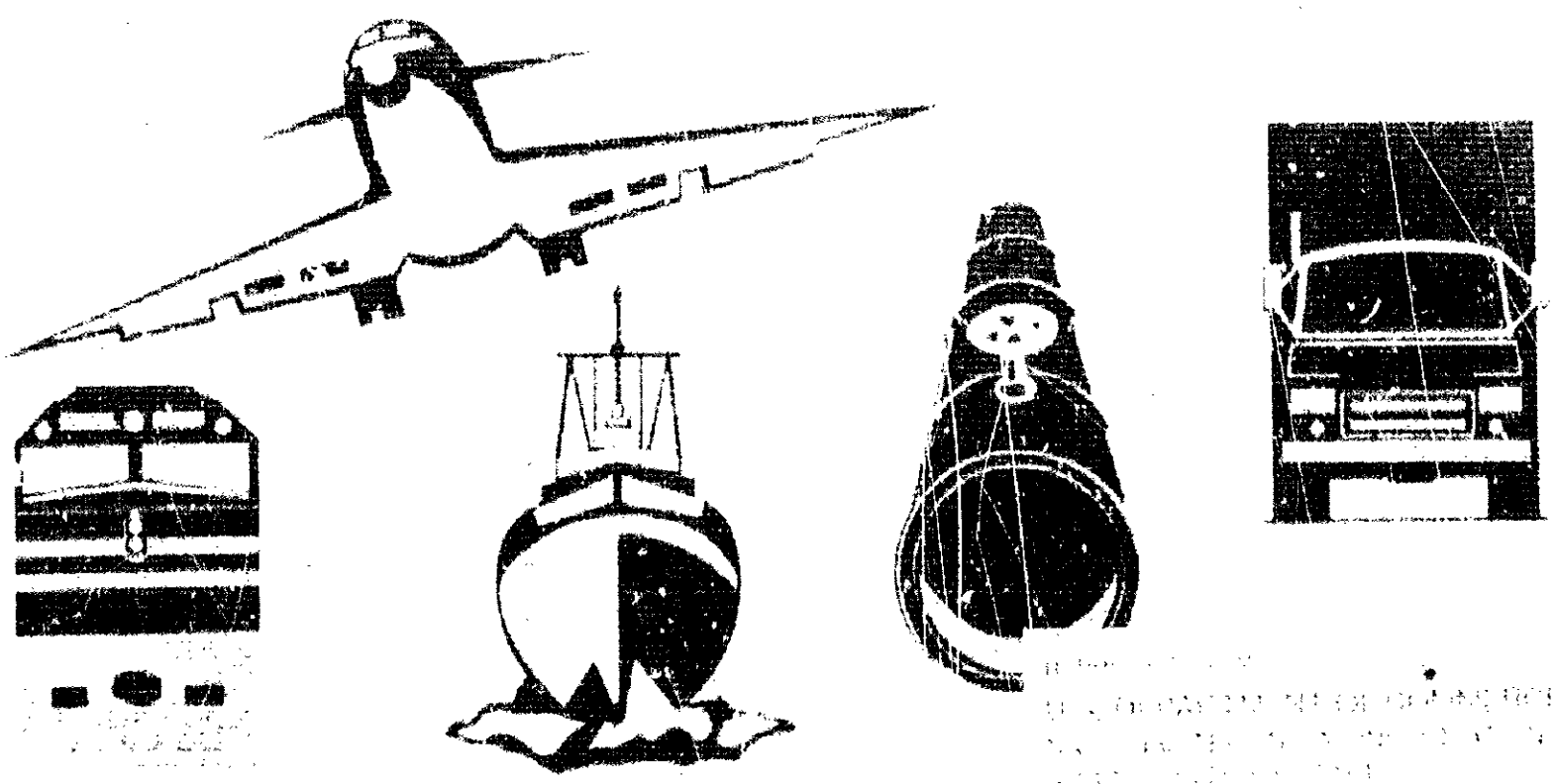
PB89-910406
NTSB/AAR-89/04

NATIONAL TRANSPORTATION SAFETY BOARD

AIRCRAFT ACCIDENT REPORT

DELTA AIR LINES, INC.
BOEING 727-232, N473DA
DALLAS-FORT WORTH INTERNATIONAL
AIRPORT, TEXAS
AUGUST 31, 1988



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16 Abstract

This report examines the crash of Delta flight 1141 while taking off at the Dallas-Forth Worth, Texas on August 31, 1988. The safety issues discussed in the report include flightcrew procedures;wake vortices; engine performance; airplane flaps and slats; takeoff warning system; cockpit discipline; aircraft rescue and firefighting; emergency evacuation; and survival factors. Recommendations addressing these issues were made to the Federal Aviation Administration, the American Association of Airport Executives, the Airport Operations Council International, and the National Fire Protection Association.

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EXECUTIVE SUMMARY

About 0901 central daylight time on August 31, 1988, Delta Air Lines, Inc., flight 1141, crashed shortly after lifting off from runway 18L at the Dallas-Fort Worth International Airport, Texas. The airplane, a Boeing 727-232, U.S. Registry N473DA, was a regularly scheduled passenger flight and was en route to Salt Lake City, Utah, with 101 passengers and 7 crewmembers.

The flightcrew reported that the takeoff roll appeared to be normal in all respects, with no warning lights, audible warnings, or unusual engine instrument conditions. The captain stated that the rotation was initially normal, but as the main gear wheels left the ground he heard "two explosions." He said it felt as though the airplane was experiencing "reverse thrust." The captain stated that the airplane began to "roll violently."

The airplane struck the instrument landing system (ILS) localizer antenna array approximately 1,000 feet beyond the end of runway 18L, and came to rest about 3,200 feet beyond the departure end of the runway. The flight was airborne approximately 22 seconds from liftoff to the first ground impact near the ILS localizer antenna. The airplane was destroyed by impact forces and the postcrash fire.

Of the persons on board flight 1141 12 passengers and 2 crewmembers were killed, 21 passengers and 5 crewmembers were seriously injured, and 68 passengers sustained minor or no injuries.

The National Transportation Safety Board determines that the probable cause of this accident to be (1) the Captain and First Officer's inadequate cockpit discipline which resulted in the flightcrew's attempt to takeoff without the wing flaps and slats properly configured; and (2) the failure of the takeoff configuration warning system to alert the crew that the airplane was not properly configured for the takeoff.

Contributing to the accident was Delta's slow implementation of necessary modifications to its operating procedures, manuals, checklists, training and crew checking programs which was necessitated by significant changes in the airline following rapid growth and merger.

Also contributing to the accident was the lack of sufficiently agressive action by the FAA to have known deficiencies corrected by Delta and the lack of sufficient accountability within the FAA's air carrier inspection process.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

DELTA AIR LINES, INC.
BOEING 727-232, N473DA
DALLAS-FORT WORTH INTERNATIONAL AIRPORT, TEXAS
AUGUST 31, 1988

1. FACTUAL INFORMATION

1.1 History of the Flight

On August 31, 1988, Delta Air Lines, Inc., flight 1141, a Boeing 727-232, N473DA, was a regularly scheduled passenger flight from Jackson, Mississippi to Salt Lake City, Utah, with an intermediate stop at the Dallas-Fort Worth International Airport (DFW), Texas. The flight was conducted subject to the provisions of Title 14 Code of Federal Regulations (CFR), Part 121.

Flight 1141 departed Jackson, Mississippi for DFW at 0630 eastern daylight time. The only logbook discrepancy was an inoperative No. 1 main fuel tank quantity gauge. The first officer flew the leg to DFW and noted nothing out of the ordinary en route. The landing and taxi-in to the gate at DFW were uneventful. Flight 1141 arrived at gate 15 at DFW at 0738 central daylight time.

The first officer and captain proceeded to company operations upon arrival. The second officer remained with the airplane and performed his walkaround inspection duties. The mechanic who handled flight 1141, while it was parked at gate 15, stated that he checked the logbook and noted that the No. 1 main fuel tank quantity gauge was inoperative. Operation of the airplane with the fuel quantity gage inoperative was permitted by Delta's minimum equipment list. He had no other involvement with the flight.

The Delta agent responsible for the proper loading of the airplane determined, as a result of dipstick and pitch and roll readings taken, that the airplane had 561 gallons of fuel remaining in the No. 1 main fuel tank. He calculated that 1,036 gallons should be added so that a total of 1,597 gallons would be contained in the No. 1 main fuel tank. This figure (1,597 gallons) was converted to 10,700 pounds of fuel. An equal amount was ordered to be the final fuel quantity in the No. 3 main fuel tank. The No. 2 main fuel tank was ordered to be filled to 10,600 pounds final weight.

The airplane fueler pumped the requested fuel quantities into the three tanks. Upon completion of fueling, he went aboard the airplane to inform the second officer of how he had refueled the airplane. While talking to the second officer, he noticed that the fuel gauge for the No. 2 main fuel tank was reading 500 pounds higher than the fuel gauge at his wing refueling station and he brought this to the attention of the second officer. The airplane was not dripsticked again after the refueling.

The second officer received the fuel slip (prepared by the fueling agent), final weather briefing, automatic terminal information service (ATIS) information, and automatic weight and balance system (AWABS) data prior to pushback. The pushback occurred at 0830, as scheduled. At 0837:20, the DFW east ground controller instructed Delta 1141 to "...join the inner for standard taxi to runway 18L." All three engines were started initially, but the captain subsequently decided to shut down the No. 3 engine to conserve fuel when it became apparent that there would be a delay before departure. Figure 1 provides a diagram of the DFW airport.

When the airplane became number four in line for departure at 0857:08, the second officer made an announcement to the flight attendants to prepare the cabin for departure. The captain then ordered that the No. 3 engine be restarted. At 0858:38, the local controller instructed, "Delta eleven forty-one taxi into position runway one eight left and hold...." With this clearance, flight 1141 was, in effect, directed to pass the airplanes ahead of it on the taxiway and take the No. 1 position. At 0859:17, the local controller instructed, "Delta eleven forty-one fly heading one eight five runway one eight left cleared for takeoff." The first officer of Delta flight 1141 acknowledged both transmissions.

After the accident, the second officer stated that when engine power was advanced for takeoff, the green AUTO PACK TRIP arming light did not illuminate. As operation of this system was not required for this flight, he did not advise the captain of this situation. He stated that the takeoff roll appeared to be normal in all respects, with no unusual lights, audible warnings, or unusual engine instrument conditions. However, immediately after liftoff, the right wing dropped and he heard the comment "engine failure" made by either the captain or first officer.

The captain stated, after the accident, that "all was normal...everything was routine" up to rotation. Rotation was initially normal, but as the main gear wheels left the ground he heard "two explosions." He said it felt as though the airplane was experiencing "reverse thrust." The captain stated that the airplane began to "roll violently...it was all I could do to control the airplane."

The airplane struck the ILS localizer antenna array about 1,000 feet beyond the end of runway 18L, came to rest approximately 3,200 feet beyond the departure end of the runway (see figure 2) and was destroyed by impact forces and the postcrash fire. The flight lasted approximately 22 seconds from liftoff to the first ground impact near the ILS localizer antenna.

Witnesses in the control tower and on the ground generally agreed that flight 1141's takeoff roll appeared to be normal until shortly after rotation. They stated that the airplane rotated in the vicinity of taxiways

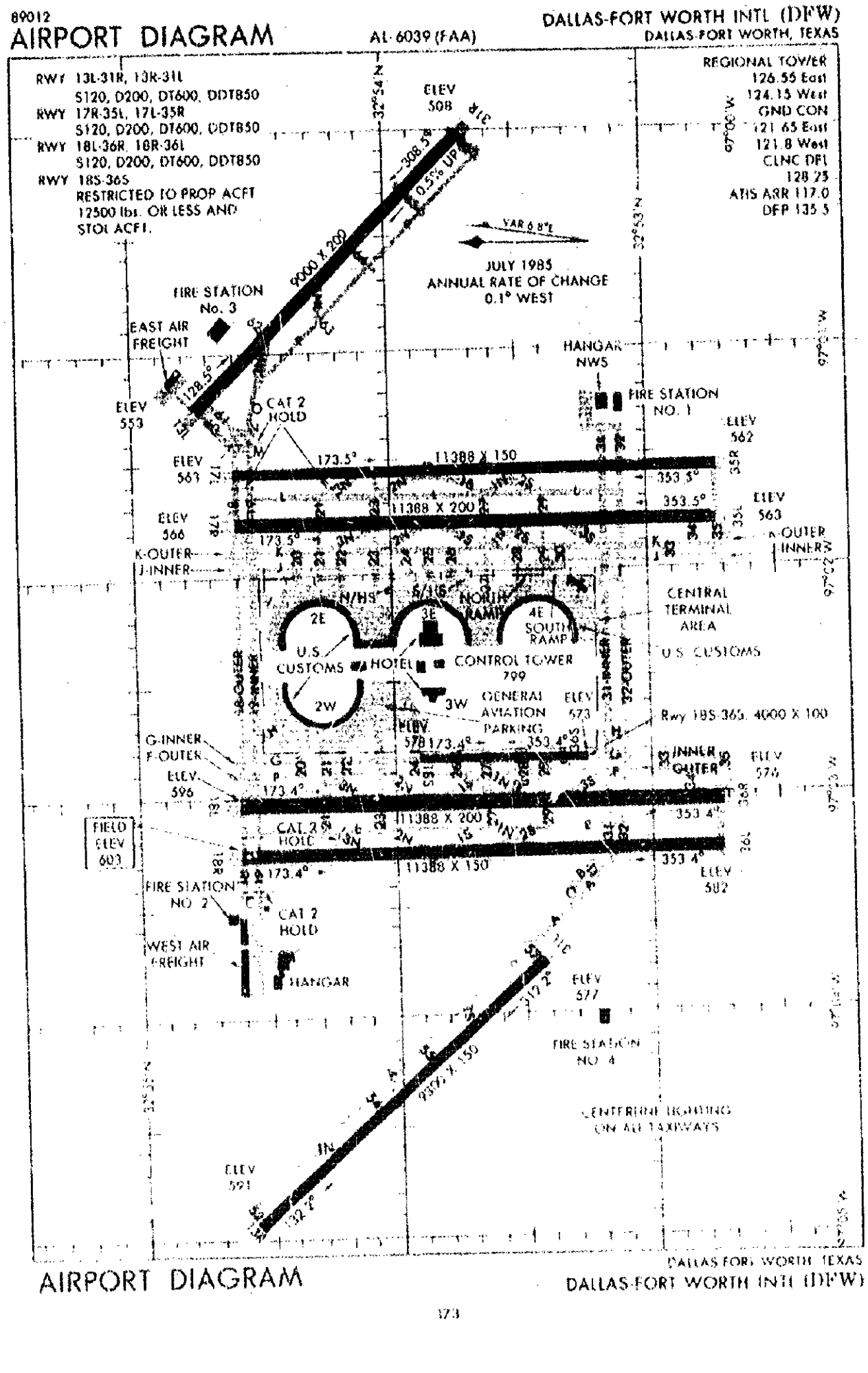


Figure 1.--Airport Diagram.

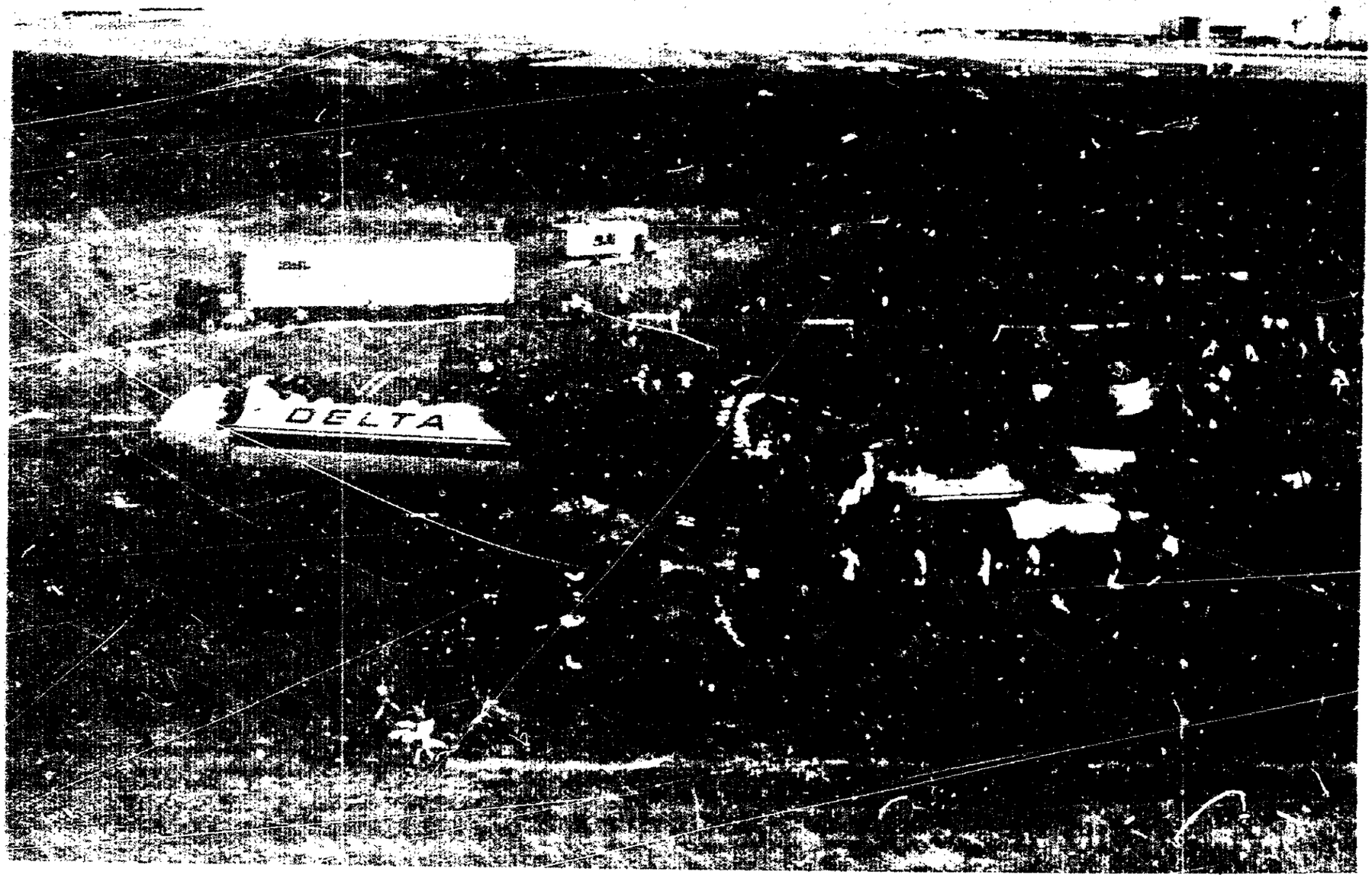


Figure 2.--General aerial view of left side of main aircraft wreckage, wreckage path, and the departure end of runway 18L looking north.

29 and 30 to a higher than normal pitch angle and that flames or sparks were emanating from the rear of the airplane. They said that as the airplane continued down the runway, the wings rocked from side to side and the airplane appeared to be out of control. The witnesses lost sight of the airplane after it struck the ground and disappeared into a cloud of dust. None of the ground witnesses could recall the position of the flaps during the takeoff roll or prior to impact. One passenger aboard the airplane stated that shortly after liftoff, he noticed that the trailing edge of the left wing appeared not to be in a straight line. He interpreted this observation to be that the flaps were down to some extent.

On board flight 1141 were 101 passengers, 3 flightcrew members and 4 cabin crew. Two flight attendants and 12 passengers were fatally injured. Twenty-six persons, including the flightcrew and cabin crew, sustained serious injuries. Sixty-eight passengers received minor or no injuries.

The accident occurred during the hours of daylight at latitude/longitude coordinates of 32°52'N 97°03'W.

1.2 Injuries to Persons

	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	0	2	12*	0	14
Serious	2	2	22	0	26
Minor	1	0	49	0	50
None	0	0	18	0	18
Total	3	4	101	0	108

*One passenger successfully exited the aircraft, but was severely burned when he attempted to reenter the cabin. He died 11 days later. It is believed that he attempted to reenter the cabin in an effort to provide assistance to his wife and other passengers in escaping from the aircraft.

1.3 Damage to the Airplane

The Boeing 727 232 was destroyed by ground impact and post impact fire. Its value was estimated at $6-6.5 million.

1.4 Other Damage

Ground damage was confined to two airport runway/taxiway markers, the ILS localizer antenna installation, and an airport boundary fence. There also was ground fire damage to terrain vegetation.

1.5 Personnel Information

The flightcrew and cabin crew of flight 1141 were qualified in accordance with applicable Federal Aviation Regulations (FAR) and Delta's procedures. (See appendix B.) Examination of the flightcrew's personal

background and actions during the 2 to 3 days before the accident flight revealed nothing remarkable. The flightcrew's training records also were unremarkable. FAA records did not contain any incident or violation history on any of the crewmembers.

The Captain.--The 48-year-old captain was hired by Delta Air Lines on October 18, 1965. The captain had been employed continuously by Delta since his date of hire.

The captain upgraded to captain initially on the DC-9 on May 22, 1975. However, due to Delta's reduction in flying time in the DC-9, he returned to his previous position as an L-1011 first officer. On August 30, 1978, he was upgraded again to captain on the DC-9 and remained in this capacity until August 1979. He completed Boeing 727 transition training in August 1979, and he remained as a 727 captain until the time of the accident.

The captain had received recurrent training on July 27-28, 1988, and a proficiency check was administered on July 29, 1988. His most recent en route check was completed on August 9, 1988. The simulator instructor who gave the captain's last proficiency check described the captain's performance as "text book" with no problems encountered. The captain possessed a first class medical certificate with a limitation that corrective lenses are to be worn to correct for near vision.

The First Officer.--The 36-year-old first officer was hired by Delta on January 26, 1979. He had been continuously employed by the airlines since that time. The first officer completed second officer qualification training in March 1979. He remained as a second officer until November 1987.

The first officer completed Delta's B-727 first officer qualification training on December 9, 1987. He remained in this position until the time of the accident.

The first officer's last recurrent training was November 4-5, 1987, and his last proficiency check was on November 20, 1987. His last en route check was accomplished on December 6, 1987. These checks were conducted during his initial first officer training. He possessed a second class medical certificate with no limitations.

The Second Officer.--The 30-year-old second officer was hired by Delta on November 20, 1987. The second officer attended Delta's B-727 second officer training program and was qualified as a second officer on January 20, 1988. No additional training was required from the time he completed initial training until the date of the accident. The second officer possessed a second class medical certificate with no limitations.

1.6 Airplane Information

The Boeing 727-232, U.S. registry N473DA, was delivered to Delta Air Lines in November 1973. The airplane was serial No. 20750, line No. 992.

The airplane was a Boeing Commercial Airplane Company model 727-232, equipped with three aft-mounted Pratt & Whitney JT8D-15 series turbofan engines. It was delivered in a passenger configuration. The airplane had a total of four floor level exits and four over wing emergency exits, and a ventral stairway exit.

The certificated maximum taxi weight of N473DA was 185,200 pounds. The maximum takeoff weight was 184,200 pounds, and its maximum landing weight was 154,500 pounds. The maximum zero fuel weight was 138,000 pounds.

The certificated usable fuel quantities were 1,818 gallons in fuel tanks Nos. 1 and 3, and 4,550 gallons in fuel tank No. 2. The total usable fuel quantity was 8,186 gallons, or 54,845 pounds. There was one fuel tank in each wing and one fuel tank in the wing center section. The aircraft was configured with two cargo compartments beneath the passenger cabin: one located forward of the wing, and one aft of the wing.

1.6.1 Weight and Balance

Delta utilizes an AWABS, in which the gate agent enters into a computer the details of the loading of the aircraft. The pilots are provided with a final AWABS record prior to pushback.

The maximum allowable takeoff weight for the flight was 175,440 pounds, dictated by the maximum allowable structural landing weight at Salt Lake City. This weight was below the maximum takeoff weights authorized for runway 18L.

Delta provides its flightcrews with performance data for each runway, using the most limiting factor, i.e., runway allowable or climb limit. With flight 1141's actual takeoff weight of about 157,683 pounds, the crew was authorized to use alternate power, i.e. reduced thrust, and a flap setting of 15° for runway 18L.

1.6.2 Lift and Roll Systems

Lift devices of the Boeing 727-232, consist of three leading edge flaps (Krueger flaps) located on the inboard lower surface of each wing, four leading edge slats on the outboard portion of the wing, and inboard and outboard trailing edge flaps (see figure 3). The trailing edge flaps are driven by two completely independent systems. Each drive system normally is hydraulically powered; electrical power is available for alternate operation. Each trailing edge flap is actuated by two flap transmission assemblies. The transmission assemblies on the outboard flaps are connected through torque tubes and gearboxes to a hydraulic motor which is the primary driving source. Another separate set of torque tubes and gearboxes interconnect the transmission assemblies on the two inboard flaps. This system is driven by a single hydraulic motor. Power to the motors is controlled by two differential control valves with feedback modulation from the power transmitting torque tubes.

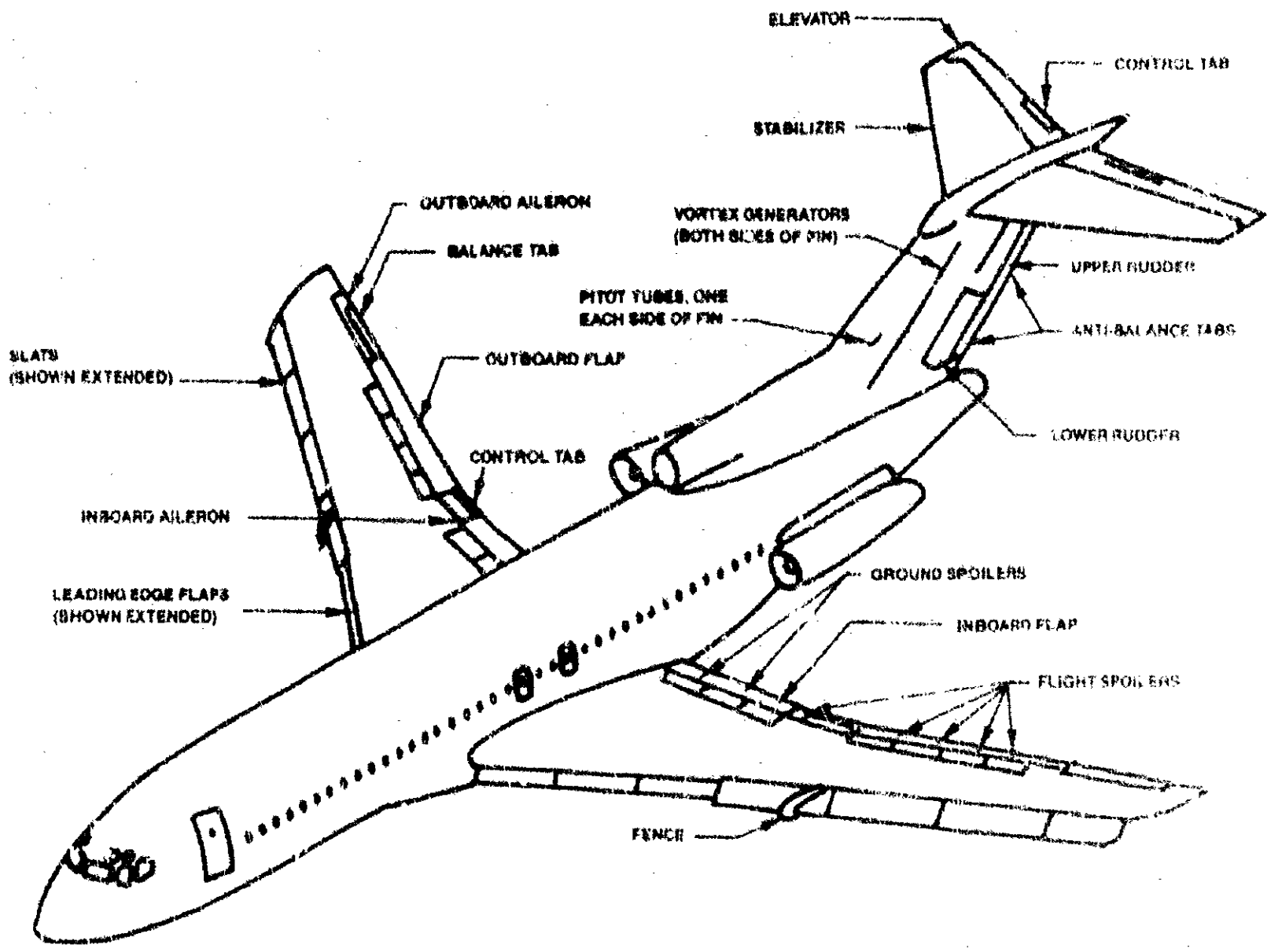


Figure 3.--Boeing 727 flight control surfaces.

The leading edge flaps and slats are driven by linear hydraulic actuators. The actuators are controlled through a three-position control valve activated by the outboard flap follow-up system. At 2° of flap, only the middle two slats on each wing are deployed. The remaining leading edge flaps and slats deploy after the flap handle is selected past 2°. An amber light on the center instrument panel illuminates when the slats are in transit. A green light illuminates when the slats are extended. (See figure 4.)

Flap settings are controlled from the cockpit by moving the flap lever through a detented arc on the right side of the center control stand. This lever has control cable linkage to the differential control valves. The flap lever is spring-loaded to lock in each of the detents and must be lifted about 1/4 inch to allow movement to another detent.

