin attendants in this section of the aircraft lost consciousness as they attempted to retrieve the portable oxygen bottles. The Board believes that such a situation can seriously threaten the safety of occupants of the lower galley.

2. Two portable oxygen units which were located in the lower lobe galley of the aircraft were stowed on the forward wall of the galley and outboard of the escape ladder. One bottle was fitted with a "full-face" smoke mask, which was sealed in a plastic container. The other bottle was the type which must be fitted with a supply hose and a K-S disposable mask before it may be used. Not only is the Board concerned about the time required to unpack parts for these units and assemble them, but it also believes that their location makes them virtually inaccessible when service carts are in their storage place in the galley.

Our staff has learned informally that some of the problems delineated above are being assessed by Flight Standards personnel of the FAA's Western Region to determine whether shortcomings in design and servicing exist.

The Safety Board is continuing its investigation and may make further recommendations regarding this accident. However, it believes that the safety of the traveling public requires immediate steps to prevent recurrence of the problems outlined above.

Accordingly, the National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Require all operators of aircraft which contain individual chemical oxygen-generating units to inspect these installations to ensure that canisters are correctly installed in the mounts and that approved packing procedures have been followed for the supply hoses and oxygen masks.

2. Issue an Airworthiness Directive to require changes in the method of mounting these oxygen-generating units to eliminate the possibility of improper installation and inservice failures.

Honorable Alexander P. Butterfield (4)

3. Issue a maintenance bulletin to verify operator compliance with the provision of 14 CFR 25.1447 regarding the immediate availability of portable oxygen units and the necessity of having supply hoses and masks attached to these units.

4. Issue an Airworthiness Directive to require aircraft certificated under 14 CFR 25, that each occupiable area, which is separated from others to such an extent that significantly different decompression rates can occur, is equipped with an aneroid device to detect pressure losses in that area.

5. Require a more accessible location for the portable oxygen units in the lower lobe galley of all DC-10 aircraft and relocate portable oxygen units in all other aircraft, where required, to ensure accessibility of portable oxygen units and compliance with the FAR's.

Personnel from our Bureau of Aviation Safety offices will be made available if any further information or assistance is desired.

REED, Chairman, McADAMS, and HALEY, Members, concurred in the above recommendations. THAYER and BURGESS, Members, were absent, not voting.

John H. Reed

By: John H. Reed
Chairman

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

FEB 21 1974

Honorable John H. Reed
Chairman, National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

Notation 1230A

Dear Mr. Chairman:

This is in response to NTSB Safety Recommendations A-74-7 thru -11.

Recommendation No. A-74-7. Require all operators of aircraft which contain individual chemical oxygen-generating units to inspect these installations to ensure that canisters are correctly installed in the mounts and that approved packing procedures have been followed for the supply hoses and oxygen masks.

Comment. We are issuing a maintenance bulletin which will instruct principal inspectors to review the air carrier operators' maintenance programs to determine that sufficient inspections are specified for the oxygen generating units and associated supply hoses and masks. Principal inspectors will request more frequent inspections if necessary.

Recommendation No. A-74-8. Issue an Airworthiness Directive to require changes in the method of mounting these oxygen-generating units to eliminate the possibility of improper installation and in-service failures.

Comment. We are working with the Douglas Aircraft Company to assess the DC-10 passenger oxygen units. This investigation will result in a redesign and modification of the units. Airworthiness directives or other appropriate directives will be issued to implement the new design.

Recommendation No. A-74-9. Issue a maintenance bulletin to verify operator compliance with the provision of 14 CFR 25.1447 regarding the immediate availability of portable oxygen units and the necessity of having supply hoses and masks attached to these units.

Comment. The maintenance bulletin will include instructions to the principal inspectors to determine that portable oxygen bottles with hose and mask assemblies attached are immediately available to all crewmembers.

2

Recommendation No. A-74-10. Issue an Airworthiness Directive to require aircraft certificated under 14 CFR 25, that each occupiable area, which is separated from others to such an extent that significantly different decompression rates can occur, is equipped with an aneroid device to detect pressure losses in that area.

Comment. We are working with Douglas to determine the best method to prevent significant pressure differentials in different compartments from occurring and what changes in the aneroid system are required to ensure oxygen system operation in all areas.

Recommendation No. A-74-11. Require a more accessible location for the portable oxygen units in the lower lobe galley of all DC-10 aircraft and relocate portable oxygen units in all other aircraft, where required, to ensure accessibility of portable oxygen units and compliance with the FAR's.

Comment. We are working with Douglas to select more accessible locations for the portable oxygen units in the lower lobe galley. When the new locations are determined, we will take appropriate action to implement relocation.

Sincerely,

Alexander P. Butterfield

Alexander P. Butterfield
Administrator

APPENDIX E

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: February 26, 1974

Forwarded to:

Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATION(S)
A-74-18

On November 3, 1973, an in-flight emergency took place aboard a National Airlines DC-10 near Albuquerque, New Mexico. The accident occurred when the fan assembly of the No. 3 engine disintegrated and pieces struck the aircraft, causing rapid decompression of the fuselage. One passenger was ejected from the aircraft, other passengers were injured, and cabin attendants were incapacitated. The captain immediately made an emergency descent and landed the aircraft 19 minutes later at Albuquerque.

According to testimony given by National Airlines personnel during the National Transportation Safety Board's public hearing, the crewmembers did not assess the structural damage to the aircraft in flight after the emergency was under initial control. Also, the cabin attendants did not inform the flightcrew of the damage to the fuselage and galley or of the fire and smoke in the cabin.

The flightcrew, cabin attendants, and training personnel of National Airlines testified that the carrier does not have established procedures for assessing damage that results from in-flight emergencies.

Flightcrews of some other carriers who were questioned about their in-flight emergency procedures also indicated that they do not have such procedures nor receive training on the subject. This has been evident in other accidents where the flightcrew was unaware of the extent of damage.

The Safety Board believes that flightcrews should be provided procedures by which damage that results from in-flight emergencies can be assessed so that they may have all the information possible to handle such emergencies adequately.

APPENDIX E

Honorable Alexander P. Butterfield

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Issue an operations alert bulletin to ascertain compliance with 14 CFR 25.1585(a)(4), relative to a procedure for the assessment of aircraft damage that results from in-flight emergencies.

Personnel from our Bureau of Aviation Safety will be made available if any further information or assistance is desired.

McADAMS, THAYER, BURGESS, and HALEY, Members, concurred in the above recommendation. REED, Chairman, was absent, not voting.

John H. Reed

By: John H. Reed
Chairman

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

FEB 27 1974

Notation 1230B

Honorable John H. Reed
Chairman, National Transportation
Safety Board
Department of Transportation
Washington, D. C. 20591

Dear Mr. Chairman:

I have reviewed Safety Recommendation A-74-18 concerning the Board's investigation of National Airlines' DC-10 accident near Albuquerque, New Mexico, on November 3, 1973.

We essentially agree on the need for procedures to assist air carrier flight crews to assess inflight damage to the aircraft and will issue an appropriate bulletin on this subject.

Sincerely,

Alexander P. Butterfield
Administrator

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