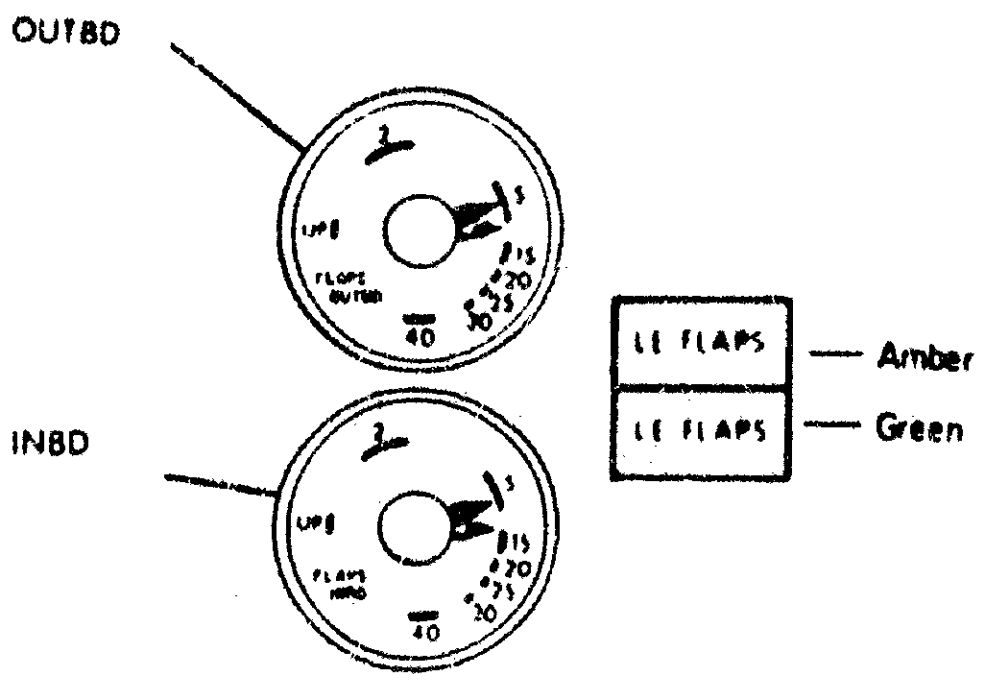
Alternate provisions for flap extension are incorporated in the system in the event of normal system failure. During alternate operations, the trailing edge flaps are extended and retracted by two electric motors which are coupled to the torque tubes. The leading edge flaps and slats can be extended by a standby hydraulic pump. Pump operation is controlled by the alternate flap control system.

An electro-mechanical flap position transmitter assembly is provided for each trailing edge flap. The units mechanically sense the position of each flap and generate an electrical signal which is fed to two dual needle indicators in the cockpit. The indicators, located on the center of the instrument panel, show the position of the inboard and outboard flaps, respectively.

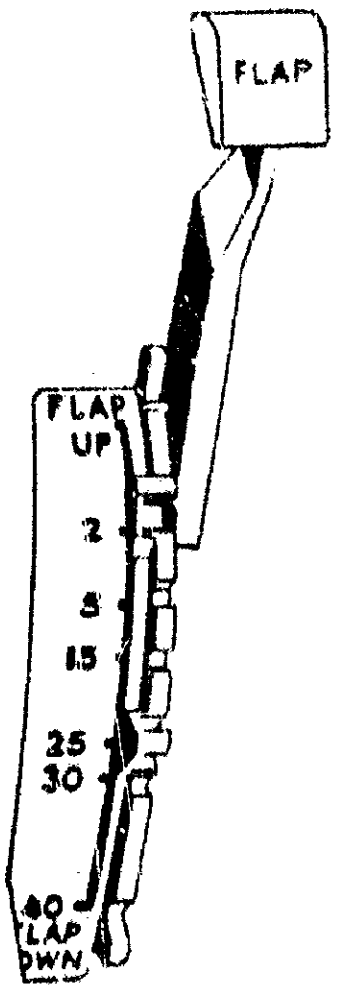
Two identical electrically operated protection systems are provided to prevent asymmetrical operation of the trailing edge flaps. One system prevents inboard flap asymmetry while the other prevents outboard flap asymmetry. The airplane is not equipped with a mechanical system to prevent the inboard or outboard set of flaps from deploying without the other set.

The outboard flaps are mechanically connected to the outboard ailerons in such a way as to lock the outboard ailerons in the faired position when the outboard flaps are in the up position. This feature is incorporated into the system because deflection of the inboard ailerons and flight spoilers are sufficient for high speed flight control. When the flaps are extended down, both the inboard and outboard ailerons are operated together. The lockout mechanism consists of an angle gearbox, torque tube, jackscrew, and bellcrank.

The Boeing 727-232 has seven spoilers on each wing. The five outboard spoilers are flight spoilers and the inboard two are ground spoilers. The flight spoilers augment the ailerons in roll control and at the same time are available to act as an air drag device. The ground spoilers can be extended only when the airplane is on the ground and they serve together with the flight spoilers as speed brakes to shorten the landing roll. Each spoiler is positioned by its own hydraulic actuator.



FLAPS POSITION INDICATOR AND LEADING EDGE FLAPS LIGHTS



FLAPS SELECTOR LEVER

Figure 4.--Boeing 727 flap position indicator and flap selector lever.

1.6.3 Takeoff Warning System

The Boeing 727-232 is equipped with a takeoff warning system to warn the crew when the aircraft is improperly configured for takeoff. The warning system is activated when thrust lever No. 3 is advanced beyond a predetermined position. The takeoff warning horn will sound when one or more of the following conditions exist: (1) the stabilizer trim is outside the takeoff range; (2) outboard trailing edge flaps are less than 5°; (3) the No. 4 and No. 5 leading edge slats are not extended; or (4) speedbrake handle is not in the down detent position.

1.6.4 Stall Protection System

The aircraft is equipped with a stall warning system. This system is actuated by an angle-of-attack sensor and uses the inboard flap position as part of its actuation logic. In the event of activation, a stickshaker vibrates the pilot's control columns and creates a unique sound. The system is active only when airborne.

Prior to the accident, Delta's maintenance program required that a takeoff warning system check be accomplished at every major inspection interval and at every fourth service check. On August 11, 1988, during an inspection of the accident airplane (an A-2 check), a discrepancy was noted during the takeoff warning horn test. This discrepancy was entered as: "aural warning horn weak and intermittent when throttles pushed forward." The aural warning unit was replaced and the airplane was returned to service. The contact points on the removed unit were cleaned and the unit functioned properly during a bench test at Delta's maintenance facilities.

1.6.5 Auto Pack Trip System

The Boeing 727-232 aircraft is equipped with a system that automatically shuts down the air-conditioning packs in the event of loss of engine thrust during takeoff or initial climb. Turning off the packs conserves engine bleed air to provide maximum available engine thrust. Three indicator lights are provided on the air-conditioning control panel, which are labeled AUTO PACK TRIP ARMED, LEFT A/C PACK TRIP OFF, and RIGHT A/C PACK TRIP OFF. Engine fail lights are provided on the captain's/first officer's glare shield.

The Auto Pack Trip switch on the flight engineer's panel is selected to NORMAL prior to flight. The system will then arm if the main landing gear struts are compressed, the inboard flaps are extended out of the UP position, and all engines are set above approximately 1.5 EPR. A green light on the flight engineer's upper panel illuminates when the system is armed. Thrust loss on any one engine will then trip off both packs, shut down both pack cooling fans, and illuminate the ENG FAIL lights.

1.7 Meteorological Information

The DFW ATIS prior to the accident indicated: "DFW airport departure information Golf, one two five two zulu weather, sky clear; visibility one zero; temperature, six six; dew point, five niner; wind, calm; altimeter, two niner niner niner; runways one three, one seven, one eight departures in progress, use caution for bird activity on and in the vicinity of the airport, advise clearance delivery that you have Golf."

Observations recorded by the National Weather Service immediately prior to and after the accident indicated the following weather conditions:

> 0851 - clear, visibility, ten miles; temperature, seven three; dew point, five one; wind, one zero zero at eight; altimeter, two nine nine nine.
>
> 0906 - clear, visibility, ten miles; temperature, seven four, dew point, five seven, wind, zero nine zero at nine, altimeter, two nine nine nine.

There was no activation of the low level windshear alert system (LLWAS) prior to, or after the accident.

1.8 Navigational Aids

There were no known difficulties with navigational aids.

1.9 Communications

There were no known difficulties with communication equipment or facilities.

1.10 Aerodrome Information

The DFW airport is located approximately midway between the cities of Dallas and Fort Worth, Texas. It is owned by these cities and governed by an eleven-member board of directors. Airport elevation is 603 feet. The central terminal area is located between north/south parallel runways located on the east and west side of the terminal area. The airport has three sets of parallel runways. Runway 18L on which flight 1141 departed is 11,387 feet long and 200 feet wide; runway 18L has elevations of 596 feet mean sea level (msl) at the north end and 576 feet msl at the south end. It is equipped with high intensity edge lights, centerline and touchdown zone lights. The runway is an ILS CAT I equipped, instrument runway; runway 18L ILS localizer antenna array is situated approximately 1,000 feet south of the departure end, and its upper-most elevation is 579 feet msl.

Seventeen local notice to airmen (NOTAMS) were in effect at the time of the departure of flight 1141. These NOTAMS concerned areas of construction, closed taxiways and flocks of birds sighted on, and in the vicinity of, the airport.

The DFW air traffic control (ATC) facility is a Level V FAA facility which operates 24-hours per day. The tower and terminal radar approach control (TRACON) are split; i.e., the controllers are assigned exclusively to either the tower or the TRACON. Administration of both the tower and the TRACON is under the control of the facility manager and his staff.

The DFW control tower operations exceed 670,000 annually and was the third busiest airport in the country at the time of the accident. The facility utilizes two airport surveillance radars (ASR-7 & ASR-8) which is augmented with automated radar tracking system (ARTS) IIIA computer tracking. The control tower has 10 positions of operation. These may be combined or de-combined to meet daily and hourly traffic demand.

1.11 Flight Recorders

The airplane was equipped with a Fairchild model A-100A cockpit voice recorder (CVR), serial No. 51362, and a Lockheed Model 109-D flight data recorder (FDR), serial No. 654. The recorders were taken to the Safety Board's flight and voice data recorder laboratories in Washington, D.C., for examination and readout.

1.11.1 The Cockpit Voice Recorder

The CVR starts at 0828:38 central daylight time (see appendix C) just prior to pushback from the gate at DFW, and continues until 0900:39.4. Seven minutes and 42 seconds of nonpertinent conversations, beginning at 0839:42, were edited from the transcript. These conversations consisted of casual, nonduty related topics among the flightcrew and included a conversation with a flight attendant who was in the cockpit on two occasions during the ground operation. The transcript starts again at 0847:28, just as the flight changed from the DFW east ground controller to the west ground controller. At 0848:14, 1 minute and 18 seconds and again at 0850:01, 1 minute and 22 seconds of the transcript were edited. These conversations consisted of casual, nonduty related topics. At 0853:12, the transcript starts again and continues unedited until the end of the recording.

The flight started monitoring local control, i.e., the control tower, frequency at 0857:22. The flight attendant left the cockpit and the door was closed at 0857:35 after the second officer called for the flight attendants to prepare the airplane for departure. The No. 3 engine was restarted at 0857:42 and the last part of the taxi checklist was accomplished. During this portion of the taxi checklist, in response to the second officer's prompt of "FLAPS", the first officer stated "FIFTEEN, FIFTEEN, GREEN LIGHT." The flight was cleared onto the runway at 0858:38 and was cleared for takeoff at 0859:17.

The sound of increasing engine noise can be heard at 0859:35 followed by the first officer callouts of "Power set" and "Engine instruments look good." A callout of V_R was made at 0900:05.5 and V_2 at 0900:10.7. The takeoff appeared normal until 0900:15.1 when the airplane stall warning stickshaker is heard. Starting at 0900:17.6, five sounds that were identified as engine compressor stall/surge sounds can be heard. A momentary

(less than .2 seconds) electrical power interruption is experienced by the CVR recorder at 0900:22.9 just after the callout of an "Engine failure" by one of the crewmembers. A callout by the captain of "FULL POWER" was recorded 0.6 seconds prior to the sound of the first impact. The sound of the first impact was recorded at 0900:35.3, followed by three more distinct impact sounds over the final 4 seconds of the recording.

A "snap" sound is heard on the CVR at 0900:12.5 which was believed to have been produced by the landing gear down-lock solenoid moving to the retracted position. A study was undertaken to compare the sound signature of the "snap" with several other recordings of the landing gear solenoid retracting on similar model Boeing 727 airplanes. Two of the comparison recordings were made on regularly scheduled revenue Delta flights. The third comparison was a recording of the solenoid being manually actuated by ground personnel. The results of the study indicated that there was an inconclusive energy versus frequency match between the test recordings and the accident airplane's "snap" sound to positively state that the source of the snap was the retraction of the landing gear solenoid.

The study of the CVR did not disclose a sound which could be associated with the movement of the flap control lever to either extend or retract the flaps.

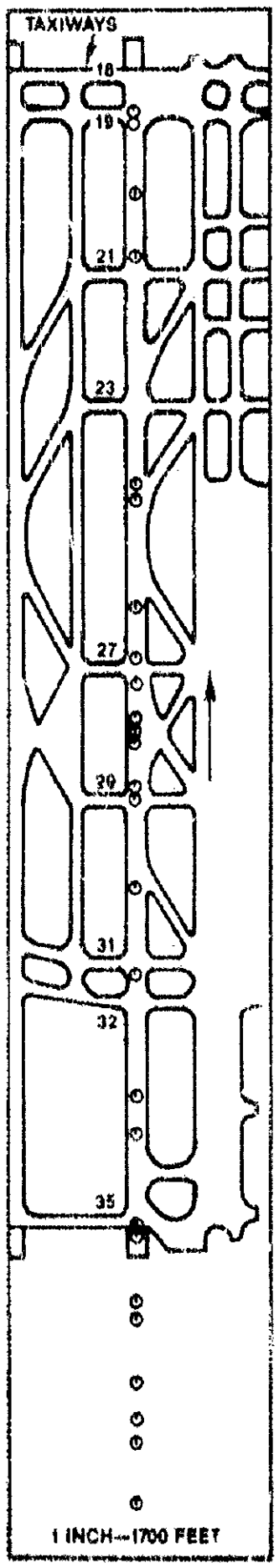
1.11.2 The Flight Data Recorder

The foil type recorder recorded the airplane's altitude, indicated airspeed, magnetic heading, normal acceleration (i.e., perpendicular to the airplane longitudinal axis), as well as microphone keying, and time. The aluminum foil recording medium was removed with all parameter and ancillary traces present. There was a slight jump in the altitude recording during takeoff which was considered to be due to a sticking needle. There were no indications of recorder malfunction or recording abnormalities during the previous takeoff at Jackson, Mississippi.

1.12 Wreckage and Impact Information

1.12.1 Impact Marks and Ground Damage

The first impact mark was made by the tail skid contacting the runway centerline and a runway centerline light between taxiways 27 and 29, at a distance of approximately 4,990 feet prior to the departure end of runway 18L (see figure 5). About 650 feet from this point, the right wing tip struck the right side of the runway near taxiway 29, approximately 4,340 feet prior to the departure end of runway 18L. The taxiway markers for taxiways 31 and 32 were found knocked over, but they did not exhibit any impact damage. Additionally, the grass was found to be scorched between the end of the runway and the ILS antenna. Approximately 5,300 feet from the point of the right wing tip runway contact, and approximately 900 feet beyond the departure end of runway 18L, the airplane impacted and destroyed the ILS localizer antenna. From this point and beyond, airplane component such as the right wing tip and portions of the right inboard and outboard ailerons began separating from the airplane.



TIME	KIAS	EVENT	DISTANCE
— 08:59:33	0	START	350 FT
— 08:59:35	0	(INCREASING ENGINE RPM)	417 FT
— 08:59:48	38	"POWER SET"	1,213 FT
— 08:59:54	82	"80 KNOTS"	1,840 FT
— 09:00:06	131	"VEE R"	4,041 FT
— 09:00:07	134	(NOSE STRUT EXTENSION)	4,263 FT
— 09:00:11	145	"VEE TWO"	5,304 FT
— 09:00:13	150	(SNAP SOUND)	5,775 FT
— 09:00:13	154	ESTIMATED LIFTOFF	6,017 FT
— 09:00:15	155	TAIL SKID CONTACT	6,400 FT
— 09:00:16	156	(STICK SHAKER)	6,488 FT
— 09:00:16	156	"SOMETHIN'S WRONG/OOH"	6,600 FT
— 09:00:17	158	RIGHT WING TIP CONTACT	7,050 FT
— 09:00:18	156	(FIRST COMPRESSOR SURGE)	7,187 FT
— 09:00:21	161	(LAST COMPRESSOR SURGE)	8,180 FT
— 09:00:23	162	BEACON RADAR RETURN	8,843 FT
— 09:00:28	163	BEACON RADAR RETURN	10,113 FT
— 09:00:29	163	"ELEVEN FORTY ONE'S"	10,429 FT
— 09:00:32	163	CROSS END OF RUNWAY 18L	11,387 FT
— 09:00:32	164	BEACON RADAR RETURN	11,444 FT
— 09:00:36	164	"FULL POWER"	12,113 FT
— 09:00:36	164	(1ST IMPACT—ILS ANTENNA)	12,268 FT
— 09:00:37		(3RD IMPACT)	12,697 FT
— 09:00:39		(4TH IMPACT)	13,217 FT
— 09:00:39	-----	END OF TAPE -----	
—	-----	FINAL POSITION -----	14,670 FT

Figure 5.— Flight 1141 takeoff events.

After first impacting the antenna installation, the airplane remained airborne for an additional 400 feet, then struck the ground with the main landing gear wheels which produced a 350-foot linear ground depression. The airplane then traversed a ground depression that was approximately 150 feet wide and 16 feet deep. As the airplane crossed the depression, it impacted the ground on the far side. The airplane track then began to gradually swerve to the right of the extended runway centerline. This portion of the wreckage track was approximately 800 feet long.

The last 600 feet of the wreckage track indicated that the remaining airplane structure slid sideways; most of the right wing structure outboard of the center fuel tank had disintegrated, until it came to rest near the airport boundary fence located approximately 3,200 feet from the departure end of runway 18L. (See figure 1.)

1.12.2 Airplane Damage

The respective actuators for the nose and main landing gears were in the extended positions. The tail skid shoe was intact and exhibited evidence of ground contact with a runway light. Although the tail skid cartridge sustained some damage at the end on one side, the cartridge was intact and showed no evidence of being compressed, which would indicate light contact between the skid and the runway. A runway centerline light had a series of gouges and ridges that matched the ridges and gouges on the tail skid shoe.

The Nos. 1 and 2 engines remained with the empennage. The No. 3 engine separated from the empennage. Most of the external hardware and accessories separated from the No. 3 engine during the crash sequence and were fragmented. On scene inspection of the Nos. 1 and 2 engines found that the N_1 rotors rotated freely with no engine case penetrations. There was no damage to the inlet guide vanes and no evidence of bird ingestion.

The No. 3 engine core was approximately 500 feet north of the main wreckage. There was no evidence of bird ingestion. All 1st stage fan blades had leading and trailing edge damage. The 2nd stage fan blades had severe damage to the leading and trailing edges and were bent opposite to the direction of rotation. No thermal damage or distress was observed in the turbine area.

The thrust reversers for all three engines were in the stowed position. The reversers for the Nos. 1 and 2 engines were found attached to their respective engines. The No. 2 engine lower thrust reverser actuator fairing was crushed inwards. It contained pieces of the ILS electrical junction box and other evidence of ground contact.

Shortly after the accident, the three engines were disassembled at the facility of the engine manufacturer. The No. 3 engine's 2nd through 6th, 8th, 9th and 11th compressor stages had blades which were bent opposite to the direction of rotation. The inspection of the engines disclosed no mechanical problems that would have precluded normal operation prior to impact.

Fuselage and Empennage.--The fuselage had separated into three major sections: (1) the forward section consisted of the nose forward of fuselage station (FS)-420 (see figure 6); (2) the center fuselage section included the body structure between FS-420 and FS-950c; and (3) the aft fuselage section extended from FS-950c aft to the end of the No. 2 engine tailpipe.

The forward fuselage section had rotated to the left about 45°. The entire lower fuselage structure sustained various degrees of tearing, buckling and general overall distortion. Some sooting was noted in the area between the first officer's side window and the separation.

The center fuselage section came to rest right side up and was supported by the left wing and right wing center section. The left side forward of FS720e showed no evidence of fire damage and all passenger windows were intact. However, the left side between FS-720e and FS-950c had sustained varying degrees of fire damage. In the general area of FS-950c, some fuselage structure had been consumed by fire.

The right side of the center fuselage section between FS-420 and FS-950c also contained fire damage with some fuselage areas totally consumed by fire. All passenger windows on the right side were missing or melted.

The fuselage crown between FS-450 and FS-680 from the top of the passenger window line on the right side to the top of the Delta logo on the left side was consumed by fire. Another area of the top fuselage, between FS-720c and FS-840, was consumed by fire from the top of the right forward overwing emergency exit door to the fuselage centerline.

The aft fuselage section had rolled to the left and rotated counterclockwise about 45°. The aft fuselage skin structure between FS-950c and FS-950e on the left side was consumed by fire. The aft fuselage skin structure on the right side between FS-950e and FS-1030 was found laying on the ground alongside the fuselage. The entire aft fuselage section generally sustained various degrees of breakup and fire damage.

Vertical/Horizontal Stabilizer.--The vertical/horizontal stabilizer assembly had folded downward to the left. It was nearly inverted but still partially attached to the lower portion of the vertical stabilizer by several stringers.

Left Wing.--The left wing was complete and attached to the fuselage with varying degrees of ground impact, heat, and fire damage throughout. All flight control surfaces except for the outboard trailing edge flap assembly remained attached to the wing. The left wing lower surface was intact but contained spanwise scratch and scuff marks.

Right Wing.--The entire right wing assembly was fragmented and the pieces were recovered along the entire wreckage path. Most of the fragmented wing pieces sustained fire damage. The wing tip leading edge lower surface exhibited a deep lateral compression buckle. The outboard trailing edge tip

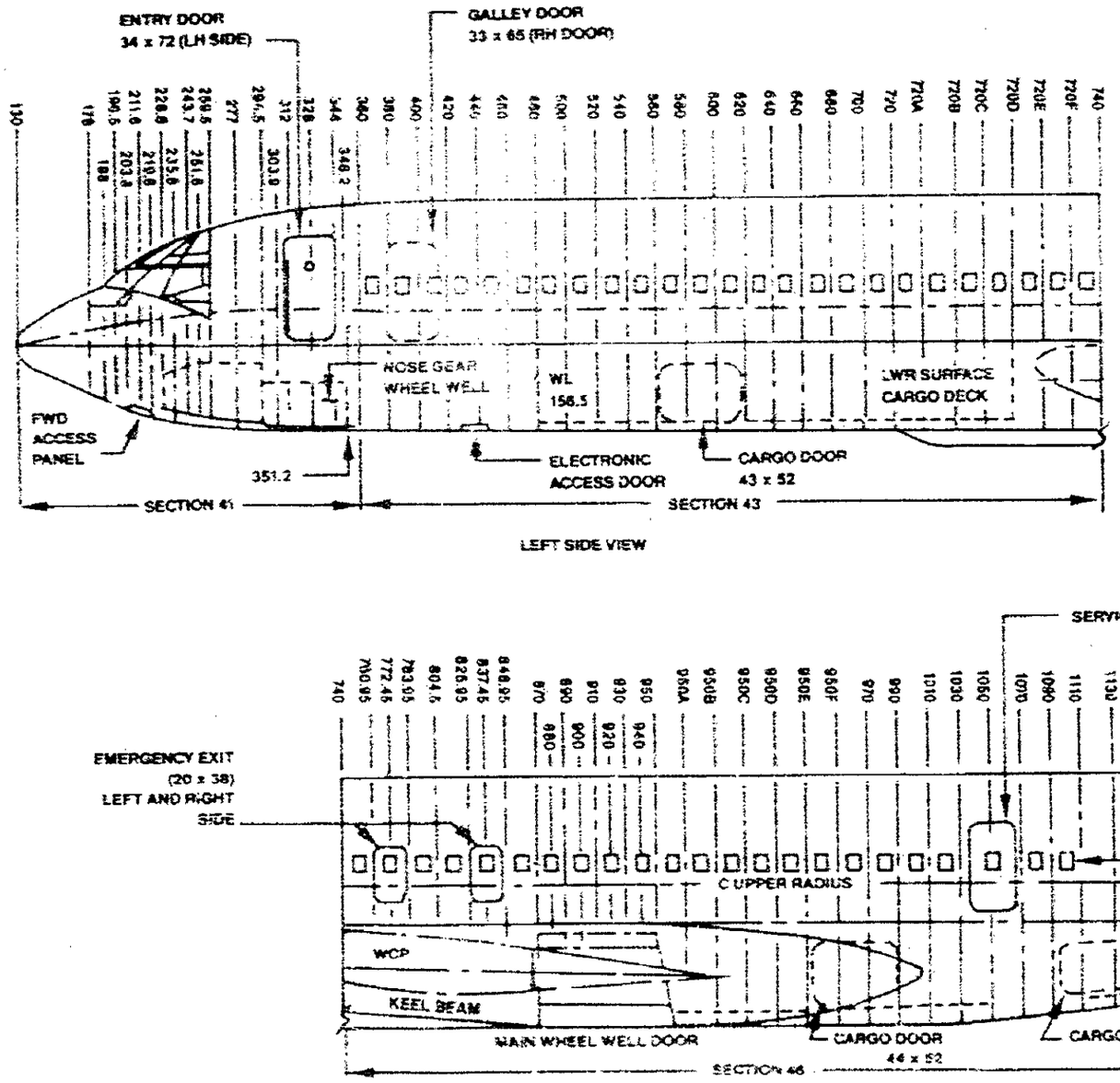


Figure 6.--Fuselage station diagram.

and static wick were partially ground away. The position light boom, located inboard of the tip outboard end, had also been partially ground away on its lower surface, within 8 inches from its aft end. The distance between the light boom and the trailing edge tip was equal to the distance between the marks found on the runway.

Wing - Center Section.--The left side of the wing center section upper surface, above the main landing gear strut well, approximately 5 feet outboard of the fuselage, exhibited a 15-inch burnthrough triangular hole. The upper wing surface at the left wing root fillet panel exhibited a 4- by 3-foot burn-through hole that penetrated into the wheel well. The left main landing gear assembly was attached to the left side of the wing center section. There was no evidence of preimpact failure of the wing center section.

Spoiler System.--The area in the right wheel well where the spoiler mixer is located had sustained severe fire damage, but the mixer could be moved. The spring cartridge rod from the aileron power control unit and the mixer control rod from the spoiler ratio changer were severed by fire. The spoiler control cables to the left wing were intact, and the cables to the right wing were attached but slack. The speedbrake cable was attached but was found slack.

The inboard spoiler shut-off valve lever in the right wheel well was in the No. 1, or normal, position. The outboard spoiler shut-off valve in the left wheel well was consumed by fire. The ground spoiler control valve crank rig pin hole was aligned. The ground spoiler by-pass valve in the left wheel well was damaged by the gear collapse but moved freely.

All the spoiler panels on the left wing, except ground spoiler No. 6, were in the stowed position and locked. All spoiler installations appeared normal except for being smoke covered.

The No. 6 spoiler could be raised manually. The actuator was subsequently removed and tested at the airline's facility. The actuator was found to be functional, but the adjustment of the overcenter mechanism prevented downlocking.

On the right wing, the four outboard flight spoiler panels with their respective actuators and rear wing spar attachments separated from the wing. All were found to be in the stowed position and locked. The remaining flight spoiler was located in the fuselage/right wing area of the wreckage just outboard of the landing gear support beam. After the accident, the assembly was found attached to the spoiler beam, and the actuator was found in the extended position. The ground spoilers were mostly consumed by fire.

Trailing Edge Flap System.--The flap control mechanism in the cockpit area was found in the flap up position. (See figure 7.) The mechanism was intact and functional. The flap handle spring tension was normal. The flap control cables were attached, and continuity was established to the forward fuselage break. From the fuselage break, further continuity of the cables was established to the outboard flap control valve

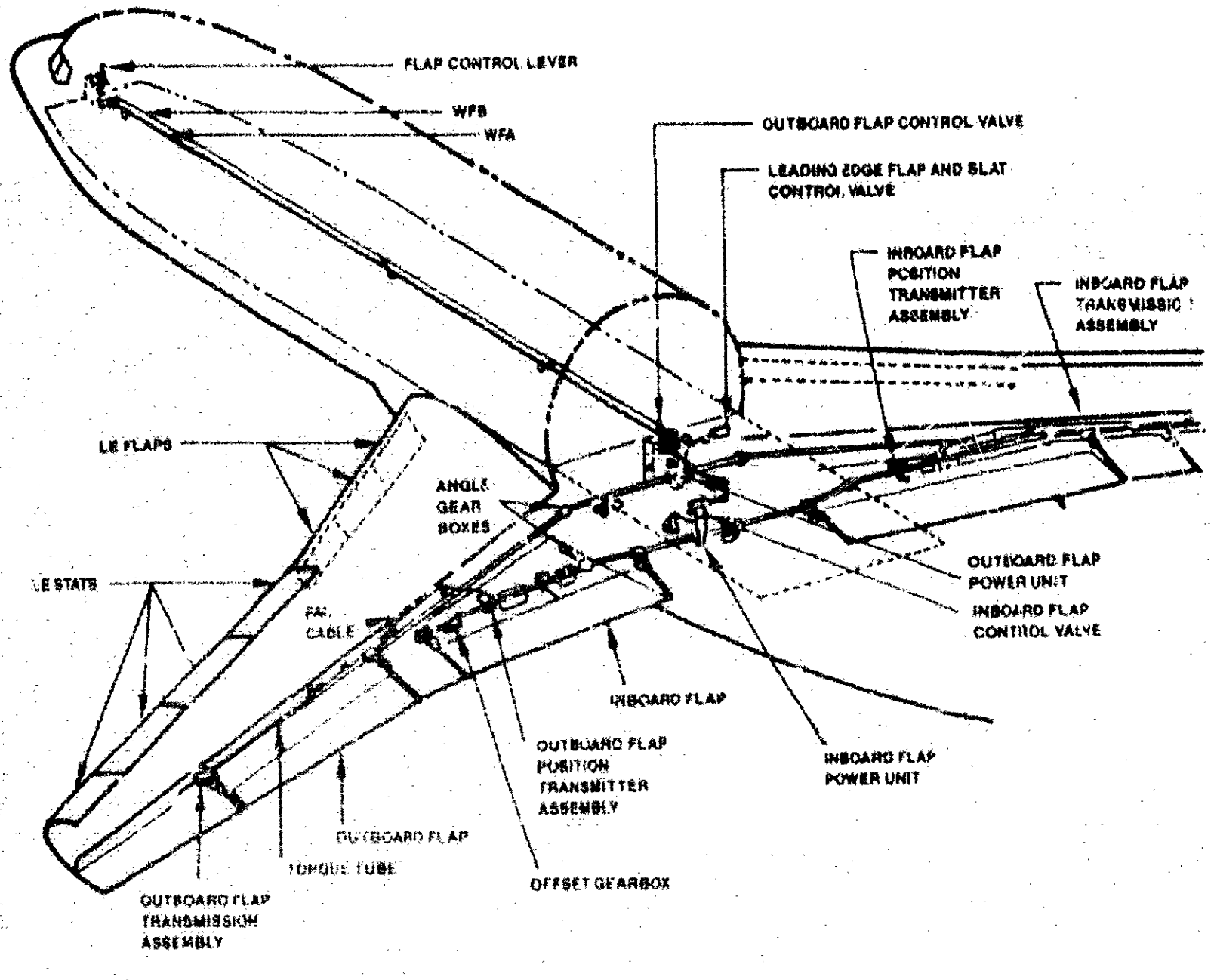


Figure 7.--Trailing edge flap system.

located at the forward wall of the right wheel well. Movement of the cables at the fuselage break produced a corresponding movement of the outboard flap control valve input linkage.

Electrical continuity of wiring from the P6 circuit breaker panel, which controls the flight control warning system to the alternate flaps master switch, was verified.

The outboard flap power drive unit, located in the right wheel well, sustained substantial fire damage. The follow-up cable from the drive to the cable drum was intact, and the rig pin hole of the drum was positioned at 1/3 to 1/2 hole-diameter from the full up position. The left wing outboard flap torque tube was intact throughout the left wing. The right wing outboard flap torque tube was severed by fire at the right side of the right wheel well.

The outboard flap alternate drive mechanism in the left wheel well sustained severe fire damage. All electrical wires were attached with their insulation burned off. The gearbox could be turned by hand, and no external damage other than fire damage was evident.

The left wing's outboard flap position transmitter was found intact in the left wing. The right wing's outboard flap position transmitter was attached to a portion of the spoiler beam that was found in the melted area of the right wing at the fuselage.

The cables from the outboard flap control valve to the quadrant on the aft wall of the right wheel well were intact. The cables were in their respective pulley grooves. The quadrant had moved forward and the cables were slack. The control rod from the quadrant to the inboard flap control valve, located at the aft wall of the left wheel well, had separated from the quadrant. The outboard flap by-pass valve was in the No. 1, or normal position, the inboard flap by-pass valve was in the No. 2, by-pass, position.

The area of the left wheel well which contained the inboard flap control valve was burned and the follow-up mechanism, from the inboard flap power drive unit to the inboard flap control valve, had been consumed by fire. The control rod attached to the inboard flap control valve was in a flap up position. The follow-up chain/cable was found laying on the power drive unit and was not broken.

The inboard flap power drive unit was jammed. The right wing's inboard flap torque tube leading to the alternate drive gearbox located in the right wheel well was intact. The right wing inboard flap torque tube, from the gear box to the right wing, was burned off just outboard of the gearbox.

The inboard flap alternate drive mechanism in the right wheel well sustained severe fire damage. All electrical wires were attached with their insulation burned off. The gearbox could not be turned by hand due to the jammed inboard flap power drive unit. Slight movement of the torque tube

connecting the gearbox to the power drive unit indicated that the gearbox would turn.

The left wing's inboard flap position transmitter was intact but slightly damaged by impact. The right wing's inboard flap position transmitter was found separated into two pieces along the wreckage debris path.

The left wing's outboard flap had separated from the wing with the flap tracks and carriages attached. Both actuators were detached. The outboard actuator assembly remained attached to the wing, and the inboard actuator assembly had pierced the fuselage just aft of the No. 1 engine cowl. The ballnuts on both jackscrews were within one turn of the upstop, and both ballnuts could be rotated freely.

The left wing's inboard flap was attached to the wing and was in the retracted position.

Portions of the right wing inboard flap were found throughout the wreckage debris path. The major portion of the inboard flap was found with the fore flap attached by its inboard track but otherwise separated from the assembly. The mid-flap and aft flap were intact, except for a small area of the inboard end of the mid flap and the area where the aft flap attached to its inboard track. The outboard track carriage was also attached. The inboard track carriage, the inboard and outboard tracks, and the inboard and outboard actuator assemblies were not attached.

The right wing's inboard actuator assembly transmission gearbox and jackscrew were found separately in the wreckage debris path. The transmission gearbox was crushed and could not be turned by hand. The ballnut on the jackscrew was against the upstop, was jammed, and could not be turned by hand.

The right wing's outboard actuator assembly was also found in the wreckage debris path. The ballnut was 1 1/2 turns from the upstop, and both the ballnut and transmission were free to rotate.

Portions of the right wing outboard flap were found throughout the wreckage debris path. The outboard jackscrew cover showed evidence of contact with gravel. Gravel was present at the ILS antenna installation mound. The outboard track was found attached to a piece of the lower skin. The fore flap sequence carriage was found in place on its track, capable of sliding along the track. The outboard end of the mid flap was found with the carriage and actuator assembly attached. The ballnut on the jackscrew was 2-turns from the upstop, and both the ballnut and transmission could rotate freely.

The inboard end of the right wing's outboard flap was found with the fore flap, aft flap, carriage, and actuator assembly attached. The ballnut on the jackscrew was less than 1-turn from the upstop. The gearbox housing was fractured in the plane of the drive torque tube. However, the ballnut and transmission could be rotated freely. The inboard track had

separated and had been stripped of all components except for the fore flap sequence carriage which could be slid along the track.

Leading Edge Flap and Slat System.--At the forward wall of the right wheel well, the input rod from the flap system follow-up drum to the leading edge flap and slat control valve was attached to both devices and bent. The rig pin hole in the control valve crank was positioned at 1/3 to 1/2 hole-diameter from the full up position. The control valve could not be moved by hand.

The A hydraulic system leading edge bypass valve was in the No. 1, or normal, position.

The left wing No. 1 slat was extended from the retracted position and resting on the ground. The upper fairing was extended approximately 2 inches from the fully retracted position, and the actuator rod was out of the uplock position. When the wing was raised, the slat could not be moved by hand due to fire and impact damage.

The left wing's No. 2 slat was extended from the retracted position and resting on the ground. The upper fairing was extended approximately 4 3/4 to 5 inches from the fully retracted position, and the actuator rod was out of the uplock position. When the wing was lifted, the slat moved down slightly, but not to the fully extended position. It was determined from smoke stains that the slat actuator rod had been extended 6 1/2 inches prior to the wing being raised.

The left wing's No. 3 slat was extended from the retracted position and resting on the ground. The upper fairing was extended approximately 4 3/4 to 5 inches from the fully retracted position, and the actuator rod was out of the uplock position. When the wing was raised, the slat moved down slightly, but not to the fully extended position. It was determined from smoke stains that the slat actuator rod was extended 7 inches prior to the wing being lifted.

The left wing's No. 4 slat was in the retracted and uplock position. When the wing was lifted, the slat could not be moved by hand due to impact damage.

The left wing's No. 1 leading edge (Krueger) flap was extended from the retracted position and resting on the ground. The upper fairing was extended approximately 2 inches from the fully retracted position.

The left wing's No.2 leading edge flap was extended from the retracted position and resting on the ground. The upper fairing was extended approximately 3/4 inch of the fully retracted position. When the wing was raised, the flap moved down slightly, but not to the fully extended position. It was determined from the smoke stains that the slat actuator rod had been extended 6 1/2 inches prior to the wing being raised. Full extension on the flap actuator rod is 17.98 inches, and fully retracted the rod measures 5.5 inches.

The left wing's No. 3 leading edge flap was in the fully extended and downlock position. It was determined from the smoke stains that the acuator rod was near the fully extended and downlock position after the accident.

The right wing's No. 4 leading edge flap, with its actuator attached, was found in the melted area of the right wing adjacent to the fuselage. It was determined from smoke stains that the actuator rod was in the nearly retracted position during the postcrash fire. The right wing's No. 5 and No. 6 leading edge flaps were found along the wreckage path.

The right wing's No. 5 slat was in one piece in the wreckage debris path with its outboard track/roller rib assembly attached. The outboard slat hook had been sheared off, and the inboard slat hook aft fastener was sheared. The front of the slat, at the inboard track attachment, had been ripped out. The slat was virtually undamaged inboard of this attachment. There was a depression on the lower surface of the slat which correlated with the roller induced deformation of the slat track surface.

The outboard slat track for the No. 5 slat was also in the wreckage debris path with a large portion of the wing spar and actuator attached. The position of the actuator was not recorded at the wreckage site. However, the actuator was subsequently removed from the wreckage, and the condition of the actuator was documented. The rod end of the actuator rod was missing, and the rod was bent. The exposed portion of the rod measured 4 1/2 inches from the cylinder to the rod end separation, and the actuator was in the fully retracted and uplock position.

The right wing's No. 6 slat was torn free of all attachments. The inboard leading edge of the slat at the inboard track attachment was creased, folded, and bent up approximately 90°. For some distance outboard of the inboard track attachment, the leading edge of the slat was buckled, but there was no evidence of impact damage. The actuator was found detached from the slat. The end of the actuator rod had separated, and the rod was bent. The exposed portion of the rod measured 4 1/2 inches from the cylinder to the rod end separation, and the actuator was in the fully retracted and uplock position.

The right wing's No. 7 slat was separated just outboard of the inboard track attachment. The inboard slat track and roller rib assembly was attached. The inboard leading edge of the slat exhibited extensive impact damage. The outboard portion of the slat was found in the wreckage debris path, and the leading edge also exhibited extensive impact damage. The actuator was found separated from the slat with a portion of the slat attachment structure attached to the rod end. The rod was extended 5 1/2 inches from the cylinder to the center of the rod end, and the actuator was in a fully retracted and uplock position. That portion of the rod which is normally external to the cylinder when the actuator is in the fully retracted position was bent upward approximately 20° and outward slightly.

The right wing's No. 8 slat was separated in two and both sections were found in the wreckage debris path. The inboard 32-inch section had the inboard slat track and roller rib assembly attached. There was no impact damage along the leading edge of this section of the slat. The outboard section of the slat had the actuator attached, and the actuator had pulled free of its trunnion attachments. The actuator rod was extended 17.5 inches, and there was no noticeable bending of the rod. The outboard slat hook was missing, and the two fasteners on the inboard slat hook were sheared. This section of the slat exhibited some impact damage along the leading edge, but the slat to wing mating surface had only minimal damage.

Aileron System.--The aileron cables from the captain's yoke system pulleys were correctly attached and routed with no evidence of fraying. The bus cables between the captain's yoke system and first officer's yoke system pulleys were intact and in good condition.

The aileron trim assembly was in good condition, and the cables were correctly routed with no evidence of fraying. The aileron trim knob could be turned freely.

The aileron control mechanism in the left wheel well had sustained substantial fire damage. The bus cables were attached to the drum. The cables to the left wing were under tension, and the cables to the right wing were slack. The aileron control quadrant including the centering spring and trim mechanism was intact, and all linkages were attached. The control mechanism was seized. The input linkage between the aileron quadrant and the aileron power pack was intact, but the trim linkage and tierod had burned and separated.

All hydraulic lines to the A-hydraulic system control modular unit in the left wheel well were intact. The unit's shutoff valve lever was in the No. 1, or normal, position. The shutoff valve lever of the B hydraulic system control modular unit, located in the right wheel well, was also in the No. 1, or normal, position.

The left wing's inboard aileron had sustained fire damage. The access panel was removed, and the cables were under tension and in their respective cable guides. There was no evidence of preimpact damage.

The left wing's outboard aileron had also sustained fire damage. The aileron could not be moved. After the wing was subsequently raised, the lockout actuator was found fully extended with the crank against the stop, indicating that the ailerons were locked in the 0^{0} position. The aileron cables were intact and under tension. The shear rivets were not sheared.

The outboard end of the right wing's inboard aileron had separated, and the remainder of the inboard aileron remained attached to the top wing plank.

The right wing's outboard aileron had separated into three sections that were located along the wreckage path. The lockout mechanism bellcrank had separated from the lockout actuator and into attaching structure, and was free to rotate. The lockout actuator and its attaching structure had separated from the wing as an assembly, and the actuator was approximately 1-turn from the fully extended position with the crank intact and against the stop.

Cabin Fire Damage.--The aft cabin floor was completely consumed by fire from approximately station 950D to station 1130 with the exception of the passageway that led to the left-rear door at the galley. Fire damage to other components was also extensive in this area with most major interior components destroyed.

The area forward of station 950D had less severe fire damage to the floor and sidewall areas (continuing through station 740). As noted previously, there was a large area of burnthrough on the cabin floor from approximately station 740 to approximately station 720D on the right side. From this point forward to approximately station 400, fire damage to the right side of the interior was significantly more extensive than that of the left side. From station 400 forward, the cabin was free of fire damage.

Damage to ceilings, sidewalls, overhead stowage compartments, closets, etc., was closely correlated to areas of floor and fuselage burnthrough. From station 400 aft, no ceiling panels were in place including areas where the fuselage crown was present as well as the areas that were burned through.

All floor exit level door liners were found. The aft right exit had only the lower portion of the liner present from approximately the top of the escape slide container downward. It was heavily sooted and showed some signs of melting. The aft left door liner was essentially intact with heavy charring and melting over the upper third of the surface. Both of the left and right forward door liners were free of fire damage. The liner on the ventral door was destroyed by fire.

Sidewalls were intact on the left side of the forward cabin from station 381 to the area of the overwing exit. Many of these panels were melted at the upper portion above the window, but were in place and otherwise intact. Sidewall panels on the right side of the cabin in this zone were completely destroyed. Small portions of other right side wall panels were present near the floor toward the aft part of the cabin. Two sidewall panels on the left side at approximately stations 950B and C (immediately forward of the separation in the aft fuselage) were relatively free of fire damage but were heavily sooted.

From station 380 to station 760 on the left side, there were some large remnants of overhead stowage units hanging from the structure. These were extensively burned and melted, however, they were recognizable as overhead stowage units. No other overhead stowage units were present.

In most areas of the cabin wherever the sidewall and/or ceiling panels were destroyed, the thermal insulation was also destroyed. The following exceptions were noted:

In the aft right corner of the cabin in the sidewall area just forward of and adjacent to the last row of seats.

Some small areas over the overhead stowage bin area along the left side of the cabin between station 380 and 950.

A few sidewall areas on the right side of the cabin near station 720.

Seat Damage.--The last row triple seats (right side) showed frame burn through and residual cushion fire blocking layer. Up to and including row 28, all seats were missing, with the exception of the triple seat in row 30 left side, which had some cushion fire blocking layer remaining, along with some seat frame structure burnthrough on the seat back cushions. Rows 23 through 26 (right side) were heavily fire damaged, but some cushion fire blocking layer remained. The seat back cushions on 23E, 24E, and 26D were burned through. Seats 27D, E, and F were severely damaged and its common frame was twisted and displaced several feet rearward from the proper position. Rows 26 and 27 (left side) had fire blocking layer present (frame intact), with the exception of seat back 26C which was totally destroyed by fire. Row 25 (left side) was missing (possibly falling down into the hole of the floor area). Rows 23 and 24 (left side) had fire blocking layer remaining, except for row 24A, B, and C, in which the seat back frame were totally destroyed by fire. Seats 22B and C sustained severe damage to the seat bottoms. The remaining seats in rows 20 through 22 (left side) sustained fire damage to the seat backs, burning through the seat back frame, but the seat bottom cushions in this area had some fire blocking remaining. Rows 20 through 22 (right side) sustained fire damage to the seat back frame with some fire blocking layer remaining, except for row 20, which was pitched forward and bent up on the frame bottom.

Rows 15 through 19 (right side) sustained severe fire damage, with no fire blocking layer remaining. Rows 10 through 14 (right side) were destroyed by fire. Rows 10 through 19 (left side) had some fire blocking layer remaining on the seat back and bottom cushions, with the exception of rows 15 and 17, which sustained lesser amounts of fire damage.

In the first class section, seat row 1 (left and right sides) was intact with little fire damage. Row 2 (left side) had some fire damage to the seat back and bottom cushions with some fire blocking layer remaining. Seats 3A and B were twisted with some fire damage. Seats 4A and B were fire damaged with some cushion fire blocking layer remaining on the seat bottom. Row 3 (right side) was totally destroyed by fire. Row 4 (right side) was missing.

Cabin Doors and Overwing Exits.--The main entry door separated from its hinges and was recovered next to the forward fuselage. The forward galley service door frame was extensively damaged and the door was lodged in the wreckage.

The right floor level exit door side was found unopened. The slide and slide cover were still in place and relatively undamaged, and the girt and girt bar were missing. The steel cable intended to connect the girt bar with the slide was separated just below the swaged fitting on the cable. The floor girt bar fittings were in place and apparently in good condition and were coated with soot. The girt bar and a portion of the attachment cable were later found buried in the debris under the exit in the general area of the rear cargo compartment. The steel cable was cleanly broken with a slight flare of the broken strands; it was later reported that this cable had been cut, and the girt bar had been removed by Delta personnel at the request of CFR personnel.

The left side floor level exit door of the airplane was found closed, although there was evidence of attempts to open the door. The evacuation slide was in place, the air cylinder was pressurized, and the girt bar was stowed on the slide cover. The girt bar fittings on the floor were clean and in good condition.

As part of the investigation, an attempt was made to open this exit door from outside the airplane. The door would not open on the initial attempt. Debris on the floor inside the cabin adjacent to the exit door prevented the door from moving inward and forward as was required to position the door so it could swing outward. The debris consisted primarily of aluminum soft drink cans. The debris was cleared away, and a second attempt was made to open the door from inside the airplane. It was difficult to move the mass of the door inward and upward, due to the approximately 30^{0} downslope of the floor. With additional assistance from persons who were outside, the door was successfully opened. Subsequently, an attempt was made to close and then re-open this door. The floor and door frame were examined and cleaned for this attempt. The door would close, but it would not lock into position, and the door handle remained about 15^{0} from the fully locked position causing the door to remain slightly ajar. One person, with maximum effort, was then able to open the door from inside the airplane. The girt bar was lowered from the slide cover, and fire debris was on the slide cover under the girt. The door of the galley compartment door that contained a drawer of soft drink cans was found open and the drawer was found among the debris in the rear cabin. (During the investigation, the galley compartment door was closed and was latched without difficulty.) The latch remained secure against heavy force applied by the fingers to the edge trim of the door.

Both left side overwing exit hatches were found removed. The hatch from the forward exit was found between seat row 18A, B, C and row 19A, B, C. The hatch from the rear overwing exit was found outside the airplane, in front of the left wing. The right side rear overwing exit hatch

was found in place and was extensively damaged by fire; it was unlocked and opened without undue effort. The hatch from the forward right side window was found between seat rows 19D, E, F and 20D, E, F.

Cargo Doors.--The No. 1 forward fuselage cargo door was intact and in the closed and locked position. The No. 2 cargo door was separated from the fuselage and recovered approximately 250 feet north of the fuselage location. The door was buckled and fractured horizontally in the area between the torque tube and the door handle. The outside skin on the forward side of the lower half of the door was crushed inboard with the most deformation occurring along the forward edge. Examination of the mating fuselage door jam area disclosed a heavy inboard crush in the fuselage forward and adjacent to the lower forward portion of the door jam. With the lower portion of the No. 2 cargo door positioned in place with the mating fuselage section, the inboard crushing was continuous and consistent with the cargo door being closed while the fuselage and door were crushed along the fuselage and adjacent lower forward area of the door.

The No. 3 aft cargo door was separated from the fuselage and was recovered inside the fuselage.

Throttle Controls.--The throttle cables were intact and operable from the cockpit to the forward fuselage break. There was no binding except in the area of the fuselage break. Further continuity of the throttle cables was established to the aft fuselage break.

The throttle cables in the aft fuselage were intact from the aft fuselage break to the engine control quadrant for No. 1 and 2 engines. There was no evidence of fraying or other damage. A section of one No. 3 engine cable, which was routed through the aft inboard pulley on the right side of fuselage section 48 beside the ventral stairs, was missing. The other sections of this cable, and the other No. 3 engine cable, had separated at the aft fuselage break and at the pod separation. Short pieces of these cables remained attached to the No. 3 engine pod which had separated from the engine.

The engine control quadrants were intact and capable of normal operation.

Air Conditioning System.--The right pack cooling fan and right pack air cycle machine were found in the wreckage debris path. The fan had sustained substantial impact damage, and three blades were missing from the rotor. However, no rotational damage was evident. Both forward pack valves were found in the open position. The flow multiplier bypass valve was in the open position. The APU load control valve was in the closed position.

The left pack fan inlet door actuator was in the closed position.

Cockpit Documentation.--The position of all cockpit controls, instrumentation, and switches were normal for takeoff, except for the flap handle which was in the "up" position. The outboard flap indicator was indicating beyond the full up position on the left side and beyond the full

down position on the right side. The inboard flap indicator was on the 2° range on the left side and between the 2° range and the full up position on the right.

The landing gear handle was in the down position. The speed brake handle was full forward and in the down detent. The stabilizer trim was set to 5.7° noseup.

1.13 Medical and Pathological Information

The cause of death of the 11 passengers and the two flight attendants was determined to be smoke inhalation. Levels of carboxyhemoglobin (COH_b) ranged from 15 to 81 percent. Tests for drugs and ethanol were negative in all 13 persons. A 14th fatality was a passenger who had successfully evacuated but later attempted to reenter the burning airplane. This passenger died of severe burns, 11 days after the accident.

The captain suffered several skeletal system fractures. The first officer sustained a concussion with possible intercranial hemorrhage and lacerations, contusions and abrasions. The second officer's injuries were limited to intra-abdominal trauma.

Toxicological specimens of the three flightcrew members were taken several hours after the accident. They were negative for alcohol and drugs, except for those drugs that had been prescribed by the physicians who treated the crew after the accident.

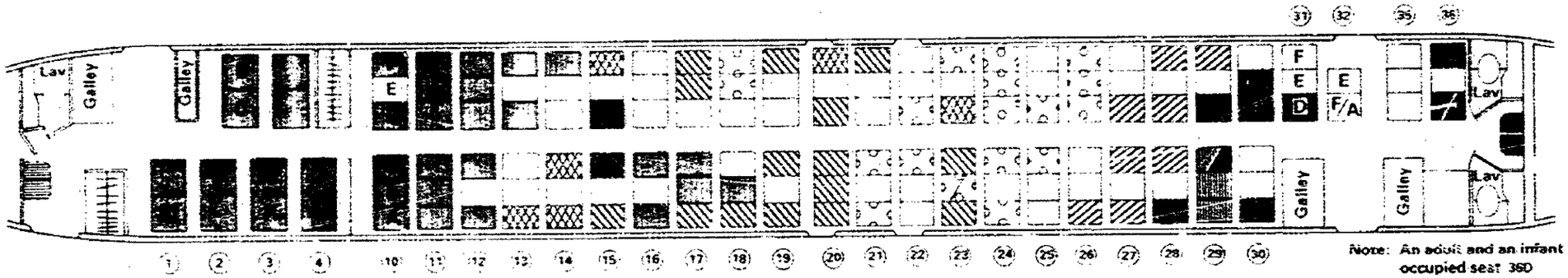
1.14 Fire

A fire ensued after the right wing contacted the ground and quickly spread to engulf the rear, right side of the airplane after it came to rest. The fire subsequently penetrated the fuselage.

1.15 Survival Aspects

The B-727-232 was configured for a three person flightcrew and 149 passengers (see figure 8). The passenger cabin was configured with 12 first-class passenger seats and 137 tourist class seats. A double occupancy aft facing flight attendant seat was on the aft left side of the cockpit rear bulkhead; a double-occupancy forward facing flight attendant seat was located on the ventral airstairs door. A single flight attendant seat was in row 32.

The investigation found that although the fuselage had separated in several places, the occupiable volume of the cabin was not substantially compromised. Passengers generally stated that impact forces were not severe. Further, the cause of deaths of the passengers in the aft section of the cabin were attributed to smoke inhalation and fire rather than impact injuries. Exit from the aft cabin was hampered by the fire that impinged on the right side of the airplane. Exit from the mid and forward cabin was through breaks in the fuselage and through the left side exits, except for the left aft service door which was not opened.



Note: The three flight crew members were removed by rescuers.

Note: An adult and an infant occupied seat 23B.

NOTE: The passenger in 29C escaped the airplane but died later

Note: An adult and an infant occupied seat 36D

EXIT USED

- Forward passenger door - left side
- Forward hole in fuselage ceiling
- Left overwing - forward
- Left overwing - aft
- Aft overhead break in fuselage
- Aft break in left side of fuselage
- Occupied - exit unknown
- Unoccupied

LEGEND

- Deceased

Figure 8.--Configuation of B727-232 and escape routes used.

1.15.1 Aircraft Rescue and Fire Fighting

About 0901, the DFW control tower notified the airport's Department of Public Safety (DPS) by means of the crash phone of an accident at the south end of runway 18L. The DPS communications immediately notified all DPS units and other airport personnel (via automated alert). Emergency telephone notifications were initiated via an automated voice system. Follow-up hospital notifications were made manually by DPS personnel via telephone for redundancy. Notifications were completed in 21 minutes.

Firefighting Response.--Immediately following the initial notification, all units responded from four airport fire stations. The first units arrived on scene about 4 minutes and 20 seconds after notification. Additional DPS personnel responded from various locations around the airport in police patrol cars.

Three trucks arrived within 5 minutes of notification; three more trucks within 6 minutes; and five more within 11 minutes. The airplane was reported to be engulfed in flames when the first fire trucks arrived. The on-scene incident commander estimated that the majority of the fire was "knocked down" within 5 minutes of the time of the alarm. The fire was extinguished (including small spot fires) in about 40 minutes. The total amounts of extinguishing agents used to suppress, contain and extinguish the fire were 15,800 gallons of water and 650 gallons of aqueous film forming foam (AFFF). Approximately 60 firefighters responded to the accident.

Police Response.--The initial police response involved searching the area for survivors and assisting firefighters. A security perimeter and traffic control points were established at surrounding major roadways. Approximately 80 DFW police personnel were involved in the response.

Medical Response.--The DPS emergency medical service responded immediately with two mobile intensive care units and one mobile rapid response vehicle. The DFW paramedics operating the rapid response venicle called for dispatch of the medical triage support trailers while en route to the site. Cellular telephones were utilized by DFW paramedics to coordinate with local area hospitals.

A team of physicians from a nearby hospital arrived by helicopter at 0947. Five area hospitals were notified of the accident by DFW DPS personnel within 6 minutes of the alarm, one hospital sent personnel to the scene. A total of 13 helicopters responded.

DFW DPS Training.--The State of Texas requires all DFW police/fire/rescue personnel to complete certification requirements for structural and aircraft firefighting as well as certification as police officers. Although most officers are usually assigned functionally to one discipline in either police or firefighting, personnel who are assigned to the patrol-rescue division provide handline and firefighting support for CFR vehicle operators, even though their normal daily activities are as police officers.

1.15.2 Disaster Plans

DFW had a current emergency plan in accordance with 14 CFR 139.325.

On August 2, 1985, a Delta Air Lines, Inc. L-1011 was involved in an accident at DFW.[1] There was a full emergency response from DFW Airport and the surrounding communities. This was considered to be equivalent to a full scale emergency drill. At the time of the accident involving flight 1141, a full scale emergency drill was being planned.

1.16 Tests and Research

1.16.1 Stall Warning System

The B-727 stall warning system is designed to activate when the airplane approaches a stall angle of attack (AOA) based upon the configuration of the wing. The system is activated by an AOA sensor and references the inboard flap position. The system is active only when the left main gear is fully extended, and there is no measurable electrical or mechanical delay before activation. The airplane body AOA required for stickshaker activation are 11^0 for flap settings of 0^0 thru 2^0, and 14^0 for flap settings of 5^0 thru 15^0. The stickshaker would not normally activate at any AOA below 11^0.

Inspection of flight 1141's stall warning module (overhead panel) and left wing flap position transmitter showed them to be functional. The AOA sensor could not be checked due to damage.

1.16.2 Takeoff Warning System

The aural warning unit was removed from the cockpit and tested at Delta's facilities in Dallas. The unit was powered by a B-727 battery through a 3-amp circuit breaker to represent the actual airplane installation, and the horn operated normally with the 3-amp circuit breaker remaining closed.

Continuity of the wiring from the terminal block to the aural warning unit (through the bus bar and the aural warning circuit breaker) was verified. Continuity of wiring from the flight control warning test switch panel to and through the takeoff throttle relay and leading edge warning inhibit relay was also verified.

The speed brake warning switch was not recovered.

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[1] Aircraft Accident Report--"Delta Air Lines Inc., Lockheed L-1011-385-1, N726DA Dallas/Fort Worth International Airport, Texas, August 2, 1985" (NTSB/AAR-86/05).

The upper and lower stabilizer takeoff warning switches were in their proper position, and both switches checked normal for continuity and activation. The flight control warning test switch, landing gear accessory module, and the associated relays tested satisfactorily.

The No. 3 autothrottle clutch pack assembly containing the takeoff warning system throttle switch was removed in its installed condition from under the cockpit. It had been torn loose and was sandwiched between the flooring and the electrical equipment compartment. It exhibited some impact damage. Continuity tests were conducted on the switch as installed in the clutch pack assembly. Continuity between the common and normally closed terminals could not be established. During the first two finger activations of the switch assembly, there was no continuity between the common and normally open terminals of the switch. During the subsequent activation, however, continuity was established. The switch exhibited a blue-green corrosion-type substance around the normally open terminals.

The switch was tested for continuity and resistance while installed in the No. 3 autothrottle clutch pack assembly using a 6 volts direct current (VDC) power supply set at 100 milliampere (ma). Upon activation, the normally open switch moved to the closed position and resistance in the switch was measured to be 1.47 ohms.

The part number of the actuator installed on the switch was ADH 3721R2, which is the correct part per Boeing drawing No. 65-42356. However, the switch manufacturer recommends actuator part number ADD 3721R for this application. The depth of the circular-cylinder-shaped button on the ADD 3721R actuator is 0.044 inches less than the button on the ADH 3721R2 actuator. (See figure 9.)

The adjustment tab on the actuator, which is provided for slight adjustments to switch operation, was bent upward 15° to 20°. The Boeing maintenance manual recommends bending the tab not more than +1/4°. (See figure 9.)

Switch activation movement, with the switch assembly still installed in the clutch pack assembly, was observed through a microscopic TV camera and recorded. The outer bottom edge of the actuator button would initially contact the top center of the switch plunger and would remain in this position as the plunger was being depressed and the switch tripped. As the switch tripped, the exposed portion of the switch plunger would slide slightly inward toward the bottom of the actuator button and become perpendicular to the switch casing. Approximately 10 switch activations were observed, and each time the switch properly tripped.

The cables that were still attached to the clutch pack assembly containing the switch assembly were then removed to free the jammed cam which moves the switch actuator mounted on the clutch pack assembly structure. Proper orientation of the cam to the switch, as it would relate to thrust lever position, was then established. During this procedure, numerous switch activation sounds were heard. Other switches are installed in the clutch

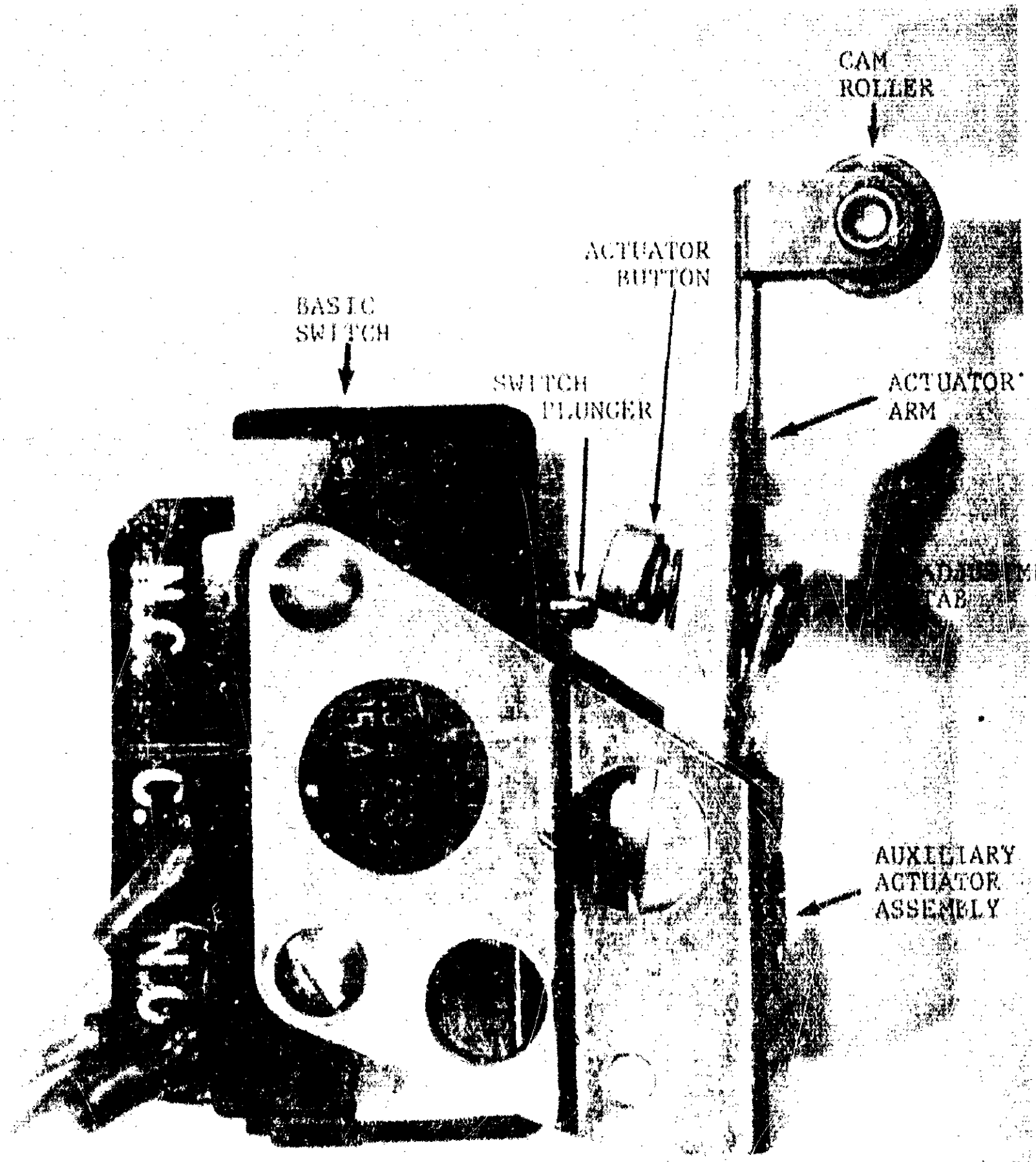

Figure 9.--Photo of throttle switch.

pack assembly. It is not known if the takeoff warning switch activated each time the outermost surface of the cam made contact with the switch actuator.

During one of the cam movements, the outer bottom edge of the actuator button was observed sliding off the top of the switch plunger and making contact with the switch housing without depressing the plunger. During subsequent switch activations, the actuator button would sometimes fully depress the switch plunger and trip the switch, and at other times would slide off the top of the switch plunger and not depress the actuator. In addition, the actuator button occasionally depressed the switch plunger but there was not sufficient travel of the plunger to trip the switch. The actuator button is mounted on the adjustment tang as a nonrigid assembly containing a "free-floating" spring. It was found that by either applying finger pressure to the button assembly or rotating the spring, the button could be positioned to: (1) fully depress the switch plunger and trip the switch, (2) partially depress the switch plunger and not trip the switch, or (3) slide off the plunger without depressing it.

Switch activation movement was again observed through a microscopic TV camera and recorded. Wear patterns were observed along the cylinder side of the button. The button was rotated to create a new wear pattern for a later comparative study.

The switch exhibited a blue-green corrosion-type substance around the normally open terminals on the exterior of the housing. In addition, the plunger hole had enlarged due to side loads having been exerted on the plunger.

The switch was later installed on a test jig provided by the manufacturer, and all plunger travel measurements met the manufacturer's specifications.

The switch was dismantled, and the internal surface of the switch housing also exhibited the blue-green corrosion-type substance. However, the switch contacts were free of this substance. There was no visible impact damage to the internal components of the switch.

The cam installed on the No. 3 autothrottle clutch assembly which operates the takeoff warning switch was designed to provide for switch activation between 11.5° and 13.5° throttle lever angle. However, the cam had been modified by machining the cam back approximately 0.55 inches to provide for switch activation between 18.5° and 20.5° throttle lever angle. The cam had been modified, per Boeing instructions, to prevent nuisance activations of the takeoff warning system when applying power to taxi in periods of high density altitudes.

The cam has two adjustment slots to allow the cam to be adjusted to compensate for manufacturing tolerences. The modified cam was found to be installed within limits, but 0.10 inches from the full travel adjustment.

1.16.3 Flap Warning Switch

The flap warning switch, located at the outboard flap follow-up drive in the right wheel well, had sustained substantial fire damage but was intact. The switch was bench tested as installed in the outboard flap follow-up drive. Eight ohms resistance was measured from the common terminal to the normally closed (NC) terminal, and 7 ohms resistance was measured from the common terminal to the normally open (NO) terminal upon switch activation, which are normal values.

1.16.4 Trailing Edge Flap System

The inboard and outboard flap position indicators were tested and the results were within manufacturer's specifications. The inboard and outboard flap asymmetry shut-off relays resistance and continuity checks were satisfactory.

The outboard flap bypass valve was found to have been in the No. 1, or normal, position. The inboard flap bypass valve was in the No. 2, or bypass, position. The inboard and outboard flap control valves were flow checked, and both valves showed flow to port-A.

1.16.5 Leading Edge Flap and Slat System

The eight leading edge slat actuators were functionally tested and disassembled. With the exception of the No. 7 actuator, the actuators could be hydraulically unlocked from both the uplock and downlock positions, and they operated normally. An attempt to unlock the No. 7 actuator from the uplock position was stopped at 2,100 psi due to safety concerns.

All leading edge slat actuators, except for the No. 7 actuator, were disassembled following the manufacturer's procedures for normal disassembly. There was no evidence of internal impact damage of actuators No. 1 through No. 6, and their locking rings were intact. One land of the No. 8 actuator's locking ring, which was intact, displayed a small smear on one side under a microscope, and there were two very small indentations on the piston flange. The actuator operated normally after reassembly.

The No. 7 actuator had to be sawed open. The interral shoulder of the actuator cylinder, located approximately 2 1/2 inches from the end of the cylinder, had completely broken off the cylinder body circumferentially. The shoulder was displaced to the rear of the actuator which prevented the locking slide movement mechanism from moving forward to the unlock position. The lockring was intact with no visible damage.

The leading edge flap and slat control valve was placed in a test fixture, and the rig pin hole in the control valve crank was 0.132 inches out from the full up position. The crank could not be moved. The valve was flushed with alcohol, and a spectrum analysis was made on the residue. During the flushing, it was noted that the valve was internally ported to an all leading edge flaps and slats retracted position.

1.16.6 Auto Pack Trip System

The test results of all the components of the auto pack trip system that could be tested, except for the engine No. 3 pressure switch, were satisfactory. During one of the three tests on the No. 3 switch, the switch activated at 128.5 psi. The test specifications require a switch activation at 120 plus or minus 5 psi. The external surface of the switch exhibited minor heat damage. The results of the remaining two tests on the No. 3 switch were satisfactory.

1.16.7 Airplane Performance

The Safety Board's performance study was based upon data derived from the airplane's FDR and CVR, radar, ground contact data, and time-correlated FDR and CVR information.

Based upon the airplane's final weight tabulation and the information contained in the company's dispatch papers, the airplane's takeoff weight was determined to be 157,683 pounds, at brake release, and the required flap setting for takeoff was to be 15 degrees. The takeoff speeds on the Delta takeoff card for that weight and configuration were as follows:

> Critical engine failure speed (V_1) was 131 knots, rotation speed (V_r) was 131 knots, and the safe climb speed with the critical engine inoperative (V_2) was 145 knots.

The performance study's computations were based on these following data: takeoff weight--157,683 pounds; center of gravity--22.5 percent mean aerodynamic chord (MAC); runway elevation--596 feet msl; runway gradient to liftoff--nominal; altimeter setting--29.99 inHg; surface winds--090 degrees at 9 knots; and the temperature--74° F.

The results of the computations were compared to the airplane's actual takeoff performance. The airplane's acceleration up to and through V_2 was in accordance with predicted rates. The first officer called both V_r and V_2, and the timing of the callouts were consistent with the computed values cited above. The airplane began to rotate at V_r. With proper takeoff configuration, the performance study determined that a normal liftoff pitch attitude would have been 8.6° noseup pitch at an airspeed of 144 knots. The liftoff point would have been 5,210 feet down the runway. The initial rate of climb after takeoff would have been about 2,500 feet per minute, at a climb angle of 9.6°, with the flaps set at 15°. Flight 1141's body pitch attitude was calculated to be approximately 10° at the estimated liftoff, with an airspeed of 158 knots.

Based upon FDR data, liftoff occurred at 9:00:13.4 at a point 6,017 feet down the runway, 807 feet beyond the normal liftoff point. The elapsed time from the start of takeoff to the estimated liftoff was 40.7 seconds. Based on the performance study, the normal elapsed time to main gear liftoff is approximately 37 seconds. The tail skid contacted the runway 1.4 seconds after the estimated liftoff, approximately 383 feet beyond the estimated liftoff point. A tail strike on the Boeing 727-232 requires a

body angle of approximately 10° with the main landing gear on the runway. At that point, the airplane's airspeed had increased to 160 knots.

Given the airplane's weight and balance, actual takeoff thrust, and compensating for ground effect, the calibrated stall airspeeds of the airplane were determined to be 154 knots with no flaps; 147 knots with 2° of flap; 127 knots with 5° of flap; and 120 knots with 15° of flap. The stall warning, i.e., stickshaker, occurred approximately 1.7 seconds after the estimated liftoff point at 161 knots and continued for 20.2 seconds until the sound of the first impact. The right wing tip struck the ground approximately 3.7 seconds after the estimated liftoff.

At normal takeoff speeds, at a body angle of 10° with 15° of flap, the accident airplane would have 53,105 pounds of lift available in excess of the weight of the airplane. With the flaps up (0° of flap), the airplane would weigh 984 pounds more than the lift produced. However, a 1 knot increase in speed would have resulted in the lift being greater than the weight even with no flaps. At 2° of flaps, the lift would have exceeded the weight by 10,125 pounds.

The airplane accelerated to V_r in 32.8 seconds after the start of takeoff. For a normal takeoff, the time to accelerate to V_r is about 34 seconds. Boeing has determined that different flap/slat positions have negligible effects on takeoff ground roll acceleration.

At the public hearing, a Boeing B-727 test pilot noted that the wing's leading edge devices were very powerful in improving lateral stability. He noted that with the flaps up the airplane is less tolerant of side slip and will tend to drop a wing as the AOA approaches stall. He stated that although the aircraft is still controllable, lateral control is degraded an additional amount with the flaps up since the outboard ailerons are locked in a trailing position. Further, the stick force gradient required to enter a flaps up stall is relatively flat, thus, there is very little discernible increase in stick force as the AOA increases. However, once the flaps are set at 5° and above, he testified that there is a noticeable increase in stick force gradient as the airplane is rotated from initial stall warning all the way to a full stall.

The UP or 2° flap positions would normally activate stickshaker if the airplane is at or above 11° AOA. For flaps at 5° or 15°, stickshaker would normally activate if the airplane is at or above 14° AOA. Airplane drag increases with increasing AOA which will reduce the acceleration possible for a given thrust setting. FDR indicated airspeed data increases from approximately 156 KIAS at the start of stickshaker to 164 KIAS when the first impact occurred. For flaps up or 2°, the stall AOA is about 14°. For flaps 5 or 15°, the stall AOA is 17 to 18°. Typically, there is a 5° margin between stall warning and stall.

Boeing's calculations and wind tunnel testing of the lift available with the outboard flaps at 15° and the inboard flaps up, i.e. "split flaps," indicated that the stall warning is at 11° and stall AOA is 18.5°. For "split flaps," the available lift would be slightly less than

with a normal flap setting of 5°. The stall AOA for "split flaps" is about 9° higher than the stall AOA for flaps at 15° or 5°. (See figures 10 and 11.) The "split flaps" scenario will be discussed later in this report.

1.16.8 Takeoff Warning System Inspections

As a result of the Northwest Airlines DC-9-82 takeoff accident at Detroit, Michigan,[2] the FAA issued Air Carrier Operations Bulletin No. 8-88-4. This bulletin specified action that was to be taken by principal inspectors to review overall takeoff warning system performance; i.e., test the systems, ensure that each carriers' procedures are consistent with airplane manufacturers' current recommendations, and ensure that the checklists appropriately support required crew actions for each of their assigned carriers. The bulletin was approved by FAA headquarters in June 1988. The flight standards district office (FSDO) responsible for Delta received the bulletin on August 30, 1988. FAA officials testified that the delay from the approval of the bulletin to its arrival at the district office was attributed to normal processing and publication time. The principal operations inspector (POI) for Delta testified that the bulletin reached his desk on September 5, 1988, and was put in the mail to Delta on September 14, 1988.

On September 16, 1988, the FAA issued Action Notice A8000.30, which addressed the need to check the takeoff warning system of Boeing Model 727 series airplanes. The result of that inspection found that all current takeoff warning systems were acceptable from a reliability standpoint, including those systems with single point sensors. The FAA's inspection of the Boeing 727 takeoff warning systems found 35 anomalies in the 1,190 airplanes that were surveyed. Anomalies included component failures as well as system adjustment problems. Twelve of the functional problems found were attributed to the throttle lever switch. It was the FAA team's opinion that this condition, if not corrected, could result in an attempted takeoff when the airplane was not in the proper takeoff configuration. The FAA team recommended that the Boeing 727 takeoff warning system be changed from a throttle activated system to an engine pressure ratio (EPR) activated system which had been the subject of a Boeing service bulletin in 1979. The Delta B-727 fleet contained airplanes that had the takeoff warning system activated by the throttle switch and others that were activated by EPR. This mixed fleet resulted from the acquisition of B-727s through Delta's merger with Western Airlines. Western Airlines had previously modified its B-727s to EPR activated systems. Delta had evaluated the service bulletin and determined that the modification was not needed for its operation, therefore, the Delta B-727s retained the throttle activated systems. As a result of this investigation, the FAA issued airworthiness directive (AD) 88-22-09, which required repetitive and functional check of the takeoff warning system

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[2]Aircraft Accident Report--"Northwest Airlines, Inc., McDonnell-Douglas DC-9-82, N312RC, Detroit Metropolitan Wayne County Airport, Romulus, Michigan, August 16, 1987" (NTSB/AAR-88/05).

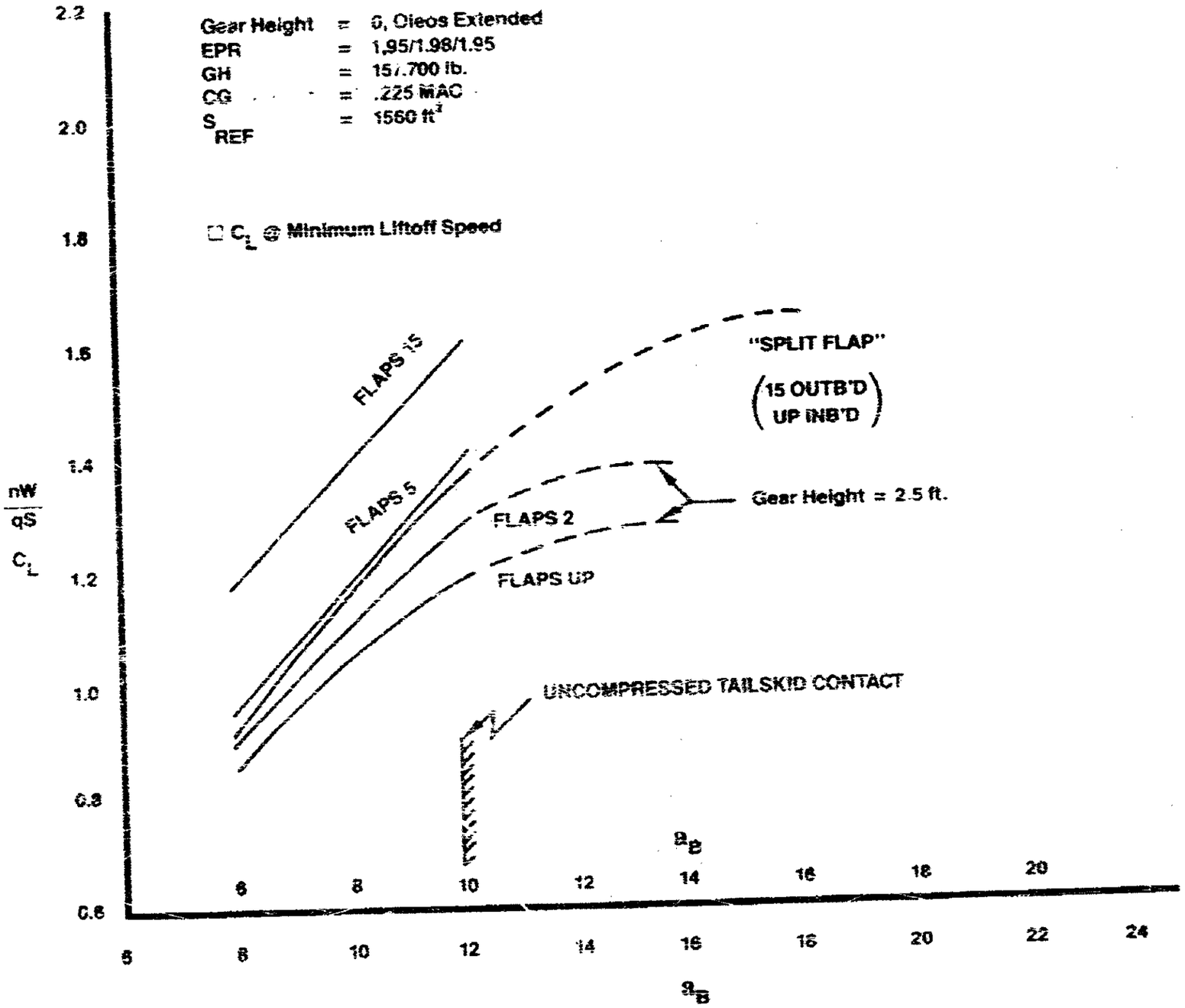

Figure 10.--Boeing 727 city curves, in ground effect zero altitude.

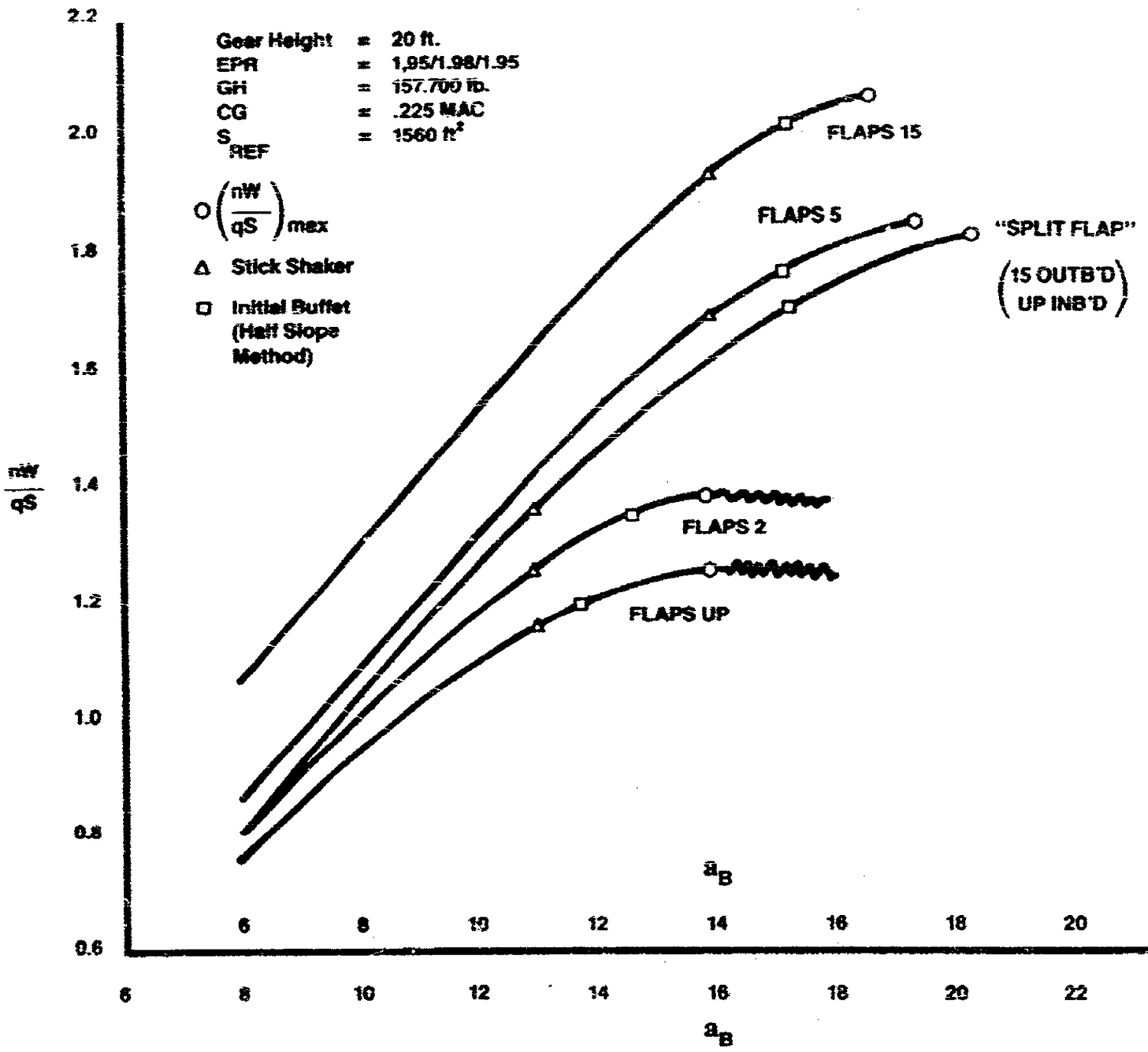

Figure 11--Boeing 727 city curves, in ground effect, altitude equal 20 feet.

200-flight-hour intervals, and repair or replacement of any inoperative component, if necessary, prior to further flight. The AD became effective on November 10, 1988.

1.16.9 Flight Demonstration

On March 21, 1989, a flight demonstration was conducted utilizing a Delta Boeing 727-200. The purpose of the flight demonstration was to validate the wind tunnel data on the Boeing 727 coefficient of lift and coefficient of drag versus AOA to actual flight data. The flight demonstration found very good correlation of the actual coefficients of lift and drag to the wind tunnel derived data.

During the investigation of the accident, parties had suggested that flight 1141 had departed in a split flap condition, and that the crew had raised the flaps prior to impact in a attempt to prevent the accident. The split flap condition was defined as the inboard flaps retracted and the outboard flaps at 15°. Flight demonstration data disclosed that the lift curve for the split flap condition was slightly below the curve for a flap setting of 5°, which closely agreed with the calculated data.

1.17 Other Information

1.17.1 Delta's Flight Standards Organization

As a result of a FAA National Inspection Team Report on the safety audit of Delta conducted in July of 1987, Delta created the position of System Manager, Flight Standards. The person in this position reports directly to the Vice President, Operations. This position oversees the line check airman program, and places the line check airman under centralized control. Fleet managers and standards managers for each aircraft type in the Delta fleet report directly to the system manager.

Fleet managers are responsible for the technical support to the pilots for the operation of their particular airplane type; they have, in part, responsibility for airplane manuals, checklists and document revisions. They also publish and distribute quarterly information packages related to their airplanes and the operation of the airplanes. Further, they are charged with standardization matters.

The line check airmen program is under the standards manager function. Line check airman at each base report to a lead check airman, who, in turn, reports directly to the standard's manager for his particular airplane type. The function of the standards manager's office is, in part, to ensure that the check airman program is executed in a standardized manner, to standardize fleet operations, and to monitor and analyze all operational aspects of fleet operations.

Delta's training department also was reorganized in 1987 and is headed by a system manager of training, who reports directly to the Vice President, Operations. The training department is responsible for the initial and recurrent training of all pilot and instructor personnel.

The investigation revealed that Delta did not insist on a standardized approach towards cockpit management. Testimony from management and training personnel indicated that captains were allowed wide latitude in their conduct of cockpit operations. Over the last few years, Delta has been developing a program to incorporate cockpit resource management (CRM) training in Delta's pilot training programs. A CRM steering committee, with assistance from consultants, has developed a CRM program and a method of intergrating this program into the existing training system. Additionally, Delta has developed an associated line oriented flight training (LOFT) syllabus which incorporates the present 6-month training cycle. Implementation of the CRM program is scheduled to begin in late 1989 and each crewmember shall have received CRM training by mid-1990.

1.17.2 Checklist Procedures

Delta's expanded checklists are contained in the Normal Procedures section of the Boeing 727 Pilot Operating Manual. The checklist contains captain, first officer, and second officer actions in which a "challenge and response" format is used. The captain is required to verbally initiate the checklist procedure. The second officer reads aloud the challenge, and the appropriate crewmember makes the proper response. Not all items on the checklist are required to be read aloud such as tasks performed by the second officer or pilot actions which the second officer verifies.

Delta procedures require that when the airplane is on the ground the captain should call for all checklists. The captain will respond to the "Before Start checklist" or delegate the first officer to respond. The first officer normally responds to all other checklists during ground operations.

In flight, the pilot who is flying the airplane calls for the appropriate checklist and the pilot not flying makes the response. The pilot flying the aircraft calls for any landing gear or flaps change and the pilot not flying accomplishes the change. When each checklist is complete, the second officer makes the appropriate announcement.

Taxi Checklist.--The Taxi checklist section of the Pilot Operating Manual contains the item "Flaps", as follows:

FLAPS ..... _____, _____, GREEN LIGHT

- Ensure INBD and OUTBD FLAP position indicators display takeoff setting
- Ensure green LE FLAPS light illuminated
- Flaps may be extended anytime after departing ramp area

The "Operating Techniques" page associated with the taxi checklist states:

> The flaps should not be extended until well clear of congested areas. Normally flaps should not be extended until all engines have been started. The FLAP lever may be moved directly to the takeoff position. Once flaps are extended, operate all flight controls through their full range of travel. Hold nose wheel steering firmly during the rudder check.

According to Delta training personnel and other Delta flightcrews, Delta's procedure prior to March 1988 had been to extend flaps only after all three engines had been started. This procedure was changed in March 1988 to allow flap extension anytime after departing the ramp area. One captain stated that, while there was no specific procedure, simulator instructors taught captains "by inference" to check the flap position when checking the rudders as part of the flight controls check on the taxi checklist. One pilot instructor stated that the captain, ultimately, is responsible for the completion of all checklist items; however, actual pilot responsibility is not specified in the Pilot Operating Manual. Another pilot stated that the assurance that a checklist had been completed was the second officer's report of checklist completion as well as the captain's mental involvement in all cockpit activities.

Before Takeoff Checklist.--The Pilot Operating Manual notes that prior to takeoff, a briefing is to be made in minimum but adequate detail outlining the plan of action for takeoff. However, it also states that this briefing may be given as part of the BEFORE START CHECK. The captain is required to brief his crew on their responsibilities during the takeoff. The briefing presumes the use of standard procedures but includes additional emphasis on items necessary for that particular takeoff, i.e., special noise abatement procedures, possible windshear, 25^{0} flap takeoff procedures, possible additional requirements. The before takeoff briefing was not heard on the CVR of flight 1141. The captain stated during the Safety Board public hearing that he accomplished the briefing prior to pushback from the gate, which was before power was applied to the CVR.

Takeoff Procedures.--Delta requires the captain to make the decision to reject or continue the takeoff. Therefore, after the initial power application, the captain must keep his hand on the throttles until V_1, to enable him to respond rapidly to a rejected takeoff situation. At V_r, the pilot flying is trained to rotate the aircraft smoothly and continuously until a stabilized climb speed of V_2 + 10 knots is achieved. Rotation rate should be approximately 2^{0} to 3^{0} per second. Initial pitch attitude will vary from approximately 13^{0} to 18^{0} depending on gross weight and flap setting. For a 15^{0} flap takeoff, the pilot flying is to maintain V_2 + 10 knots and flaps 15^{0} until clean-up altitude.

The operating manual states that on every takeoff, the captain must be prepared to reject the takeoff. If a serious malfunction is recognized prior to V_1, the takeoff should be aborted. If prior to V_1, a malfunction occurs which does not affect the safety of flight, the captain should evaluate all factors and either abort or continue the takeoff. When the captain decides either to reject or continue, he is required to announce his intentions clearly to the other crewmembers. If an engine malfunction is recognized at or after V_1, the takeoff should be continued and the pilot is expected to continue the normal rotation to the initial climb attitude.

After takeoff, the initial climb attitude is immediately adjusted to maintain a minimum of V_2. If climb airspeed exceeds V_2, the pilot is to increase pitch attitude to stop acceleration but not to reduce climb speed back to V_2. If an engine failure occurs above V_2 speed, the pilot will attempt to maintain the speed at which the engine failure occurred.

If alternate (derated) power was used for takeoff, the pilot will increase thrust to normal power on the operating engines as the situation and aircraft control permit. The flight director may be used to assist in heading control with an engine inoperative.

1.17.3 Sterile Cockpit

Delta's sterile cockpit procedure corresponds to FAR Part 121.542, which prohibits cockpit activities not related to the safe operation of the airplane during critical phases of flight. Critical phases of flight are identified in the FAR as: all ground operations involving taxi, takeoff, landing, and all other flight operations below 10,000 feet except cruise flight. Taxi is defined as movement of the aircraft under its own power on the surface of the airport. When the airplane has been stopped during the taxi phase, Delta procedures state that PA announcements promoting Delta, describing the route of flight, giving weather, etc., are permissible. Examples of activities not permitted by Delta procedures during critical phases of flight are completing paysheets, eating meals, and engaging in nonessential communications between the cockpit crew or anyone else in the cockpit. The Delta flight attendant manual provides guidance on the sterile cockpit procedure and nonessential communications with the flightcrew.

1.17.4 Human Performance Research Projects

During the Safety Board's public hearing on the Northwest Airlines, Flight 255 accident at Romulus, Michigan, on August 16, 1987 (op. cit.), the Board sought and received testimony from psychologists concerning projects which either have evaluated or are evaluating man/machine interactions and how interpersonal relationships among flightcrew personnel affect their performance of cockpit duties.

A professor of management sciences and computer information testified that, if forced to describe the term "complacency" he would state that it was a "relaxing of one's guard." He testified, "that the notion in automation is that if the equipment is reliable, and most of it is extremely reliable, this will generate complacency, a relaxing of one's guard."

The management sciences professor described what he thought of as six lines of defense against an untoward consequence resulting from human error. The first line of defense was human vigilance; the second, another crewmember detecting error; the third, secondary indications, such as cockpit displays and instrumentation; the fourth, warning and alerting devices; the fifth, persons other than crewmembers detecting the error, i.e., ATC personnel or ground personnel; and the sixth, machines that take action on their own to rectify the error, i.e., the DC-9-82's autoslat and stick pusher systems. With regard to the first line of defense, the professor testified that it was, "of course, normal procedures, and that is the crew doing the right thing, supported by checklist, training, experience, manuals, discipline, check airmen, and what not."

With regard to checklist presentations, the management sciences professor testifed that he did not know of any human factors research on how a checklist should be designed and that he could not find anything in his library on the subject. "There are a couple of human engineering handbooks and under 'checklist' about all they said was the type ought to be visible and it ought to be easy to handle..."

A National Aeronautics and Space Administration (NASA) research psychologist testified to the role structure in the cockpit environment. He testified that the term "role structure" refers basically to the degree and specificity of the structure of a group's activities. "With cockpit crews you would have a very well defined role structure, each position being well defined and having specific responsibilities in the cockpit." He testified that role structure performs a very valuable function and that, "the safety of the system, I think, in many ways is a testament to how well defined and how functional the roles are in the cockpit. But one of the other characteristics of a well defined role structure is it significantly reduces ambiguity about who is going to do what and at what particular time."

The NASA pyschologist further testified that various studies using airplane simulators have disclosed crews whose performances could be classified as "effective" or "less effective," that a number of differences which they have seen "between the so-called effective crews and the so-called less effective crews are very reliable and appear time and time again." He testified that with regard to the highly effective crews, "there is much more communication in general...but there are also differences in the type of communication...you see much more task oriented communication." He testified that one of the patterns visible, "is what we call the information acknowledgment sequence...We find that (with) crews that are highly effective...we tend to see many more acknowledgments to anything that is said."

The psychologist testified that the manner in which the subject flightcrews used their checklists also was evaluated. He testified that it was rare to see a checklist ignored completely or not done, but this had occurred from time to time during various phases of flight in the simulator. There was a lot of variation with regard to checklist usage, from the conduct described above to a "very clearly read challenge/response methodology."

Additionally, he testified that evidence suggested that the way the checklists were used directly related to the number of errors made by the flightcrews. The flightcrews that performed their checklist duties "by the book", challenge (and) response methodology...tend to perform more effectively." He testified that he was not familiar with any body of research relating to the construction and presentation of checklists, but it was his opinion that, "there are probably many ways to do a checklist correctly. What's important is that everyone agrees on how it should be done, and then it's done the same way every time by all the people that are concerned."

An article in the Boeing Airliner Magazine[3] concerning flightcrew-caused accidents and citing the Boeing fleet over a 10-year period as an example stated that:

> 16 percent of the operators have crew-caused accident rates higher than the fleet average, and these operators account for over 80 percent of the total accidents.
>
> Conversely, 80 percent of the operators had no crew-caused accidents over the same period...

The authors of the article contacted a small group of operators, "most of which had a better than average crew-caused accident history," with a view to obtaining information on the policies and techniques that contributed to their safe operations. They found that:

> Management recognizes the need for aircrews performing in a standardized way and the importance of cockpit discipline in providing the environment for proper crew coordination.

The article noted that a strong check airman program acts as a continuous quality control check on the training department and that methods exist for assuring the uniformity of check pilot techniques and instruction.

Some of the cockpit discipline procedures used by these operators were:

> There is a firm requirement for in-depth takeoff and approach briefings for each flight segment...One operator requires an RTO (rejected takeoff) touch drill in which each control used during the RTO is sequentially touched by the pilot making the takeoff.
>
> Cockpit procedural language is tightly controlled to maintain consistency and to avoid confusion from non-standard callouts, which can result from crewmembers using differing phraseology. Callouts and responses are done verbatim. The

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[3] L.G. Lautman and P.L. Gallimore, "Control of the Crew-Caused Accident" Airliner Magazine, Boeing Commercial Airplane Company, April-June 1987.

recurrent training program and check pilot system rigidly enforce this requirement.

1.17.5 FAA Surveillance

Delta Air Lines holds air carrier certificate No. 26 and is authorized to conduct domestic and flag passenger and cargo operations under 14 CFR Part 121. The certificate-holding office is FAA Flight Standards District Office No. 67.

In addition to the principal operations inspector (POI), one assistant principal operations inspector and five aircrew program managers (APM) provide FAA operations certificate supervision. Mid-South FSDO-67 currently has an office manager plus five operations inspectors type-rated in the B-727. The office currently has a total of 14 operations inspectors who are qualified to conduct air carrier surveillance and inspections of Part 121 operators.

Inspection and surveillance activities conducted by Flight Standards District Office No. 67 on Delta's, B-727 operations and training since October 1, 1987 until the day of the accident consist of: 69 organizational or technical inspections, 123 airmen certification inspections, and 149 general surveillance inspections.

FAA records indicate that for the period of August 1, 1986, to September 2, 1988, Delta Air Lines, Inc. had experienced: 3 accidents and 108 incidents; 284 enforcement actions had been initiated. Also the FAA had conducted three major inspections of Delta since 1985. The inspections included:

(1) a 1985 inspection of Delta by the FAA's Southern Region as a result of the Delta 191 accident.

(2) a 1986 regularly-scheduled NASIP inspection of Delta.

(3) a 1987 safety audit of Delta as a result of six highly-publicized incidents.

Additionally, after the accident involving flight 1141, the FAA conducted a follow-up survey of its 1987 Safety Audit in the fall of 1988.

In November 1985, the FAA's Southern Region conducted a special review of Delta Air Lines' operational procedures, largely as a result of the Delta 191 accident at DFW on August 2, 1985. The review culminated with the debriefing of the regional director and the division manager, the POI, and Delta management on November 26, 1985. Among the findings of the review team were:

(1) Delta Air Lines' method of recording maneuvers on roficiency checks and in-lieu-of training does not specify unsatisfactory performance. If an airman's performance is not satisfactory, he is not given credit for the maneuver until he demonstrates the task satisfactorily. This results in extension of the training period for the training or evaluation or rescheduling to another day. This occurred on numerous occasions during this review period. A review of prior records should reveal similar occurrences when not under the eyes of the FAA. If this is not the finding, it is very likely that a substandard performance is being accepted by some check airmen.

(2) Flightcrews are not being trained as a crew. Instead, check airmen often act as second officer and the check airman. When captains are scheduled together, they act as first officer for each other. The result in all cases is a decrease in the productivity of the training or checking process.

(3) Check airmen or instructors accepted a marginal or unsatisfactory performance by airmen as an acceptable level of performance.

During the spring of 1986, the FAA dispatched a NASIP team to Delta Air Lines, Inc. The NASIP team concept was formed as a result of the FAA's desire to periodically review all the major air carriers' compliance with regulations. Airworthiness and Operations teams were formed to review the carriers' operational and maintenance procedures.

Whereas the 1985, 1987, and 1988 inspections conducted at Delta reviewed the carrier in a "qualitative" manner, the NASIP teams strictly assess compliance with regulations. As such, the findings of the NASIP team tend to be very specific, and only regard noncompliance of regulations. While the NASIP team did cite a few problems in Delta's training and proficiency check programs, the findings in general do not reflect a concern as to Delta's training and check airmen procedures.

In mid-1987, Delta experienced a series of highly publicized, pilot-related incidents. These incidents included: an inadvertent shutdown of both engines on a B-767 after takeoff; a navigational error that resulted in a near midair collision over the Atlantic Ocean; landing on the wrong runway; landing at the wrong airport; and twice departing without an ATC clearance. As a result, the POI assigned to Delta and the division manager of Flight Standards, Southern Region, concluded that an inspection should be conducted at Delta in order to determine the relationship, if any, between the incidents and Delta's operational procedures. The request for the inspection was coordinated with the Manager, Evaluation Staff, Office of Flight Standards, FAA headquarters. The special inspection team met at Delta's headquarters on July 24, 1987. The areas examined included:

(1) Enroute inspection and line check program
(2) Flight manuals and procedures
(3) Flight training program
(4) Delta's long range navigation procedures

In its final report, this inspection team noted "...instances of a breakdown of communications, a lack of crew coordination, and lapses of discipline in Delta's cockpits." The report associated this behavior to "...a lack of clear-cut, definitive guidance from those responsible for developing and standardizing cockpit procedures. Delta's management has maintained a policy of delegating the maximum degree of responsibility and discretion to its crewmembers. The behaviors discussed...are a direct reflection of Delta's training programs and manuals. Guidance, training, and practice in crew coordination and cockpit management are minimal."

The report also contained other areas of concern. These included cockpit discipline and coordination observed during en route inspections, manuals and checklists that contained minimal guidance, excessive training and failure to report unsatisfactory performances on checkrides, and minimum training standards. At the Safety Board's public hearing in Dallas, Texas, the team leader of the 1987 inspection testified that all the key FAA personnel from the Southern Region and Washington headquarters were debriefed as to the results of the inspection.

Interviews by Safety Board personnel of Delta flightcrews and management subsequent to the accident indicated a lack of knowledge related to specific crewmember duties, for example the crewmember(s) responsible for verifying flap position. The investigation found that Delta management permitted maximum flightcrew discretion in cockpit operations. In Delta's critique on the 1987 Safety Audit, the Vice President, Operations stated: "While each (FAA) team member may have come with a preconceived scenario for flight deck operation, it should be recognized that deviation from that scenario does not, per se, indicate an absence of standardization or discipline. In fact, many of the elements of our procedures are left to the discretion of the captain." Testimony at the public hearing from the POI for Delta indicated that he believed that the FAA was well aware of this philosophy at Delta, and the possible negative effect it had on flightcrew performance.

In an August 31, 1988, memorandum, the FAA's POI for Delta summarized the changes instituted by Delta Airlines as a result of the 1987 FAA inspection. These changes included, in part, the following:

1. The Line Check Airman Program has been reorganized.

2. The Flight Training Department has been reorganized.

3. Before-takeoff briefings and before-landing briefings are now being conducted with greater emphasis on details.

4. Numerous checklist changes have been made reflecting the changed procedures and additional briefing items.

5. All proficiency check airmen and line check airmen were briefed on the results of the FAA inspection. Emphasis was placed on the need for maintaining high standards at all times.

6. A new policy on the documentation of training/checking of crewmembers was developed. Unsatisfactory proficiency checks and any additional training conducted are now fully documented on the crewmember's training record.

7. Additional checklists were developed for line check airmen to aid in standardizing training and to reemphasize the initial operating experience training.

8. Line checks conducted by line check airmen have improved with an emphasis on higher standards, standardization and cockpit resource management.

9. Proficiency checks have become more challenging by emphasizing higher standards. These higher standards have been reflected in the larger number of unsatisfactory proficiency checks being recorded. Additionally, all failures are reported to the mid-south Flight Standards Office and all rechecks are conducted by the FAA when possible.

At the public hearing, the FAA's Manager of the Flight Standards Division, Southern Region, testified that the 1987 special inspection "confirmed some of our suspicions, based on our surveillance and the trends we had noted, and pointed out some areas that we felt we needed to discuss with Delta and see what they would offer as resolutions to these problems." The POI stated that the problem areas were generally non-regulatory in nature and that he had to rely on his own salesmanship to convince Delta on the need to act on the special inspection teams recommendations.

A follow-up survey of Delta was accomplished by the FAA in the fall 1988. The purpose of this survey was to reexamine Delta's operations in those areas defined in the 1987 audit, determine the corrective actions taken by Delta with regard to the findings and recommendations contained in the Safety Audit Report, define any issues which have yet to be resolved, and to estimate the future effectiveness of Delta's actions. The team found that:

> Delta's management has instituted programs to improve both line operations and the training program. Organizational changes have been made which created a Flight Standards Department, centralized management of the Line Check Airman program, and realigned responsibility for development of operational procedures and manuals. Both line operations and

training were found to be improved over last year's audit. However, deficiencies identified in the previous audit were observed. Ineffective crew coordination and failure to follow established procedures were observed in line operations. A minimum degree of challenge to the flight crewmembers and the acceptance of minimum standards were observed on proficiency checks. Manuals and procedures have been improved where specific findings and recommendations were previously made. However, fundamental changes to checklists and procedures are still pending. The team observes that some of the major actions taken by management have not yet become fully operational or have not yet become effective. For instance, the effect of the changes in the line check airman program is only now beginning to be apparent. On the average, each captain would have only been administered on line check since revision of the program. A Cockpit Resource Management (CRM) training program has been in development for some time but is not scheduled for implementation until January 1, 1989."

Some of the major actions taken by Delta management that had not become fully operational or effective at the time of the team's survey were CRM training and LOFT training.

1.18 Useful or Effective Investigative Techniques

During the initial portion of the takeoff, a sound could be heard on the area microphone of the CVR recording. This sound increased in frequency as the airplane accelerated down the runway for takeoff. The unknown sound was associated with the airplane moving down runway 18L at DFW but the exact source could not be immediately identified. The list of possible sources of the sound could have been the runway grooving, the nose gear tires or wheel bearings, or the main gear tires or wheel bearings. The approximate aircraft ground speed was calculated using indicated airspeed information from the FDR and the reported temperature and winds at the time of the accident. With this information, the airplane's tires and the wheel bearings were mathematically eliminated as possible sources of the sounds. The runway grooving was identified as the source of the sounds. Measurements were taken of the grooving and a test recording was made in a like Boeing 727 airplane taking off on the same runway which verified the results of the CVR-derived groundspeed calculations for the accident airplane.

2. ANALYSIS

2.1 General

The investigation determined that the flightcrew was qualified in accordance with applicable Federal Aviation regulations and company regulations.

The airplane had been maintained and operated in accordance with applicable Federal Aviation regulations and company operations specifications. There was no evidence of any preexisting discrepancies or of any preimpact structural, flight control, or engine failures which would have been causal to the accident.

Although the No. 1 fuel gauge was inoperative and the fuel tanks were not drip sticked following refueling, the evidence indicates that the airplane was refueled properly. There was no evidence that there was a fuel imbalance that would have caused flight control problems.

There were no abnormal airplane movements prior to takeoff, changes in ground control frequencies, or weather-related factors which could have distracted the flightcrew from its duties.

The analysis of this accident addressed the performance of the airplane's trailing edge flap and leading edge flap and slat control systems, as well as the performance of the airplane's takeoff warning system and the performance of the engines. Also addressed in this analysis was the FAA's surveillance of Delta and Delta's efforts to correct or improve problem areas identified during FAA inspections.

2.2 The Accident

The following were determined from evidence obtained from the airplane's CVR and FDR, and marks on the surface of runway 18L: (1) the airplane accelerated normally to V_1/V_R; (2) the captain began rotating the airplane to the takeoff attitude at about 131 knots indicated airspeed (KIAS),-- which was the proper rotation airspeed for takeoff conditions and gross weight with the airplane configured with 15° trailing edge flaps and extended leading edge flaps and slats; (3) the calculated aerodynamic data indicate that a positive load factor, i.e., liftoff, should have occurred at 144 knots calibrated airspeed (KCAS) with a noseup attitude of about 8.6° and 15° of flaps. However, actual liftoff occurred when it reached a noseup attitude of about 10° and an airspeed of about 158 KCAS.

The investigation found that the airplane's rotation attitude is limited to about 10° by the airplane's geometry while it is on the runway and the marks found on the runway surface confirmed that the tail skid struck the runway at or immediately after the main landing gear lifted off.

Data correlation showed that the stall warning stickshaker activated within 2 seconds after liftoff at a pitch attitude of about 11.4° and an airspeed of about 161 KCAS; 2 seconds later the airplane rolled

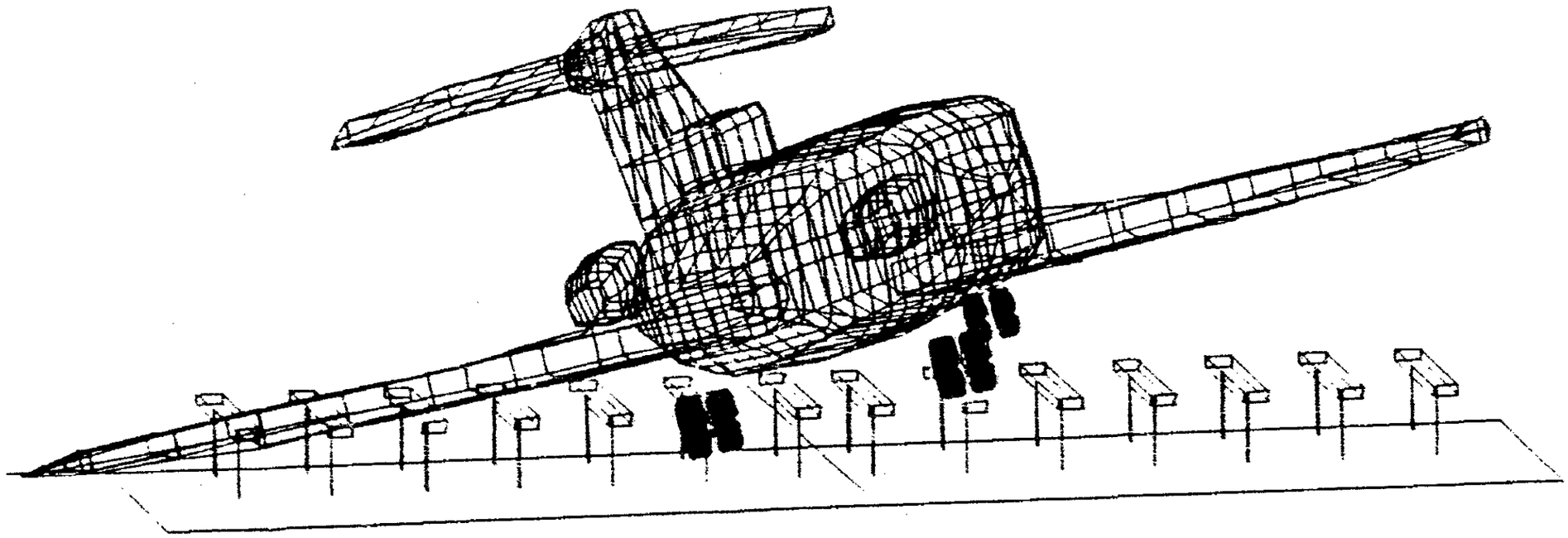
sharply to the right and the right wing tip struck the runway surface. Compressor surges from one or more engines were heard immediately thereafter. The airplane reached a height above the liftoff point of about 20 feet and then it began to descend. The first impact with the localizer antenna installation occurred only 22 seconds after liftoff. (See figure 12.) After initial activation, the stall warning stickshaker sounded continually until impact.

The point during takeoff at which an airplane leaves the ground and the climb gradient is established depends upon the force of lift which is acting on the airplane. Although the vertical component of engine thrust contributes to the total lift force when the airplane rotates to a noseup pitch attitude, the primary component of the total lift force is the aerodynamic lift produced by the airplane's wing. This aerodynamic wing lift force, for any specific trailing edge flap and leading edge flap and slat configuration, is a function of the airspeed and wing AOA. The evidence in this accident is conclusive that the aerodynamic wing lift force to establish a safe takeoff (which should have been developed with the flaps set at 15° from the time that the airplane was rotated beyond an 8.6° noseup attitude at an airspeed in excess of 144 KCAS) was never attained.

Although the possibility of degraded engine performance was suggested by the evidence of compressor surges, a reduction of thrust does not explain the lift deficiency evident by the airplane's failure to climb. Based upon this rationale, engine performance has been ruled out as an initiating cause of this accident. However, the occurrence of the compressor surges after the stickshaker activation and the possible effect on the flightcrew actions and airplane performance during the 22-second flight are discussed further in this analysis.

In analyzing the causes of this accident, consideration was given to all conceivable factors that could explain why the magnitude of the lift force developed by the wing was less than that which would be expected. Contamination of the wing's airfoil which could have affected the aerodynamic characteristics was disregarded since the magnitude of the lift deficiency was too great to be attributed to leading edge roughness, particularly in the absence of freezing precipitation temperatures. The possibility of windshear as a cause was also ruled out for two reasons: (1) the effect of a horizontal wind shear is a sudden decrease in airspeed which correspondingly decreases wing lift, an occurrence which is not consistent with the airspeeds recorded during flight 1141's takeoff; and (2) the existing weather was not conducive to the strong convective activity associated with significant downdrafts or windshears that would affect the airplane's climb performance.

Consideration was also given to the possibility that the airplane encountered the wingtip vortex generated by a departing airplane immediately preceding the flight. Recorded radar data disclosed that at the time that Delta flight 1141 was receiving its takeoff clearance, the preceding flight, Delta Flight 1486, a B-727, was in excess of 7,000 feet down the runway and about 100 feet in the air. This separation exceeded the FAA's requirements, which state that a departing aircraft cannot begin its takeoff roll until the other aircraft is airborne and that, for Category III aircraft, a minimum



PERSPECTIVE FRONT VIEW

14 DEGREES PITCH
11 DEGREES ROLL

Figure 17.--Perspective front view of flight 1141 impacting ILS antenna array.

distance of 6,000 feet is established. Additionally, as the required separation distance was established between the two airplanes and as the preceding airplane was not categorized as a "heavy" airplane, there was no requirement for the controller to issue a wake turbulence cautionary advisory.

Analysis of the surface winds at departure times of flight 1486 and flight 1141 and the possible rate of sink for wingtip vortices indicated that the vortices created by flight 1486 were not near the runway when flight 1141 rotated for takeoff. Even those analyses which assumed that all of the factors which would be most conducive to a vortex encounter, i.e., no loss of vortex strength or interaction with the ground and worst case movement of the vortex, showed that the vortex from flight 1486 would still be at least 700 feet to the southwest of flight 1141's takeoff flight path. Therefore, the Safety Board determined that an encounter with a wake vortex was not a factor in this accident.

The only remaining plausible explanation for the deficiency in aerodynamic lift is that the airplane's wings were not properly configured for takeoff. That is, either the ground or flight spoilers were deployed or the wing leading and trailing edge devices were not extended during the takeoff roll.

Therefore the possibility was considered that the wing flaps and slats were properly extended, but for some unknown reason spoilers might have deployed during the attempted takeoff. Spoilers decrease lift while simultaneously increasing the drag force. Ground spoilers reduce the lift force and increase drag during the ground run, allowing landing distances to be shortened. Flight spoilers are used to assist in roll control or to increase the descent rate while airborne. Physical evidence indicated that all but one of the flight spoilers were in the stowed and locked position. The remaining flight spoiler was found in the wreckage path with its actuator extended. One ground spoiler on the left wing was in the stowed and locked position. The other spoiler was stowed but could not lock due to misadjustment of the overcenter mechanism. The ground spoilers on the right wing were consumed by fire. Analysis of the change in aerodynamic forces that would be expected due to deployment of either one or both types of spoilers showed that neither one matched the accident circumstances. The acceleration of Flight 1141 is higher than predicted for the case in which ground spoilers are deployed.

Therefore, the deficiency in aerodynamic lift must have been because all or some of the trailing edge flaps and the leading edge flaps and slats were not extended. In this case the aerodynamic lift produced by the wing at the normal takeoff and climb airspeeds would be significantly less than that required for normal performance. There is considerable physical evidence that all of the trailing edge flaps and some of the leading edge flaps and slats were fully retracted when the airplane came to rest after impact. The physical evidence regarding the position of the trailing edge flaps and leading edge flaps and slats at the initiation of and during the takeoff is less conclusive. Accordingly, the Safety Board sought to determine the position of these lift devices.

2.3 Determination of Trailing Edge Flap and Leading Edge Flap and Slat Position at Impact

The evidence considered in the determination of the positions of the trailing edge flaps and leading edge flaps and slats at the time of impact included the wreckage documentation of the cockpit flap control mechanism, the trailing edge flap drive mechanisms, the outboard aileron lockout mechanisms, and the leading edge flap and slat actuators.

Cockpit Flap Control Lever.--The cockpit flap control lever was found in the 0^{o} (flaps up) detent. The flap control mechanism was intact and functional after the accident. The control lever is spring-loaded to lock in each of the seven/flap position detents. To move the lever from a detent, it must be raised about 1/4 inch before it can be moved to a new position. Further, the mechanism quadrant contains a gate at the 2^{o} position which is designed to prevent the lever from being inadvertently moved to the 0^{o} position. Thus, a movement of the lever from the 15^{o} position to the 0^{o} position requires that the lever be raised out of the 15^{o} detent, moved over the 10^{o} and 5^{o} positions to the 2^{o} detent, depressed and passed under a "gate", and reraised before movement to the 0^{o} detent position. It is unlikely that this sequence of lever movements occurred during the impact. Although the flap control lever could have been moved by a crewmember or rescue personnel following the accident, such a movement would have had to be intentional and, most likely, accomplished by someone familiar with the mechanism. There is no evidence that such an action occurred.

Trailing Edge Flap Drive Mechanisms.--The movement of the flap control lever is mechanically transmitted to the inboard and outboard trailing edge flap hydraulic control valves. These hydraulic valves are thereby repositioned so that hydraulic fluid flow under pressure is applied to the inboard and outboard flap drive motors. These motors, in turn, rotate torque tubes which transmit rotary motion to jackscrews which move the trailing edge flap panels. All of the trailing edge flap drive mechanisms, the jackscrews on the left-wing outboard flaps, the torque tube on the left-wing inboard flaps, and the jackscrews on both the inboard and outboard right-wing flaps, were found in positions which corresponded to near fully retracted trailing edge flaps. It was noted that the jackscrew ballnuts were not on the upstops and the rigpin holes were slightly out of the flaps up position. However, it is believed that these positions were either the current rig of the airplane or that a hydraulic transient surge during the impact sequence caused actuators to move slightly. The flap drive mechanisms are irreversible by design; i.e., an externally applied load to the flap surfaces will not cause the jackscrews to rotate. Therefore, the positions of the flap drive mechanisms can not be attributed to impact damage.

Outboard Aileron Control Lockout Device.--Roll control of the B-727 airplane is achieved by a set of inboard ailerons, a set of outboard ailerons, and spoilers. When the wing flaps are retracted to the 0^{o} position, the outboard ailerons are "locked out" so that they remain in the neutral position irrespective of inputs from the aileron control system. The outboard aileron control lockout mechanism consists of a jackscrew which

changes the geometry of the linkage to the control surface. The jackscrews are driven by the outboard trailing edge flap torque tubes via gearboxes. In the cases of the accident airplane, the left and right outboard aileron lockout jackscrews were both found fully extended, corresponding to locked-out ailerons. The jackscrew positions were consistent with the other physical evidence that the trailing edge flaps were retracted. These mechanisms are also of a design which is not susceptible to movement as a result of impact loading.

Leading Edge Flaps and Slats.--The leading edge flaps and slats are positioned in conjunction with the trailing edge flaps. When the trailing edge flaps are extended, mechanical motion is transmitted through cables and linkages from the outboard trailing edge flaps to the leading edge flap and slat hydraulic control valve. When the outboard trailing edge flaps are extended to 2^{o}, the control valve is positioned to port hydraulic fluid under pressure to extend two of the four leading edge slats on each wing. When the outboard trailing edge flaps are extended to 5^{o}, the hydraulic pressure is applied to all of the leading edge flaps and slats. The leading edge flap actuators are linear hydraulic cylinders which have an internal mechanism to lock them in the fully extended position only. Thus, when hydraulic pressure is removed, unless the pistons are fully extended, they are free to move within the cylinders with externally applied loads. Therefore, the postimpact position of the leading edge flaps in the extended position is not necessarily indicative of the preimpact position.

The leading edge slat actuators are also linear hydraulic cylinders, but, unlike the leading edge flaps the slat actuators have hydromechanical locking mechanisms in both the fully-extended and fully-retracted positions. If the actuator piston rods are in a midstroke position when hydraulic pressure is removed, they can be driven by external loads to the extended or retracted position. However, if the actuators are fully extended or fully retracted when hydraulic pressure is removed, the actuator piston rods will remain mechanically locked unless external loads of sufficient magnitude and in the proper direction are applied to damage the internal locking mechanism. In the accident airplane, four of the eight leading edge slat actuators were found in the fully retracted (uplock) position. The other four were in a midstroke position without evidence of damage to the internal locking mechanisms.

This finding led to the consideration of the possibility that the leading edge slats were in the process of retracting when impact occurred. However, as the trailing edge flaps are retracted from 5^{o} to 0^{o}, the Nos. 1, 4, 5, and 8 leading edge slats and the leading edge flaps will retract to the full up position before the Nos. 2, 3, 6, and 7 slats begin to retract. The slat actuators that were found in the midstroke position (Nos. 1, 2, 3, and 8) are not consistent with the sequence of operation during flap retraction or extension.

Three of the right wing's four leading edge slats were in the locked position, and three of the left wing's four leading edge slats were in the unlocked position.

Since there is inconsistency between the four hydraulically unlocked leading edge slats and the flaps up position of the trailing edge flaps, the slats must have been hydraulically unlocked during the wing separation. The leading edge flap and slat control valve is located in the right wheel well. This control valve is connected to the outboard flap follow-up drum by a control rod, and the valve and drum are mounted on different structural portions of the fuselage. The airplane struck the ground with sufficient force to separate both the forward fuselage and the tail section aft of the wing. The control rod would only have had to move momentarily 1.0 to 1.5 inches to port hydraulic fluid to all of the leading edge devices. The fact that three of the right wing's four slats remained in the locked position is logical since that wing disintegrated at the same time the control valve moved, and hydraulic continuity was lost, and there was no pressure or flow to unlock the slats. The left wing remained attached to the fuselage throughout the impact sequence, and three of those slats were in the unlocked position. The postimpact position of the leading edge slats actuators is probably the result of the sequence of events during the impact; i.e., a deflection of the mechanical linkage at the leading edge flap and slat control valve while there still existed residual hydraulic pressure sufficient to unlock some of the leading edge slat actuators.

Based on the physical evidence and its analysis of the position of the trailing edge flap drive mechanism, the outboard aileron lockout mechanism and the leading edge flap and slat actuators, the Safety Board concludes that the cockpit flap control lever was in the 0^{o} detent and that the trailing edge flaps and leading edge flaps and slats were fully retracted before impact. This conclusion suggests that, either the takeoff was initiated with the flaps retracted, or that a flightcrew member repositioned the cockpit flap control lever subsequent to the beginning of the takeoff and at a sufficient time interval before impact to permit full hydraulic retraction of the trailing edge flaps and leading edge slats. It takes about 20 seconds, on the average, to retract the flaps and slats from an initial setting of 15^{o}. Thus, there was insufficient time, assuming the flap control lever was moved by a crewmember between stickshaker and impact, for the flaps to have retracted.

2.4 Determination of Trailing Edge Flap and Leading Edge Flap and Slat Position During Takeoff

While the physical evidence from wreckage documentation was conclusive that the wing was in a clean, i.e., flaps and slats retracted, configuration at the time of impact, other evidence is used to analyze the possibilities that the flaps were not set by the flightcrew during pre-takeoff activities, or that the flaps were set and subsequently retracted before impact. The evidence consisted of knowledge of the pre-takeoff activities from the conversations and sounds recorded on the CVR, information obtained from the flightcrew and witness interviews and testimony taken at the Safety Board's public hearing, findings from the examination of the airplane's takeoff warning system, air-conditioning system components, and trailing edge flap bypass valves, and the study of the airplane's aerodynamic performance based on the airspeeds, altitudes and normal accelerations which were recorded on the FDR.

Accomplishment of Checklists.--According to Delta's procedure at the time of the accident, the first officer was to set the wing flaps to the takeoff position after departing the ramp area. The procedure did not require that the first officer announce his actions of setting the flaps. However, the CVR was examined for noises that might have been made during a movement of the cockpit flap control lever from the 0° detent to the 15° detent. Three different sound sequences were identified as possible movement of the flap control lever. However, in a spectrum analysis, only one of these sound sequences bore some similarity to the sound sequences of flap control lever movement which was recorded on another B-727 for comparison purposes. That sound sequence occurred as the No. 3 engine was being restarted after it was shut down because of an air traffic control takeoff delay. Since that sound sequence did not positively correlate to flap lever movement, and because the first officer stated that he did not set the flaps as the No. 3 engine was restarted, the sound was attributed to other routine cockpit activity. Thus, it is concluded that the action of setting the wing flaps to the 15° detent could not be verified from the CVR examination.

As a result of the takeoff delay and in accordance with Delta's procedures, the flightcrew shut down the No. 3 engine and withheld the accomplishment of part of the TAXI and the BEFORE TAKEOFF checklist items until after the No. 3 engine was restarted. The flightcrew began to restart the engine when they believed that they were No. 4 for takeoff. Within 15 seconds they received clearance from the tower controller to taxi onto runway 18L and hold for takeoff. At this point, the CVR shows a distinct difference in the crew's conduct in the accomplishment of the checklists. Apparently, the second and first officer recognized the need for expeditious completion of the remaining checklist to prevent delay on the runway. Thus, where the checklists previously had been accomplished in a orderly/measured manner, the tone and behavior of the crewmembers clearly became rushed. The second officer and first officer hurried to complete the challenge and response checklist items as the airplane was being taxied from taxiway F to the runway. Upon the second officer's prompt of "FLAPS", the first officer responded "FIFTEEN, FIFTEEN, GREEN LIGHT." Presumably, the first officer's response would be based on a visual check of the needle position on the inboard and outboard flap position indicators and illumination of the green leading edge flaps and slats indicating light located on the center instrument panel. There were no background sounds recorded on the CVR as the first officer responded to suggest that controls or switches were being manipulated in response to the "FLAP" or 'FLIGHT CONTROLS' challenges. Further, the time between the checklist challenges and responses was less than one second, with little time to accomplish actions required to satisfy the proper response.

At the Safety Board's public hearing, all three members of the flightcrew testifed that, by habit, they would have verified the trailing edge flap indicators and leading edge flap and slat light indicators during the checklist completion; however, none specifically recalled having done so on the accident flight. It is likely that the captain's attention was diverted to the visual task of taxiing the airplane onto the runway and that the second officer was attempting to complete the checklist hurriedly to

prepare for the takeoff, and, consequently, neither the captain or second officer looked specifically at the instrument panel to verify the first officer's response. It is not possible to know whether the first officer actually looked at the flap position indicators and light as he answered the "FLAPS" challenge. Because of the repetitive nature of checklist accomplishments, it is not uncommon for crewmembers to fall into a habit of answering to challenges by rote with the normal response without actually observing the appropriate indicator, light or switch. During the public hearing the second officer mentioned an incident where a first officer provided the correct response of Flaps 25° when, in fact, the flaps were set at 15°. This can be particularly true if the respondent has a mindset that the action necessary to satisfy the indicator checklist has been completed. Furthermore, on the B-727 flap position indicators, the 0° position is at 9 o'clock while the 15° position is directly opposite at 3 o'clock. Thus, in both cases, the needles would be oriented horizontally. It is conceivable that a person observing the indicators quickly could perceive that the left and right needles on both the inboard flap and outboard flap indicators were matched and horizontal without noting that this actual orientation was opposite to normal. It is less conceivable that a person would miss an indication of a significant split between the left and right needles on either the inboard or outboard indicator, or that they would miss a difference in the directional orientation of the needles on the two collocated indicators. Finally, it is even more difficult to explain how a person would respond "green" to a light that is colocated with the flap/slat gages when that light is not illuminated. Therefore, the Safety Board concludes that first officer responded to the flap challenge in the taxi checklist without looking at the status of the light and indicators.

In any event, the first officer's proper response to the taxi checklist regarding flap position cannot be considered as assurance that the flaps were properly set before takeoff, and such a presumption is contradicted by other substantial evidence.

Additionally, the passenger's statement that he noticed that the trailing edge of the wing was not straight cannot be taken as assurance that the flaps were extended. It is possible that what he noticed was the deployment of the flight spoilers or inboard aileron as the captain tried to regain control of the airplane. Glancing at the wing while the spoiler was up, would have given the appearance of an "unstraight" trailing edge. In the excitement of the moment he may have interpreted this appearance as the flaps being extended.

Takeoff Warning System.--The B-727 takeoff warning system is designed to provide an aural alarm in the cockpit when the No. 3 engine thrust lever is advanced past a predetermined position while the airplane is on the ground, and the outboard trailing edge flaps are not extended. The input for the trailing edge flap position is taken from a switch on the outboard flap follow up mechanism. When the outboard flaps are retracted or extended to a position less than 5°, the ground circuit to the takeoff warning system is completed and will cause the alarm horn to sound. The input for the leading edge slats is taken from the No. 4 slat on the left wing and the No. 5 slat on the right wing. If either of these slats are not

extended, the ground circuit will be completed and the alarm horn will sound when the No. 3 engine thrust lever is advanced.

If the takeoff warning horn had sounded as the captain of flight 1141 advanced the thrust levers for takeoff, the sounds would have been clearly evident on the CVR. The lack of the alarm leads to two possible conclusions: (1) that only the outboard trailing edge flaps and the leading edge flaps and slats were properly set for the takeoff and subsequently were retracted at or before liftoff; or (2) the takeoff warning system malfunctioned.

The device that arms the takeoff warning system consists of a switch and switch actuator mounted on the No. 3 engine autothrottle clutch assembly. Advancement of the No. 3 engine thrust lever causes a cam in the clutch assembly to engage the switch actuator which translates the rotary cam motion into linear motion to operate the switch. The button on the actuator depresses the plunger on the switch, closing a circuit and arming the aural takeoff warning system. Until the system is armed by the thrust lever switch, the electrical circuit between the takeoff warning system horn and the flight control position switches remains open.

During the first two activations of the switch assembly by finger manipulation during the on-scene phase of the investigation, there was no electrical continuity indicated between the common and normally open terminals of the switch. A third activation did indicate electrical continuity. Based upon this inconsistency and the observation of a blue-green corrosion-type substance surrounding the normally open terminals, a follow-on teardown inspection of the switch assembly was conducted.

The first misactuation of the switch, i.e., the actuator button slipping off the switch plunger, was observed during the early stages of this teardown investigation. Because of this and subsequent switch misactuations observed by the group, Boeing proceeded to conduct extensive examinations of the switch assembly. Their reports concluded that it was unlikely that any misactuation occurred prior to the group's examination of the switch assembly due to a lack of multiple scoring marks on the switch plunger. However, the reports also concluded that preexisting corrosion type contamination could have adversely affected the electrical performance of the switch.

The investigation noted that the Boeing service manual and Boeing Service Bulletin 727-31-30 are not consistent regarding adjustment of the switch. Revision 4 of the service bulletin, which was applicable at the time of the accident, stated that the tab adjustment of the switch may be bent to adjust for the correct switch operating point. There is no limit given for the amount of bending adjustment possible. The maintenance manual, dated January 20, 1985, states not to bend the actuator tab more than $\pm 1/4^{o}$ from the plane of the actuator arm and that adjustments are to be made by moving the switch body in the slotted switch support mount.

The investigation noted that it is possible to bend the adjustment tab without visually checking that the actuator button and the switch plunger are making contact over the majority of their surfaces. Thus it is possible for maintenance personnel, who are not aware of the limitations stated in the maintenance manual, to bend the tab to the point that the button and plunger no longer make firm contact while attempting to adjust the activation of the warning system. This would explain why the tab of the switch from the accident airplane was found bent well past the limits given in the maintenance manual.

Irrespective of Boeing Company conclusions, the findings that (1) the switch did not electrically close during the first two attempts at the accident site; (2) successful activations of the switch during the teardown investigation was "hit-or-miss" due to the positioning of the actuator button to the switch plunger; and (3) the internal contacts of the switch showed contamination, will support a conclusion that the takeoff warning system did not arm when the No. 3 engine thrust lever was advanced for takeoff.

Such a conclusion is supported further by the Safety Board's findings that 3 weeks prior to the accident, the aural warning horn had been written up in the airplane's maintenance records in the "A2" inspection as being weak and intermittent. The corrective action taken by maintenance personnel was to replace the aural warning horn and test the system. The removed unit was taken to the repair shop where its contacts were cleaned and functionally tested. The unit was found to function properly and was sent to the spare parts inventory.

The Safety Board's investigation could not determine if, at the time that the aural warning horn was replaced, all components of the takeoff warning system were inspected to verify that indeed the warning horn was the cause of the intermittent operation. Discussions with maintenance personnel disclosed that the warning horn is readily accessible and easily replaced. Therefore, it normally is the first component of the system to be removed and replaced by a serviceable unit from the spare parts inventory. If the system then functions properly, it is most likely that no further work or troubleshooting would be accomplished. While such a procedure is expedient it does not assure that an intermittent condition has, in fact, been corrected because the other components of the system have not been checked. Therefore, the possibility exists that the aural warning horn was not the cause of the problem and because other components in the system were not tested after the unit was replaced, the real cause of the problem may well have gone undetected.

Therefore, the evidence suggests that there was an intermittent problem in the takeoff warning system that was not detected and corrected during the last maintenance action. This problem could have manifested itself during the takeoff of flight 1141; and thus the flightcrew was not provided with the aural warning of misconfigured airplane which is the function of the takeoff warning system.

Air Conditioning Auto Pack Trip Systems.--The B-727 auto pack trip system is designed to automatically shut down the air-conditioning system in the event of an engine thrust loss during takeoff so that the thrust produced from the remaining operating engines is not reduced by the extraction of bleed air that is needed for air conditioning. The system is normally armed when the bleed air pressure from each engine reaches 120 psi, the airplane is on the ground, the auto pack trip arm switch is in the NORMAL position, and the inboard trailing edge flaps are out of the 0^{0} position.

The first indication of an abnormality during flight 1141 was the second officer's observation that the green auto pack trip arming light failed to illuminate when engine thrust was advanced for takeoff. The second officer is required to verify that the auto pack trip arm switch is in the NORMAL position during his completion of the BEFORE TAKEOFF checklists and the switch was found to be in NORMAL when the cockpit was examined after the accident. There was no history of any discrepancies of the auto pack trip system or other evidence that would explain the failure of the system to arm, provided the arming criteria were satisfied. The failure of the system to arm can be attributed to discontinuity in the arming circuit because the inboard trailing edge flap up limit switch was found open.

The failure of the auto pack trip system to arm is corroborating evidence that the inboard flaps were retracted when the takeoff roll was initiated. It is controversial as to whether or not the second officer should have notified the captain that the auto pack trip light failed to illuminate during the takeoff ground roll. As the system was not required for this takeoff, the second officer believed that he was not required to inform the captain of the failure. However, Delta procedures require that the captain should be informed of all malfunctions. Since the accident, Delta's procedures have been modified to eliminate this dichotomy.

Flap Bypass Valve Positions.--The inboard and outboard trailing edge flaps on the B-727 are independent, both mechanically and hydraulically; i.e., the inboard flaps and outboard flaps are driven by separate hydraulic motors that are connected to independent hydraulic circuits. Although the inboard and outboard flaps are independent, the left and right inboard flaps are mechanically connected and the left and right outboard flaps are mechanically connected by their respective torque tube drives so that, precluding a mechanical failure, the left and right flaps will move symmetrically. Further protection is provided against left to right flap extension asymmetry which could occur because of a failure of the torque tube drive mechanism for either the inboard or outboard flaps by an electrical comparator which senses an angular difference between the left and right pointers on the inboard or outboard flap position indicators. A separation between the left and right pointers of 8 to 20 degrees will energize an electrical circuit to drive a bypass valve in the appropriate hydraulic subsystem (inboard or outboard) to a BYPASS position. This action will remove hydraulic pressure from the flap drive motor, stopping further movement of the affected flaps.

Following the accident, the inboard flap bypass valve in the airplane's left wheelwell was found in the BYPASS position, while the outboard flap bypass valve in the right wheelwell was found in the NORMAL position. If these valves had been in the "as found" positions before takeoff, the outboard flaps would have extended to a position corresponding to the cockpit flap control lever placement, but the inboard flaps would have remained at the position in which they were when the bypass valve moved to BYPASS. This finding led to speculation that the first officer may have set the flaps to 15°, but only the outboard flaps extended while the inboard flaps remained retracted.

The known sequence of events during the accident provides a rational understanding of these postimpact findings. The airplane's right wing was severely damaged and separated from the airplane while the left wing remained relatively undamaged and intact. The damage to the right wing undoubtedly resulted in damage to the right inboard and outboard flap follow-up mechanisms or a separation in electrical continuity during the crash sequence which would have been sensed by the flap position indicator comparator as left to right asymmetry. It is reasonable to conclude that the electrical continuity to the left wheelwell remained for the 1 second necessary to drive the motor-operated inboard flap bypass valve to the BYPASS position, and that electrical circuits to the outboard bypass valve were destroyed before that valve could be driven from the NORMAL position. Therefore, the "as found" position of the flap bypass valves provide no positive evidence upon which to assess the pre-takeoff flap setting.

Witness Observation.--The passenger who had been seated in 28C stated at the public hearing that his attention was directed to the left wing of the airplane just after rotation when he felt a sudden roll to the right. From his seated position, he could observe the outboard trailing edge of the left wing and he stated that the flaps appeared to be extended. Although the witness had some piloting experience in light airplanes and had general knowledge regarding the location and function of the flaps, his testimony can be given only limited credibility. For example, he was not able to correctly identify the location of the flight spoilers. This may be significant since the flight spoilers are immediately forward of the outboard flaps. Thus, the break in the upper wing surface produced by spoiler deflection, as would be expected as the pilot attempted to stabilize lateral oscillations, could have been perceived as flap extension.

Perhaps of more significance, the witness stated that he did not perceive up or down deflection of the outboard aileron. Since the airplane was rolling due to lateral instability at the time that the witness was observing the outboard wing trailing edge, it is reasonable to believe that he would have observed aileron movement. That he didn't observe such movement could support the conclusion that ailerons were locked out, a condition which would have existed only if the outboard flaps were retracted.

2.5 Airplane Performance Study

The failure of the takeoff warning system to provide an alarm, the failure of the auto pack trip system to arm, and the perception of the outboard flap position by the witness could be explained by an abnormal takeoff wing flap configuration; the inboard trailing edge flaps retracted and the outboard trailing edge flaps extended, i.e., "split flaps". Further, the possibility that the first officer set the flaps to 15^{0} and failed to note the disparity between the inboard and outboard flap position indications could not be ruled out based on evidence presented so far because of the position of the inboard flap bypass valve as found after impact. Therefore, the possibility that the takeoff was initiated with the airplane in this "split flap" configuration and the flaps were retracted before impact was examined thoroughly in the context of other evidence. The comparison of the events and airspeed-altitude profile of flight 1141 with the known aerodynamic performance, stall characteristics, and handling qualities of the B-727 airplane was the most compelling evidence to discount the "split flap" takeoff theory.

As previously stated, the generation of a lift force by a wing airfoil depends upon a smooth flow of air passing over the wing and the amount of the lift force depends upon the speed of the air passing over the wing and the angle at which the air impinges the wing's leading edge (AOA). As the AOA is increased, the lift generated by the wing is increased until the AOA reaches a point at which the airflow can no longer adhere to the upper surface of the wing. The wing is said to be stalled when a further increase in AOA and consequent airflow separation results in a sometimes drastic reduction in the amount of lift produced. In this condition the air behind the wing is turbulent and the airplane may experience severe buffeting. Since the airflow separation can occur non-uniformly across the wing's span and between the left and right wings, the airplane may roll suddenly as it approaches the stall AOA. Furthermore, the turbulent air behind the wing entering the inlets of rear fuselage mounted engines may cause engine compressor surges.

The leading edge flaps and slats have an aerodynamic effect that permits an airplane to fly at higher AOA before the smooth flow of air begins to separate from the wing's upper surface. Thus, with the leading edge devices extended, a wing can generate greater amounts of lift at AOA beyond that at which stall would occur without the leading edge devices extended, irrespective of the position of the trailing edge flaps. Trailing edge flaps add to the amount of lift generated by a wing at a given airspeed and AOA by increasing the camber of the wing. However, for the same leading edge configuration, the increase in wing camber from the extension of the trailing edge flaps will cause airflow separation and stall to occur at a slightly lesser AOA than with the flaps retracted (less than 1^{0}).

Since the B-727's leading edge flaps and slats are hydraulically extended as a result of a mechanical interconnection with the outboard trailing edge flaps, a failure of the inboard flaps to extend for any reason would not have precluded the extension of the airplane's leading edge devices. Therefore, the performance of a B-727 with the inboard trailing

edge flaps retracted, the outboard trailing edge flaps extended to 15°, and the leading edge flaps and slats extended was analyzed and compared with the performance achieved by flight 1141. (See figure 13.) It is readily apparent from the calculated aerodynamic effects of trailing edge flaps and leading edge devices that the wing in the "split flap" configuration would have generated less lift at a given airspeed and AOA than it would have with all of the trailing edge flaps extended to 15°; but it is also apparent that the AOA at which airflow separation would have occurred with "split flaps" would have been about the same (or even slightly higher on the inboard wing section) than it would have been in the normal 15° trailing edge flap configuration. The theoretical aerodynamic data provided for the split flap configuration by the Boeing Company indicate that the stall AOA is about 18°; the data obtained from the March 23, 1989, demonstration flight indicate that an airplane under the conditions of flight 1141 maintains good flight characteristics without airflow separation (as indicated by buffet or roll instability) up to AOA greater than 15°. However, unlike the takeoff warning system, the stall warning stickshaker circuitry is predicated upon the inboard flap position and an assumption that the leading edge devices are also retracted when the inboard flaps are retracted. Thus, the stickshaker stall warning will alarm at an AOA of 11° appropriate to stall for the clean wing configuration. In the split flap configuration, the 11° AOA stickshaker warning would have provided about 16 percent airspeed and 7° AOA margin to stall. If the stickshaker warning was set at 14° AOA, the more typical 7 percent airspeed and 4° AOA margin to stall would have been available.

The performance analysis, based upon the lift versus AOA data for the split flap configuration, indicates that had flight 1141 been so configured during the takeoff roll, the airplane's tail may have contacted the runway surface as the captain rotated to the takeoff attitude. However, the airplane, with its geometry-limited 10° pitch attitude would have lifted off at about 150 KCAS instead of the actual liftoff speed of 158 KCAS. A continued rotation at a rate greater than 1.5° per second would have resulted in stickshaker activation; but there would have been considerable margin to stall when the warning occurred and the airplane would have transitioned to a climbing flightpath with a vertical acceleration in excess of 1.2G. If the captain had ignored the stickshaker warning and continued to exert sufficient back force on the control column to raise the airplane's nose at a rate of 3° per second, the airplane would have achieved a 3° climbing flightpath at an AOA of about 15° within 2 seconds after liftoff. There would have been no airflow separation to explain the sudden roll of the airplane, and there would have been no engine inlet air turbulence to explain the compressor surges which were evident on the CVR. A more likely and proper flight crew reaction to the stickshaker activation would have been to relax the back force on the control column to silence the stickshaker, provided that that response would not result in a loss of critical altitude. Under such circumstances, the airplane would have continued to accelerate while developing sufficient lift force to transition to a climbing flightpath. These performance data indicate that about 10 seconds after liftoff, the airplane would have been about 100 feet above the ground and climbing at about 1,200 feet per minute. The stickshaker would have activated only momentarily.

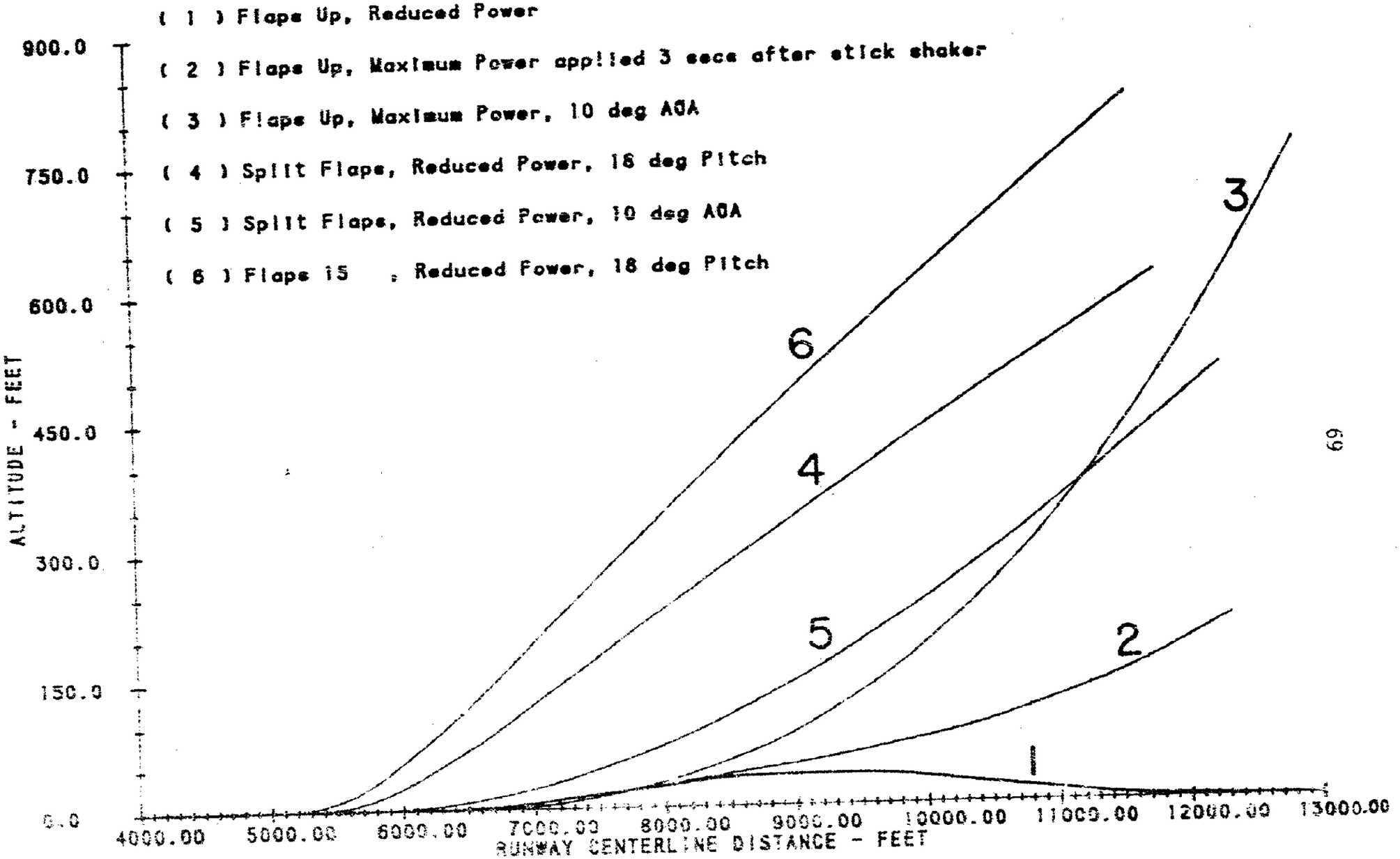


Figure 13.--Takeoff profiles.

The Safety Board concludes that the actual performance of flight 1141 is not explainable by the "split flap" theory. A possibility that one flightcrew member reacted to the delayed liftoff and stickshaker onset by intentionally or inadvertently retracting the flaps to 0° is also implausible, since the 20 seconds required for the trailing edge flaps and leading edge devices to retract with consequent effect on flight performance would place the airplane far beyond the point at which the roll instability and engine compressor surges actually occurred. If the flaps retraction sequence had started at rotation, the airplane would have had sufficient lift to climb several hundred feet prior to the flaps reaching 0°. Furthermore, each of the flightcrew members positively stated that they did not reset the flap control lever after the takeoff was initiated, and that they knew of no situation in which they would have done so.

The airplane performance study indicated that all of the events as they occurred on flight 1141 only can be explained by assuming that the takeoff was initiated with the trailing edge flaps and leading edge devices fully retracted. An analysis of the calculated lift versus AOA characteristics for a B-727 with a clean wing showed that the airplane would fail to lift off the runway when rotated to the 10° geometry-limited attitude until it reached a CAS between 158 and 159 knots, which correlates precisely with the actual lift-off airspeed of flight 1141 as indicated on the FDR. The airplane continued to accelerate thus achieving a slight lift-versus-weight margin to climb. However, the data indicated that the captain continued to exert back force on the control column as he attempted to raise the airplane's nose to the normal climb attitude. The airplane's vertical acceleration when the stickshaker activated at 11° AOA and 161 KCAS is consistent with the theoretical performance of the airplane in the clean wing configuration, with consideration for ground effect. The continued increase in pitch attitude resulted in little change in climb performance, typical of an airplane very near stall. The sudden roll to the right and the cyclic vertical accelerations evident on the FDR are indications of airflow separation on the outboard wing. Such roll instability is a known characteristic of the B-727 with leading edge devices retracted and the outboard ailerons locked out. According to statements by a Boeing test pilot, the B-727 tends to retain roll stability and control during approach to stall with the leading edge devices extended and the outboard ailerons active. The roll, itself, and the control action (spoiler deflections) used to correct the roll resulted in a further loss in lift and climb performance. The engine compressor surges also are consistent with airflow separation on the inboard wing section which produces turbulence at the side fuselage-mounted engine inlets. It is probable, based on data from the engine manufacturer, that the compressor surges did not significantly degrade the thrust produced by the engines. The airplane performance analysis shows that the minimal acceleration of the airplane from liftoff to impact was the result of the high drag force produced at high AOA, rather than a loss of thrust.

The airplane's performance during and subsequent to the takeoff rotation, including the delayed liftoff, the roll instability, the engine compressor surge and the flight profile ending at impact, strongly support a conclusion that the trailing edge flaps and leading edge devices were fully

retracted when flight 1141 began its takeoff roll. This conclusion is further supported by the evidence that the inboard and outboard flaps were retracted at the instant of impact, combined with statements by the flightcrew that no one moved the flap lever during the flight. It is considered extremely unlikely that a flightcrew member would move the flap lever during takeoff without verbalizing such intended action. No such comments were recorded on the CVR nor were there any noises which could be construed as recorded flap lever movement. Thus, it is concluded that the flap lever was not set to the 15° detent during pre-takeoff activities, the first officer, as well as the other crewmembers, did not note the actual flap position when he responded to the checklist challenge, and the airplane's takeoff warning systems did not provide a warning of improper takeoff configuration.

2.6 Flightcrew Actions After Takeoff

Even though the analysis determined that the flightcrew did not configure the airplane properly for takeoff, the accident may not have been inevitable. Thus, the flightcrew's actions after takeoff were analyzed to determine whether the accident could have been prevented or otherwise minimized.

The sound of stickshaker was heard on the CVR tape at 0900:15.1 and continued until impact. At 0900:34.7, the CVR tape indicated that the captain states "full power." This call was made 0.6 seconds prior to the sound of the first impact. In his testimony at the public hearing, the captain stated that he made the call "full power" after he had already applied full power. Unfortunately, due to aerodynamic noise masking the engine noises, it is not possible to determine if the engines were accelerating prior to impact. However, it does not seem likely that a person would make such a callout after accomplishing the action. It is more likely that such a call would be made coincident with the application of power, or would be a request for the first officer to advance the throttles. Given the roll oscillations that were noted by witnesses, it would be expected that the captain would have had both hands on the control yoke in trying to regain control of the aircraft. During the public hearing, the second officer testified that, after the aircraft rolled to the right, he observed that both of the captain's hands were on the control yoke. Therefore, it is concluded that the captain's call of "full power" was a command for the first officer to advance the throttles and that power had not been increased prior to 0900:34.7. Despite the captain's statement at the public hearing that he applied maximum power before impact, there is no evidence that power was ever actually increased above the reduced takeoff rating.

The captain testified that Delta's procedures when encountering stickshaker after liftoff were to apply maximum available thrust, rotate toward 15° of pitch, and to respect all stall warnings, i.e., stickshaker or buffeting. Additionally, the captain testified that he followed Delta's procedures after encountering stickshaker. The performance study found that the airplane was rotated over 13° when it passed the ILS antenna and may have exceeded 15° at various portions of the flight. In any event, the nose of the airplane was not lowered to silence the stickshaker.

The investigation found that Delta's procedures for encountering a stickshaker or buffeting close to the ground are, in part, to apply maximum power and to rotate toward 15° of noseup pitch attitude. Additionally, the Delta procedure states that the pilot is to stop rotation if stickshaker or buffeting is encountered. It is concluded that not applying maximum thrust after the onset of stickshaker and not respecting stickshaker warnings were the significant reasons for the captain's inability to gain control of the airplane after liftoff.

The investigation found that the most appropriate reaction after activation of the stickshaker was to apply maximum available thrust and to lower the nose below stickshaker AOA. Although a clean wing is not an authorized takeoff configuration for the B-727, the airplane performance analysis showed that a marginal climb capability was available if stickshaker AOA had not been exceeded and/or if maximum power had been applied within 3 seconds of initial stickshaker activation. Maximum throttle position increases thrust approximately 25 percent from about 34,500 to 43,000 pounds total thrust. Therefore, had maximum power been applied 3 seconds after stickshaker, performance calculations predict that the airplane would have gained 20 knots of airspeed and over 200 feet of altitude before reaching the ILS antenna. If stickshaker AOA had not been exceeded, further altitude gain could have been expected. Moreover, a check of configuration--the flap control lever and flap indications--immediately upon activation of the stickshaker would have disclosed the reason for the airplane's performance deficiency. Had the first officer or second officer moved the flap control immediately, the extension of the leading edge devices would have provided sufficient stall margin to regain control.

2.7 Cockpit Management and Crew Discipline

The Safety Board sought to determine the relationship between crew performance and the events in this accident. The investigation revealed that Delta did not insist on a standardized approach towards cockpit management. Testimony from management and training personnel indicated that captains were allowed wide latitude in their conduct of cockpit operations. The CVR indicated that the captain's approach towards cockpit management was passive and that he allowed events to materialize rather than firmly control the sequence of events.

The CVR transcript shows that the captain only occasionally entered the conversation in the cockpit which was carried almost exclusively by the first officer. The first officer acted as the social element in the cockpit, initiating and sustaining informal discussions, commenting on political events and past flying experiences and generally acting as the social focus in the cockpit. The second officer, while occasionally drawn into the conversation, appeared to be business-like and more professional. For instance, in the absence of any requests for specific checklist, he seemed to keep track of events and the airplane's progress and he initiated the appropriate checklists on his own. He subtly prompted the flight attendant to leave the cockpit when the airplane became number 4 for departure by initiating the pre-departure cabin announcement on the PA system in which the flight attendants are told to prepare the cabin for departure. This action

by the second officer also may have been a not so subtle reminder for the captain that the number 3 engine had yet to be restarted.

It can be argued that the second officer had as much a responsibility as the captain and the first officer to verify the flap position when the first officer responded to the flap challenge on the BEFORE TAKEOFF checklist. However, when the runway lineup and takeoff clearances were received in short order and earlier than expected, the second officer became quite rushed in accomplishing the remainder of the TAXI checklist as well as the entire BEFORE TAKEOFF checklist. He then had the responsibility to accomplish a number of additional items before he could turn and slide his seat forward in order to monitor the takeoff. Thus, it is readily evident that the nonspecific and unspecified task of monitoring the captain's and first officer's responsibilities could become a task to be carried out "as time permits" for the second officer. The record is clear in this case that insufficient time was available to the second officer to carry out this task. Thus, the Safety Board believes that the second officer's actions were appropriate and not causally related to the flap position anomaly which resulted in this accident.

The captain is responsible for the logical and timely completion of cockpit duties by the crewmembers. Guidelines for the timing and logic of cockpit duties are provided by procedures recommended by the airplane manufacturer and instituted by the carrier through the publication of these procedures in its training manuals and its Pilot's Handbook or Operating Manual. It is the captain's responsibility to maintain the necessary discipline in the cockpit so that company procedures are carried out properly. In other words, the captain sets the tone and working atmosphere in the cockpit. If he does not do so, crew discipline in the cockpit can deteriorate rapidly. The evidence indicates that this was the case in this accident.

The captain did not stop the first officer's interruptions of cockpit duties when he initiated nonrelevant conversation or made comments about his observations outside the cockpit while the airplane was being pushed back, while the engine start checklist was run, when the airplane was taxied from the push-back position and during the subsequent 25 minutes taxi time before takeoff clearance was received. At the point where the first officer would have lowered the flaps to the takeoff position, ramp control gave flight 1141 instructions to give way to another airplane, and he became engaged in a conversation with the captain about the position of that airplane. When flight 1141 started moving again, the first officer had another opportunity to continue his normal routine and lower the flaps; however, the second officer initiated the taxi checklist at that point and the first officer became involved in the required responses to the checklist items. Immediately after the taxi checklist was completed, the first officer began lengthy conversations with a flight attendant. Thus, his routine was interrupted at key points and an entire segment of the first officer's habit pattern was overtaken by subsequent routines. The Safety Board believes that, had the captain exercised his responsibility and asked the flight attendant to leave the cockpit or, as a minimum, stopped the nonpertinent

conversations, the 25-minute taxi time could have been utilized more constructively and the flap position discrepancy might have been discovered.

In any event, because the captain apparently relied on the other crewmembers to accomplish cockpit activities, rather than monitoring and setting the pace of these activities himself, the Safety Board believes that the captain never perceived a need to visually or tactually check whether the first officer lowered the flaps after he taxied the airplane from the ramp or when the flaps were called just prior to takeoff. Instead, he relied on the professionalism of the first officer for the proper execution of his duties when the taxi checklist was being completed just before takeoff, and the first officer responded positively to the flap challenge on the checklist.

The Safety Board believes that, had the captain taken a more active role in running the cockpit, the accident may have been prevented. The investigation found that the cockpit discipline problems noted on flight 1141 were not isolated to this cockpit. These problems were previously observed and reported at Delta in FAA inspection reports. However, neither FAA nor company management initiated sufficient corrective action. In its Northwest Airlines DC-9-82 accident report, the Safety Board observed almost identical cockpit management shortcomings. As a result of that accident, the Safety Board observed that the FAA should require its operations inspectors and designated check airmen to emphasize the importance of disciplined application of operating procedures and rigorous adherence to prescribed checklist procedures. (Safety Recommendations A-88-69 and A-88-71, which will be discussed later in this report). The Safety Board reiterates its conviction of the need for rigorous FAA surveillance of training programs that emphasize cockpit management procedures.

With respect to the issue of checklist discipline, there is no evidence that the intent, presentation, and execution of checklists at Delta were significantly different than at any other company in the industry. Procedures were in place that provided for an orderly execution of all required items; i.e., the captain was required to ask for the appropriate checklist to be completed and the first and second officers were expected to accomplish the items on the checklist or verify that they had been accomplished. Because of the repetitive nature of checklist accomplishment and the fact that the required response to checklist items is most often the same, (i.e., flaps are usually set at 15^{0} for takeoff; there always is a green light associated with the slat setting), it is very easy for crewmembers to fall into a habit of reciting checklist challenge and response items by rote and providing a response to a challenge on the basis of what should be the proper response rather than the actual condition of the system that was queried. Examples of such mistakes were brought out at the public hearing, when both the first and the second officers recounted instances of responses to flap position challenges being given on the basis of expectations rather than reality. The Safety Board believes that this accident once again points out the paramount importance of cockpit discipline in the accomplishment of checklists. Because there is no ideal way for management to monitor individual performances of crewmembers in a cockpit, standard operating procedures and checklists are developed as a means for crewmembers to self-monitor their performance. This requires self-discipline

on the part of all crewmembers and positive leadership on the part of the captain. These concepts can be instilled in crewmembers through the training process.

However, a greater involvement is necessary to make the safety performance of an air carrier successful. That involvement must emanate from an awareness by management that the effectiveness of an air carrier's safety posture begins at the top of an organization. This safety concept was illustrated well in the previously referenced Boeing study on "Control of Crew-Caused Accidents," in which it was shown that the difference in the safety performance between air carriers appears to be the strong emphasis by top management on safety issues and management's acknowledgement of its accountability in that regard.

The connection between crew behavior, as evidenced in this accident, and the management attitude at Delta Air Lines, as observed by FAA as well as Safety Board personnel, was characterized well by Bruggink in his paper on air carrier management accountability:[4]

> An attitude of disrespect for the disciplined application of checklist procedures does not develop overnight; it develops after prolonged exposure to an attitude of indifference.

The same paper summarized:

> Unless management first acknowledges its own role in the development of operational settings that provide errors,
>
> human error avoidance programs can not serve their intended purpose in a practical and cost-effective manner.

There is evidence to show that Delta Air Lines' management had initiated training and other policy changes after the series of mishaps that were experienced in 1987. Some of these changes included the initiation of a cockpit resource management (CRM) program. The Safety Board realizes that it takes time to bring about fundamental and far reaching changes in an organization as large as Delta Air Lines. Furthermore, Delta was in a period of rapid growth and had recently merged with another airline with its attendant problems of cultural differences, management integration and a host of personnel problems, to name only a few. While the Safety Board views these problems sympathetically, it believes that Delta Air Lines management could have been more attentive to the obvious shortcomings in its safety posture and more agressive in implementing changes in its training and crew checking programs and the guidance provided its crewmembers. In light of this discussion, the Safety Board finds that the slow implementation of procedural modifications by Delta Air Lines were a contributing factor in this accident.

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[4] Bruggink, G.M. "Reflections on Air Carrier Safety" ISF Flight Safety Digest, June 1988.

2.8 Delta Air Lines Operations and Training

In mid-1987, Delta flightcrews were involved in six incidents resulting from pilot operational errors. The FAA's 1987 special inspection of Delta, conducted as a result of these incidents, confirmed that Delta's policy of delegating the maximum degree of responsibility and discretion to its crewmembers was, in large part, responsible for--"observed instances of a breakdown of communications, a lack of crew coordination, and lapses of discipline in Delta's cockpits." In response to a finding by the FAA's 1987 special inspection team of a "...lack of organization, coordination, standardization and discipline in the cockpit that can be attributed to minimal guidance in the flight manuals and a lack of direction from those who develop, supervise and manage flight training and standardization programs ...", Delta's vice president of Flight Operations and chief pilot responded that "many elements of our procedures are left to the discretion of the captain." A similar response was noted by Safety Board investigators when Delta management and training officials were interviewed subsequent to the flight 1141 accident.

The lack of the cockpit coordination and discipline noted by FAA inspectors in the inspection was evident in the cockpit of flight 1141. The CVR transcript indicated that the captain did not initiate even one checklist; the second officer called only one checklist complete; required callouts were not made by the captain and second officer during the engine start procedure; the captain did not give a takeoff briefing; the first officer did not call out "V_1"; the sterile cockpit policy was violated; and all three crewmembers did not notice that the flaps were in the up position prior to takeoff.

Another deficiency noted by the FAA special inspection teams were inadequate manuals and procedures. In its 1987 special inspection final report, the FAA team recommended that "Delta Air Lines study, develop, and publish specific crew duties for each crewmember. These functions should be placed in applicable manuals, and receive wide emphasis during the training and checking phases." Examples of the absence of such guidance to crewmembers in the cockpit of flight 1141 were: (1) the captain and second officer not knowing each other's responsibility with respect to verifying the flap indicator; and (2) the second officer's not announcing that the API system had not armed because he believed it was not required, yet the captain and first officer expected that he would call it out. Subsequent to the accident, when Safety Board investigators asked Delta pilots, instructors, and management personnel "who would be responsible for verifying the flap position?", a variety of answers were given. With this ambiguity among management and training instructors, it is understandable that the flightcrew did not know each other's responsibility with respect to flap position verification. Consequently, the Safety Board believes that Delta did not provide its flightcrews sufficient guidance regarding its operating procedures.

The Safety Board noted also that Delta had been criticized by FAA inspectors in 1985 and 1987 for providing "excessive training" to its crewmembers in lieu of noting performance deficiencies during proficiency

checks. In fact, the 1987 special inspection team report noted that "team members observed numerous occasions on which check airman conducted excessive training during check rides...." As a result, the FAA team admonished Delta for documented cases of proficiency check airman failing to record unsatisfactory performances by Delta pilots. The report stated, "In the opinion of General Counsel this practice constitutes a lack of compliance with FAR 121.401(c)...." The team recommended that Delta management and each check airmen should be informed of the General Counsel's opinion and that all unsatisfactory performance should be recorded.

Additionally, the 1987 special inspection team report noted that Delta s check airmen were not upholding a high level of standards on proficiency checks. The final report stated that "the team observed that orals are in general very brief, questions shallow, and the standard of knowledge low." The inspection team recommended that "Delta's management needs to give serious consideration to the implications of tolerating minimum standards in training and on proficiency checks."

Concern over the continuing breakdown in cockpit discipline at Delta Air Lines as exhibited by the crewmembers of flight 1141 caused the FAA to follow up on its 1987 special investigation. A national inspection team headed by the team leader of the 1987 inspection surveyed the airline in October 1988. The stated purpose of the survey was "...to re-examine Delta's operations in those areas defined in the 1987 audit, determine the corrective actions taken by Delta with regard to the findings and recommendations contained in the Safety Audit Report, define any issues which have yet to be resolved, and to estimate the future effectiveness of Delta's actions."

The inspection team in its November 10, 1988, report found that, while deficiencies identified in the previous audit were observed, Delta Air Lines management had instituted programs to improve both line operations and the training program. Also, organizational changes were made which created a Flight Standards Department, centralized the management of the Line Check Airman Program and realigned responsibility for the development of operational procedures and manuals.

The Safety Board notes that in February 1989, Delta Air Lines received FAA approval for its revised operating and training procedures. Included in these procedures are revised checklists which incorporate "critical" items requiring status verification of systems critical to flight by all crewmembers. The Safety Board acknowledges these improvements, including the establishment of a Cockpit Resource Management (CRM) training program.

The lack of CRM training and Line Oriented Flight Training (LOFT) was evident in the circumstances surrounding this accident. It was obvious that these crewmembers did not exercise the management, communications, and interactive skills necessary for effective cockpit management. These attributes are of increasing importance in the present day cockpit environment with its sophisticated and often complex electronic flight management systems. It has been shown that CRM training, combined with realistic LOFT scenarios can be effective in alleviating the human

performance problems that have continued to dominate the causal elements of a majority of past accidents.

The Safety Board since 1968 has made numerous safety recommendations aimed at improving the manner in which pilots are trained. These recommendations were directed towards maximizing the utilization of resources available to the pilots and the effective coordination of these resources involving the entire cockpit crew. Thus, the Safety Board in these recommendations focused on skills in communications, interpersonal relations, and information processing as elements of CRM training. Delta at the time of this accident was in the process of implementing a CRM training program; the Safety Board is aware that this training program presently is a functional entity within Delta's training department. However, the Safety Board is disappointed that the FAA has not seen fit to mandate such training for the entire air carrier industry, despite its demonstrated safety value.

As a result of the Safety Board's Safety Recommendation A-88-69, regarding the need for CRM training, the FAA on February 22, 1989, published Notice of Proposed Rulemaking (NPRM) 89-4.[5] This NPRM proposes to "establish a voluntary alternative method for meeting the training, evaluation, certification and qualification requirements for flight crewmembers, flight attendants, aircraft dispatchers, instructors, evaluators and other operations personnel subject to the training requirements of 14 CFR 121 and 135". The Notice was published to coincide with a draft Advisory Circular (AC-120-xx), which provides a means acceptable to the Administrator for approval of an Advanced Qualification program (AQP), based on the above mentioned NPRM. The AC proposes guidelines for operators who have advanced flight simulators on how to set up a CRM program for its crewmembers.

In response to FAA's request for comments on this NPRM, the Safety Board, in a letter dated June 27, 1989, expressed cautious optimism about the apparent progress being made by the FAA towards the fulfillment of several long-standing safety recommendations. However, it also believes that the voluntary progress of air carrier operators towards CRM must be buttressed by a standardized regulatory program. The Safety Board believes that various aspects of the proposed AQP will require close attention by the FAA. One of these is the need for a means to assure standard implementation of the AQP. Also, the FAA must establish rigid criteria for approving extensions of the time periods during which recurring training sessions must be held under the AQP because the frequency of proficiency evaluations for flight crewmembers is a direct function of the frequency of the recurring training sessions. Since the proposed Special Federal Aviation Regulations (SFAR) contains no guidelines or other criteria on which to base the granting of extensions, the Safety Board believes that the FAA should eliminate the extension provisions from the SFAR, pending the establishment of such guidelines and criteria.

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[5]Federal Register 54FR7670, February 22, 1989; 'Federal Aviation Administration; Docket No. 25804, Notice No. 89-4; 14 CFR 61, 63, 65, 121, 135; Special Aviation Regulation No. XX; Advance Qualification Program.

2.9 FAA Surveillance

The investigation of this accident found that the FAA had conducted four inspections of Delta since 1985. With the exception of the 1986 NASIP inspection, there were consistent observations of deficiencies in Delta's training, checking, and line operations that were evident from 1985 to as recently as October 1988. These deficiencies included poor flightcrew discipline and coordination, including improper use of checklists, and abuses in Delta's training and checking programs.

The Safety Board gathered considerable testimony at the public hearing concerning the oversight of Delta by the FAA. The relationship between an air carrier and the FAA is unique and complex. Deregulation of the industry in 1978, combined with the growth in air travel, has made the FAA's job of overseeing the airlines more difficult than it use to be. Nevertheless, the FAA was aware of certain deficiencies in Delta's check airman program as far back as 1985. Additionally, in 1987, the incidents involving Delta flightcrews and the findings of the 1987 inspection team should have indicated to Delta and the FAA that immediate corrective action was necessary.

The results of the 1987 and 1988 special inspections of Delta indicated that a potential for a mishap existed if remedial action was not taken. Many of the observations made by the inspection teams were evident in the cockpit of flight 1141--that is, poor discipline, poor crew coordination, and a lack of knowledge concerning individual responsibility. While the air carrier has the primary responsibility to operate in a safe manner, the deficiencies noted by the FAA special inspection teams warranted corrective action by Delta and agressive followup by the FAA. The FAA personnel questioned on this point at the public hearing responded by stating that the deficiencies noted by the special inspection teams at Delta were "nonregulatory" in nature, and therefore beyond the principal inspector's direct control. While this may be true from a technical viewpoint, the purpose of the special inspection teams sent to Delta was to look beyond minimum compliance and to identify operational areas that needed improvement.

The Safety Board recognizes the difficulty that occurs when the FAA is faced with a nonregulatory, or "gray area," such as the quality of crew coordination and discipline, unless such behavior is observed to be unsafe. In such a case, the air carrier must assume the responsibility for changing its corporate philosophy if that philosophy is found to be counter-productive to sound flightcrew behavior. However, it should be expected that the FAA would have applied more leverage in implementing changes concerning procedures or checklist usage. It is in this area that the Safety Board believes that the FAA should have taken more agressive action. For instance, the 1987 special inspection team recommended that "Delta Air Lines ... publish specific crew duties for each crewmember." At the public hearing, the POI testified that implementing this type of nonregulatory procedural change often depends on his "salesmanship" ability. However, the Safety Board notes that the rationale for conducting the 1987 inspection was to establish if the incidents that occurred in 1987 due to pilot performance

were related to Delta's operational procedures. The results of the FAA inspection did, in fact, establish that such a relationship existed. However, neither the FAA nor Delta instituted the changes recommended by the team prior to the accident involving flight 1141 or prior to the 1988 special inspection. Therefore, the Safety Board concludes that the lack of sufficiently aggressive action by the FAA to correct the known deficiencies at Delta Air Lines is a contributory factor in the cause of this accident.

It is evident that the POI may not be the best individual to ensure that recommendations are carried out after an inspection of an air carrier that he is responsible for overseeing. In that regard, an inspection of an air carrier is, in fact, an inspection of the ability of the POI to accomplish his duties. Therefore, a "quality assurance" program must be exercised by FAA headquarters to ensure that recommendations from inspection teams are expeditiously carried out. The Safety Board believes that the FAA should develop a formalized plan to address and rectify deficiencies in the implementation of corrective action recommended by inspection teams.

The investigation sought to identify existing boundaries of responsibility of the POI regarding the level of regulatory compliance and the quality of operations demonstrated by the assigned air carrier. During this investigation, evidence of accountability of the POI and the district office for the performance of the assigned carrier(s) was not apparent. Evidence suggests that FAA surveillance and inspection programs and the in-house evaluation of POI performance have no relationship to each other. The POI's performance seems to be related only to the quantity of work and the ability to handle approvals smoothly and directly. The Safety Board is concerned that the POI has the authority to approve critical areas of air carrier operational programs without being held responsible for those approvals. There does not appear to be a recurring qualitative assessment of POI approvals by FAA management.

The FAA's followup of the 1986 NASIP inspection is also indicative of a lack of POI accountability. The negative findings of an airline operational inspection become the responsibility of the POI to promote and monitor corrective action. Thus, the POI, in effect becomes the arbiter of his own shortcomings, with no assessment being made by outside interests of the quality of the corrective action. Therefore, the accountability for the on-going quality of the POI's work performance does not appear to exist.

It appears that the current surveillance system can lead to rubber stamp approvals of an air carrier's operations and maintenance programs. Improvements are needed to encourage and support the POI's efforts to secure compliance and to promote upgraded levels of performance by the assigned air carrier in both pilot training and crew coordination areas. Without such improvements, the system of program approval can be driven by the momentum and interests of the air carrier. It appears the present system is sustained by the personal motivation and dedication of the concerned FAA inspector personnel rather than by an FAA system that includes internal oversight of itself and its inspection workforce. It is apparent that the need exists for a program of FAA management emphasis on the accountability of its POIs. In addition, there is a need for a program which standardizes the approvals of

air carrier operations programs in order to promote a uniform and acceptable level of safety performance in the current competitive air carrier industry. Therefore, the Safety Board concludes that the absence of effective FAA management control of its inspector workforce, the lack of accountability of principal inspections, and the shortcomings in the NASIP program are contributory factors in the cause of this accident.

2.10 Survival Factors

2.10.1 Aircraft Rescue and Fire Fighting

Notification/Communications.--The initial notification of the DFW emergency units was timely and efficient. It took DPS communications personnel 21 minutes to complete notifications. This was a considerable improvement over the 45 minutes it took to complete the majority of notifications during the response to the Delta flight 191 accident at DFW in 1985.[6] This significant reduction in notification time is attributable, at least in part, to improvements in distributing the communications workload between the DPS communications center and the emergency operations center (EOC). In addition, the installation and operational use of the Automated Voice Notification System in the EOC significantly reduced the notification times. These changes were instituted following the Delta flight 191 accident in response to Safety Recommendation A-86-87.

Other communications improvements were most notable in the area of field communications and coordination with area hospitals. The use of cellular telephones in ambulances, in supervisory vehicles and in the new command post vehicles, afforded significant benefits to DFW DPS supervisors and hospitals in coordinating patient tracking and disposition.

The Safety Board believes that because of its benefits, operators of other large airports should evaluate the potential benefits of using Automated Voice Notification Systems for emergency/mutual aid notifications.

Medical Response.--Forty-seven injured persons received triage at the primary and secondary areas. The medical stabilization techniques used on these persons by DFW and mutual-aid paramedics enabled ambulances to deliver all surviving persons to area hospitals in stable condition less than one hour after the accident. The experience and training of the responding emergency medical services (EMS) personnel was of significant importance in the success of the on-site triage and transportation of the injured.

Police Response.--Due to the cross-training of DFW DPS personnel, police actions per se cannot be readily separated from fire and medical actions since all DFW DPS personnel also participated in firefighting and EMS roles, as required, throughout the rescue effort. Once established, security and traffic control were excellent, although this was facilitated somewhat by the fact that the aircraft came to rest just within the airport operations area fenceline.

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[6] NTSB/AAR-86/05, op.cit.

One difficulty arose when some mutual aid personnel attempted to gain entry through a nearby gate and found that it had been chained and locked with a lock to which the DPS did not have a key. It was later determined that the lock had been placed on the gate by someone other than airport personnel. Some delay was experienced by mutual aid units while they obtained a cutting tool in an attempt to gain access through this gate. This delay had no negative effect on the success of the rescue activities, since the majority of emergency vehicles and personnel were already in place on the aircraft side of the fence. It should be noted, however, that under different circumstances, such delays could have an adverse impact on rescue efforts. DFW DPS has since provided bolt cutters for all emergency vehicles in order to preclude any such recurrence. The Safety Board believes that bolt cutters should be part of the standard equipment list for emergency vehicles. Overall, the performance of the ARFF Teams indicated a well trained and coordinated approach that enhanced significantly the potential for saving lives.

2.10.2 Left Aft Galley Door

The left aft galley door was not opened during the emergency evacuation of the airplane and 10 bodies were found in the area of that galley. The physical evidence and passenger testimony during the Safety Board's public hearing showed that attempts were made to open the door, but none were successful. Several possibilities were examined to explain why it would not open.

During the investigation, when the first attempt to open the door was made, soft drink cans from the left aft galley were found at the bottom of the door. It was considered that the cans might have been dislodged during impact, but before the airplane came to rest, they rolled down the now inclined galley floor, and lodged against and jammed the bottom of the door.

However, there is some question as to whether the cans were on the floor prior to the airplane coming to rest, or were knocked out of the rack during firefighting operations. Considering the extent of the burn injuries sustained by the fatalities, it is reasonable to suspect that at least some of the cans would have bulged or burst since they were in the same area--however, none were so effected. Most notable, the aluminum drawer in which the cans were stowed was found intact in the area of the airplane which had sustained the most severe fire damage, but the drawer had sustained no thermal damage. Therefore, it must have been deposited there after the fire had been extinguished.

Also, since the girt bar was found in the stowed position, it is believed that upon discovering that the door would not open, the flight attendant who attempted to open the door was the one who stowed the girt bar. (It is assumed that at least the initial attempt to open the door was made by a flight attendant, however, the bodies of the flight attendants were not found nearest the door.) This would be in accordance with Delta's flight attendant training procedures which address difficulty opening a door following a gear-up (belly) landing. Stowing of the girt bar would not have

been possible if the soft drink cans had been laying on the girt. It is concluded therefore, that the soft drink cans were properly stowed at the time of impact and did not prevent the door from opening.

During the examination of the wreckage, it was most difficult for two male investigators outside the airplane to move the mass of the door simultaneously inward, and upward, due to the 30° left roll attitude of the fuselage. With the assistance of an additional male investigator on the inside, several more attempts were made to open the door. Not until the fourth or fifth attempt did they finally succeed in opening the door. Even then, the door could not be opened until the investigator inside the airplane was able to lift the 200-pound door assembly (160 pound door plus 40 pound slide) and move it over a restriction. These attempts spanned a time of between 5 and 10 minutes of intermittent effort with discussions of the problem taking place between attempts. It should be noted that these attempts were being made under nonstress conditions and by investigators familiar with the operation of the door.

When the door was opened, shiny, therefore fresh, burrs were seen on the door's lower aft stop fitting. This burring would not occur if the door were properly aligned in its frame. It was also noted that the door fitting had rubbed the stop fitting at the point of the burr when the door was opened and closed. Also, the door's upper hinge was sprung and the sheet metal just under the hinge was torn to just forward of the hinge. According to the record of the layover check performed on August 30, 1988, the day before the accident, no difficulties were noted with the operation of the door.

When the airplane slid along the ground during the accident sequence, it did not experience very high G loading, except for localized loading. This is borne out by the FDR information, passenger interviews, and a general, but not complete, lack of injuries indicative of high G forces. The airplane did, however, sustain impact damage as it slid along the hard uneven ground. While sliding, the underside of the airplane deformed as a result of repeated impacts. While there was no single significant G spike, the repeated impacts compounded the damage, increasing the deformation as the airplane slid. This deformation absorbed energy and would account, to some degree, for the general lack of vertical G forces felt in the cabin. The deformation in the area of the left aft galley door finally progressed to the point that the frame distorted, to an unknown degree, and caused the misalignment between the door and its frame.

After the door was opened, an attempt was made to close it. The operating hardware of both the door and frame was cleaned for the attempt. It could be closed but would not lock; the operating handle would only come to within about 15° of the fully locked position, and the door remained slightly ajar. One person, with maximum effort, was then able to open the door from inside the airplane.

In view of the aforementioned tests and examinations, it is therefore concluded that the left aft service door could not be opened due to deformation of the door frame which resulted from the airplane's repeated impacts with the ground.

The position of the bodies in the rear cabin and in the galley area indicated that there was a queue of persons waiting to use the exit, and more likely they also crowded at the exit. During this time smoke was entering the galley. This, of course, reduced visibility and induced respiratory distress, and when combined with the steep angle of the floor, probably caused those persons at the galley to fall against the door. Given the sense of urgency, if not outright panic, which surely existed as conditions worsened, combined with the angle of the floor and the worsening smoke and toxic fumes, it is likely that passengers were pushing against the flight attendant who would have been trying to open the door, totally negating attempts to open the already jammed door.

2.10.3 Aft Airstair Exit

Although the flight attendants were trained to use the aft airstair as a secondary emergency exit if the normal exits were unusable, they were also trained that the airstairs may not be usable following a gear-up landing.

In this accident, the aft airstair exit was not usable because the airplane was resting on its fuselage and the airstairs could not be lowered. Also, the pressure bulkhead door to the tailcone was jammed closed due to impact damage (for the same reasons as stated for the left aft galley door). When Delta personnel attempted to recover the FDR and CVR from the tail section of the airplane, the operating handle of the bulkhead door would not move, consequently the door would not move. They requested assistance from DPS personnel who ultimately had to use pry bars to open the door.

Since any attempt to open the solidly jammed door would have left no evidence, it could not be determined if an attempt was made to use the aft airstair exit.

2.11 Fire Propagation

Examination of the physical evidence indicated that the external fire was initiated when the right wing and tail struck the localizer antenna array. The fire intensified when the airplane struck the lip of the depression in the terrain. The right wing was destroyed and the fuel tanks lost all structural integrity. Flames not only impinged on the right side of the fuselage, but extended around the fuselage, heating the inboard wing area on the left side. As the fuselage slid, the aft cargo door opened and was pushed in. The forward door of the aft cargo compartment opened outward, and was torn off at its hinges. The hinges ripped the fuselage open causing a large opening in that area.

Evidence showed that the fire entered the aft cargo compartment before the airplane came to rest. After the airplane stopped, the fire burned through the cargo compartment liners and cabin floor. The fire also entered the cabin through the aft break in the fuselage, the opened right-hand overwing exit, and later through a burn through in the center wing box area. The fire entering the fuselage through the aft break trapped passengers in the aft end of the cabin. The fire burning through the floor probably caused the fatalities in that area. The autopsy reports showed the cause of death to all fatalities as smoke inhalation.

The forward cabin remained survivable for about 4 minutes and 20 seconds, despite the large fuel fire at the ruptured area. Some of this survival time can be attributed to the use of fire blocking materials on the seat cushions. There was evidence of the fire blocking slowing the spread of fire into the cabin. Many seat cushions remained intact or showed signs that the blocker inhibited burning. With a large fuel fire entering the cabin, fire blocking will not stop the spread of fire, but will slow it down giving added time for escape. The Safety Board's investigation found that the airport's aircraft rescue and fire fighting equipment was in place and applying extinguishing agents to the airplane about 4 minutes and 20 seconds after the accident and the last passengers to leave the airplane reported being hit by foam as they exited. The predicted survival time, based upon FAA tests without the fire blocking layers in place, would have been about 2 minutes and 50 seconds. While there is some margin for error in both times, it should be noted that the divergence of the graphs representing fire test points, hence the benefit in survival time, is greater with the passage of time.[7] (See figure 14.) It is therefore concluded that a number of lives were saved because the seat cushions were covered with fire blocking material.

Due to a number of variables such as size of the openings in the fuselage, wind, and intensity of the fire, an exact number of persons who were saved because of the fire blocking material cannot be determined. Any attempt to determine an exact number is very sensitive to assumptions. Of primary importance is an assumption of a linear evacuation rate. In this case, the evacuation rate varied greatly. At the aft break in the fuselage, nearest the fire, the evacuation progressed rapidly and it was not used by a large number of persons (three persons through the side of the break, eight through the overhead section of the break). Therefore, the evacuation there was completed while it was still in progress at the other exits. The last exit that was used during the evacuation was the forward break in the fuselage. This exit was furthest from the fire, was used by the largest number of persons, and, due to obstructions, had the slowest evacuation rate.

Another assumption which must be made in order to calculate a number of additional survivors, using available test data, is that the fuselage maintained its integrity, trapping smoke and superheated gases. In this accident, both ends of the fuselage were open at the top and around most

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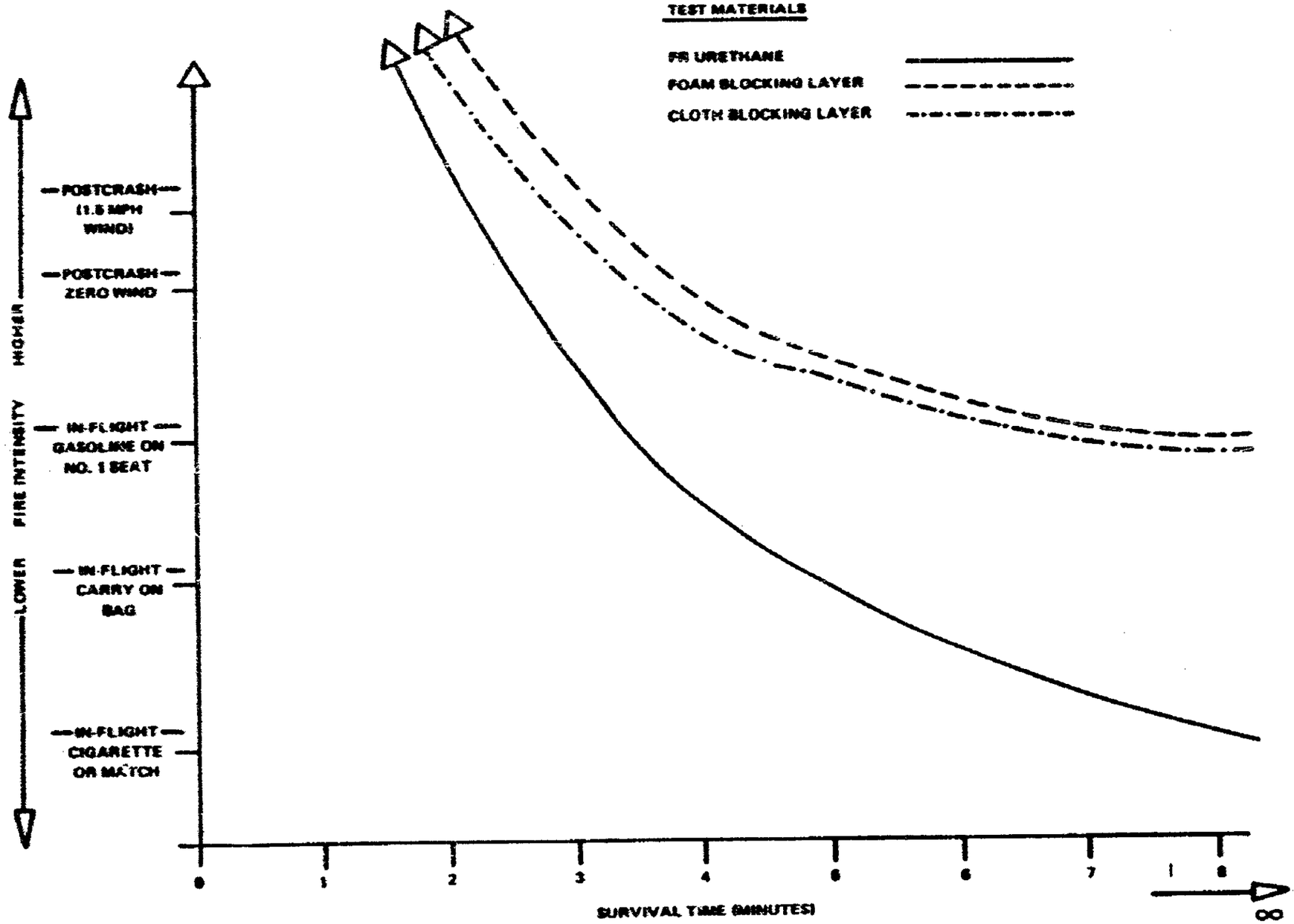
[7] DOT/FAA/CT-83/43, Aircraft Seat Fire Blocking Layers: Effectiveness and Benefits Under Various Scenarios.


TEST MATERIALS
FR URETHANE
FOAM BLOCKING LAYER
CLOTH BLOCKING LAYER
HIGHER
FIRE INTENSITY
LOWER
POSTCRASH (1.5 MPH WIND)
POSTCRASH ZERO WIND
IN-FLIGHT GASOLINE ON NO. 1 SEAT
IN-FLIGHT CARRY ON BAG
IN-FLIGHT CIGARETTE OR MATCH
0
1
2
3
4
5
6
7
8
∞
SURVIVAL TIME (MINUTES)

of the circumference, allowing smoke and gases to vent. The opened fuselage may have acted as a chimney, drawing cool clean air into the cabin, to some degree, replacing the venting air. Therefore, a determination of how many lives were saved by the fire blocking layer was not attempted.

2.12 Refueling Procedures

Though not causal to the accident, the Safety Board is concerned about the procedures used in refueling flight 1141. The investigation found that the No. 1 main fuel tank quantity indicator was inoperative and that the airplane was dripsticked and level checked in order to determine the amount of fuel to add to each tank. The airplane was not dripsticked after refueling. After the airplane was fueled, it would have been prudent to have had the fuel tanks dripsticked once again and the level of the airplane verified. The Safety Board is concerned that with an inoperative fuel gauge it is possible that the airplane could have been incorrectly fueled, i.e., too much or too little fuel in the No. 1 fuel tank. Such a situation could cause the airplane to be laterally unbalanced or not have sufficient fuel for the flight. Therefore, it is recommended that the FAA require that whenever an airplane operating under 14 CFR Parts 121 or scheduled 135 is allowed to fly with an inoperative fuel quantity gauge, that dipstick, dripstick, or other appropriate measurements of fuel quantity are taken, and that the level of the airplane is taken into consideration.

2.13 Airline Safety Programs

As part of the Safety Board's investigation of this accident, it examined the issue of airline flight safety programs. This issue was explored primarily during testimony at the Safety Board's public hearing. The purpose of this effort was to elicit industry views about the purpose of, the need for, and the conceptual framework for an airline flight safety program. No attempt was made to compare Delta Airlines' program with other airlines or with any other standard. Further, no correlation was drawn between the events that led up to the accident involving flight 1141 and the viability of Delta's safety program. In general, the Safety Board's objective was to raise an awareness about the issue of airline flight safety program as a starting point for possible improvements in the future.

In general, airline safety programs are broken down into three distinct areas: flight safety, ground (industrial) safety, and maintenance quality assurance. Ground safety essentially is governed by Occupational Safety and Health Administration (OSHA) regulations. There are no Federal Aviation Regulations (FAR) governing ground safety. Similarly, there are no FAR's governing airline flight safety programs. However, there are specific regulations that deal with airplane maintenance programs, specifically the inspection and quality assurance function of maintenance.

Part 121 of the Federal Aviation Regulations (FAR) contain requirements for airline management personnel. Included in the required management personnel is a qualified Chief Inspector. The FAR's also specify the basic qualifications of the required management personnel, including the Chief Inspector. Part 121 of the FAR's also contain requirements related to

the inspection and quality assurance functions as compared to the maintenance functions at an airplane. Specifically, airlines must establish that the person(s) performing maintenance are not the same person(s) performing inspection of completed work, and these persons cannot be reporting to the same supervisor. In fact, the regulations require that each airline establish a continuing analysis and surveillance system to evaluate the performance of its inspection and maintenance programs. These regulatory requirements provide a redundancy or "second set of eyes" within the airline maintenance departments. Further, these requirements establish specific criteria against which the FAA can assess the quality of an airline's maintenance department.

The Safety Board believes that a similar redundancy should be required for airline flight operations departments by means of an independent flight safety department. Of course, the flight operations personnel are charged with the safety of flight operations by meeting the regulations and establishing a training, checking, and operations program. However, without an independent flight safety department the redundancy is not provided.

At the Safety Board's public hearing, testimony on the subject of airline flight safety departments was obtained from the Director of Flight Safety for United Airlines, the Director of Operational Safety for Canadian Airlines International, and the Director of Aviation Safety Programs for Transport Canada within the Ministry of Transport of Canada. All three individuals emphasized the need for an independent flight safety department. The term "safety net" was used to stress the need for redundancy in preventing flightcrew errors that lead to accidents. They also emphasized the need for the flight safety officer to report directly to the Chief Operating Officer, or equivalent level, to provide the audit for oversight functions.

The testimony revealed that the Safety Advisory Committee (SAFAC) of the International Air Transport Association (IATA) had recommended to the Technical Committee of IATA that it adopt a resolution regarding airline flight safety departments. The SAFAC Committee is made up of professional safety officers of the world's airlines. The Technical Committee is made of Senior Vice President of Operations personnel from the world's airlines. The IATA Technical Committee is the senior body in IATA that addresses operational safety concerns on behalf of the membership of over 160 airlines. In 1988, the Technical Committee adopted a resolution recommending that all member airlines should establish a safety department managed by a professional safety manager. The resolution also recommended that the safety department should accomplish certain key flight safety functions.

The 21 key flight safety functions recommended by the IATA resolutions are grouped into four major categories. They are: accident prevention programs; collection, analysis, and dissemination of safety information; technical (maintenance) and training department liaison; and emergency response procedures. It is important to note that three of the major categories, which account for 17 of the 21 key functions are "proactive" accident prevention functions, as compared to the "reactive" accident and incident investigation emergency response functions. All three

of the aviation flight safety professionals who testified at the Safety Board's public hearing emphasized the need for an independent proactive flight safety program at airlines.

The Director of Aviation Safety Programs for Transport Canada testified that his agency strongly urges airlines in Canada to adopt the independent safety officer program. In fact, Transport Canada sponsors a program which includes training for airline CEO's to demonstrate to them the need and cost benefit for such programs. Further, Transport Canada provides training seminars for airline safety officers. No such programs exist within the FAA.

An accident or other unsafe incident is really a symptom of a failure somewhere in the system. It is traditionally reported from airline accident statistics that about 80% of airline accidents result from flightcrew errors. For this season alone, it seems appropriate that the flight operations department needs an audit of redundant organizational function responsible for flight safety. It is easily recognized that the person(s) responsible for flight safety within the flight operations department, such as the Chief, Pilot, the Director of Training, and the Director of Flight Operations, may not be able to recognize or admit personal or organizational shortcomings for his/her own programs. There is a real possibility that objectivity may suffer. However, an independent safety officer, who reports to the top manager of the airline would be in an excellent position to provide objective views of possible safety problems within the flight operation departments.

The Safety Board believes that the FAA should initiate a joint airline industry program to develop guidelines and regulatory provisions for airline flight safety programs. It seems logical that the same rationale that requires the separation of maintenance and inspection departments, and the quality assurance ("second set of eyes") function in airline maintenance should be applied to flight operations. Similarly, the provisions for specific management positions and qualifications of those managers contained in the extant regulations should be developed for flight safety. That is, the regulations should specify the need for a qualified safety officer and flight safety program at airlines, and separation of management oversight of these two important functions. Further guidance by means of an FAA advisory Circular, which outlines the structure, functions, and responsibilities of such a program should be developed. The guidance and regulatory provisions would then provide a means by which the FAA could evaluate an airline's safety performance other than by accidents and incidents.

2.14 Previous Safety Board Recommendations

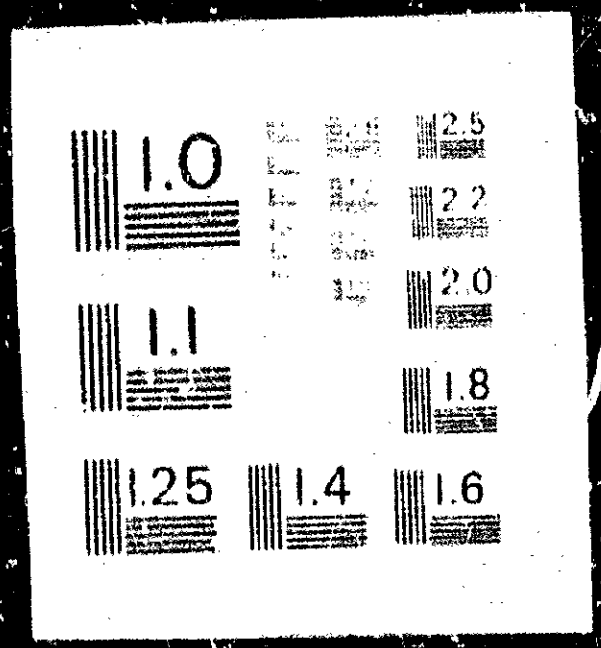
As a result of the Safety Board's investigation of an accident involving Aloha Air Lines flight 243 near Maui, Hawaii on April 28, 1988, the following safety recommendations were issued to the FAA on July 21, 1989:

> Evaluate the quality of FAA surveillance provided by the Principal Inspectors as part of the National Aviation Safety Inspection Program (NASIP).(A-89-64)

2 OF 2

PB89

910406



> Integrate the National Aviation Safety Program (NASIP) team leader in the closeout of the team findings. (A-89-65)

The Safety Board is awaiting a reply from the FAA regarding these recommendations.

As a result of the Safety Board's investigation of the Northwest Airlines, Inc., flight 255 which crashed shortly after takeoff from Detroit Metropolitan Wayne County Airport on August 6, 1987, the Safety Board sent the following recommendations to the FAA:

> Require that all 121 and 135 operators and principal operations inspectors emphasize the importance of disciplined application of standard operating procedures and, in particular, emphasize rigorous adherence to prescribed checklist procedures. (A-88-67)
>
> Convene a human performance research group of personnel from the National Aeronautics and Space Administration, industry, and pilot groups to determine if there is any type of method of presenting a checklist which produces better performance on part of user personnel. (A-88-68)
>
> Expedite the issuance of guidance material for use by Part 121 and 135 operators in the implementation of team-oriented flightcrew training techniques, such as cockpit resources management, line oriented flight training, or other techniques which emphasize crew coordination and management principles. (A-88-69)

The FAA stated in its letter of September 22, 1988, that it was planning to take positive action regarding these recommendations. The Safety Board found the actions proposed by the FAA to be responsive to the intent of the recommendations, and, therefore, classified these three recommendations as "Open Acceptable Action" pending review of the final action taken by the FAA.

Additionally, as a result of the Northwest flight 255 accident, the Safety Board sent the following recommendation to all Part 121 air carriers:

> Review initial and recurrent flightcrew training programs to ensure that they include simulator or aircraft training exercises which involve cockpit resource management and active coordination of all crewmember trainees and which will permit evaluation of crew performance and adherence to those crew coordination procedures. (A-88-71)

The Safety Board has received responses from a majority of Part 121 air carriers. These responses have indicated that most air carriers either currently have, or are developing, cockpit resource management programs. Delta provided the Safety Board with a copy of its crew resource management program. This program complied with the intent of the recommendation.

Therefore, the recommendation, in terms of Delta, was classified as "Closed--Acceptable Action."

During the investigation of the Delta flight 191 accident at DFW airport on August 2, 1985, the Safety Board noted problems in communications and coordination with off-airport medical units during the implementation of the Dallas/Fort Worth Airport emergency plan. The Safety Board issued the following recommendations to the DFW Airport Board:

> Revise its disaster response notification procedures to provide for timely and effective notification of mutual-aid agencies whose assistance is needed. (A-86-87)
>
> Revise its procedures for coordinating with area hospitals during mass casualty disasters to provide the hospitals with timely information regarding estimated numbers of victims, injury categories, destinations, and arrival times. (A-86-88)
>
> Conduct full-scale demonstrations of the Dallas/Fort Worth Airport Emergency Plan and Procedures every 2 years. (A-86-89)

In reply to Safety Recommendations A-86-87 and -88, the DFW Airport Board informed the Safety Board that a Watson Automated Voice notification system was installed at the airport and that cellular telephones have been installed in ambulances and the command post vehicles. Safety Recommendations A-86-87 and -88 have been classified as "Closed--Acceptable Action."

DFW Airport was in the process of planning a disaster drill when the accident involving flight 1141 occurred. The Safety Board has classified recommendation A-86-89 as "Closed--Acceptable Alternate Action."

As a result of the Safety Board's 1984 special study of airport certification and operations, the following recommendation was issued to the Federal Aviation Administration:

> Amend CFR 139.55 to require a full-scale demonstration of certificated airport emergency plans and procedures at least once every 2 years, and to require annual validation of notification arrangements and coordination agreements with participating parties. (A-84-34)

On January 1, 1988, 14 CFR 139, as revised, became effective and 139.325(g) (5) requires that the certificate holder: "Hold a full-scale airport emergency plan exercise at least once every 3 years." The Safety Board finds that this modification to CFR 139 complies with the intent of the recommendation. Therefore, Safety Recommendation A-84-34 is now classified as "Closed--Acceptable Action."

As a result of the Safety Board's investigation of an accident involving Pan American flight 759 at Kenner, Louisiana, on July 9, 1982, the following safety recommendation was issued to the FAA on July 13, 1982:

At an early date and pending the effective date of the recommended amendment of 14 CFR 121.343 to require installation of Digital Flight Data Recorder systems capable of recording more extensive parameters, require that operators of all aircraft equipped with foil flight data recorders be required to replace the foil recorder with a compatible digital recorder. (A-82-65)

As of April 1989, the FAA has required that all Part 121 aircraft be equipped with Digital Flight Data Recorders. This recommendation has been classified as "Closed--Acceptable Action."

3. CONCLUSIONS

3.1 Findings

1. The flightcrew was properly certificated and qualified for the flight.

2. The airplane was certificated, equipped, and maintained in accordance with Federal regulations and approved procedures.

3. The flightcrew deviated from Delta's policies and procedures with respect to checklist execution, cockpit discipline, and required callouts.

4. Extensive non-duty related conversations and the lengthy presence of the flight attendant in the cockpit reduced the flightcrew's vigilance in ensuring that the aircraft was properly prepared for flight

5. Weather was not a factor in the accident.

6. Wake vortices from the previously departing Boeing /2/ were not causal to the accident.

7. There was no preimpact failure of any engine; the compressor surges encountered after the onset of stickshaker did not substantially reduce the amount of available thrust.

8. The flightcrew did not extend the airplane's flaps or slats for takeoff.

9. The takeoff warning system had an intermittent failure problem which was not corrected during the last maintenance activity and which manifested itself during the takeoff of flight 1141.

10. Failure of the takeoff warning system to activate was most likely due to contamination or misalignment of the takeoff warning system throttle switch.

11. Failure of the auto pack trip light to illuminate as the throttles were advanced should have been reported as a malfunction to the captain by the second officer.

12. The captain's action of continuing to increase AOA after the onset of stickshaker and his failure to apply maximum power in accordance with Delta's procedures reduced the climb and acceleration performance of the airplane.

13. Delta Air Lines' corporate philosophy of permitting maximum captain discretion contributed to the poor discipline and performance of flight 1141's flightcrew.

14. The FAA was aware of the flightcrew performance deficiencies in Delta's operations, as well as irregularities in Delta's training and checking programs.

15. Neither Delta nor the FAA took sufficient corrective actions to eliminate known flightcrew performance deficiencies.

16. The initial notification of the Dallas-Fort Worth International Airport (DFW) emergency units was timely and efficient. The response by Department of Public Safety (DPS) aircraft rescue and fire fighting personal was well coordinated and enhanced significantly the potential for saving lives.

17. The left aft service door could not be opened due to deformation of the door frame which resulted from the airplane's repeated impacts with the ground.

18. A flight attendant, while attempting to open the left aft service door, stowed the girt bar on the door as per Delta's flight attendant training procedures which address the difficulty in opening a door following a gear-up landing.

19. It would have been unlikely for any one person of average strength to open the left aft service door under the circumstances existing at the time of the attempted evacuation.

20. A number of lives were saved by the use of the fire blocking layer on the passenger seats. An exact number of additional survivors could not be determined.

21. The corrective actions taken by the Dallas-Fort Worth Airport Board in response to Safety Recommendations A-86-87 and -88 following the Delta flight 191 accident in 1985 greatly improved the communications and coordination of the aircraft rescue and fire fighting personnel and medical teams in this accident.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident to be (1) the Captain and First Officer's inadequate cockpit discipline which resulted in the flightcrew's attempt to takeoff without the wing flaps and slats properly configured; and (2) the failure of the takeoff configuration warning system to alert the crew that the airplane was not properly configured for the takeoff.

Contributing to the accident was Delta's slow implementation of necessary modifications to its operating procedures, manuals, checklists, training, and crew checking programs which were necessitated by significant changes in the airline following rapid growth and merger.

Also contributing to the accident was the lack of sufficiently aggressive action by the FAA to have known deficiencies corrected by Delta and the lack of sufficient accountability within the FAA's air carrier inspection process.

4. RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board made the following safety recommendations:

--to the Federal Aviation Administration:

Require that principal operations inspectors review the operations manuals of their assigned carriers and ensure that the manuals clearly state the roles of each flight crewmember in visually confirming the accomplishment of all operating checklist items, especially those checklist items considered "critical" to flight. (Class II, Priority Action) (A-89-121)

Direct all principal operations inspectors to review the training and operations manuals of their assigned air carriers and ensure that the verification of flap position during stall recognition and recovery procedures is a part of those procedures. (Class II, Priority Action) (A-89-122)

Modify National Aviation Safety Inspection Program inspection procedures to ensure that following safety inspections of Part 121 air carriers, deficiencies are corrected expeditiously and that the leader of the inspection team is made part of the evaluation of the proposed actions. (Class II, Priority Action) (A-89-123)

Require 14 CFR Part 121 operators to develop and use Cockpit Resource Management programs in their training methodology by a specified date. (Class II, Priority Action) (A-89-124)

Perform a directed engineering study of the takeoff warning system(s) in the Boeing 727 model airplanes, with special emphasis on the takeoff warning system throttle switch installation. The study should evaluate the reliability, maintainability, and methods to improve the design of the system. (Class II, Priority Action) (A-89-125)

Issue an Airworthiness Directive to require modification of the takeoff warning system in the Boeing 727 model airplanes based upon the results of the directed engineering study. (Class II, Priority Action) (A-89-126)

Modify the Boeing 727 checklists to require flightcrews to check the operation of the takeoff warning system prior to each flight. (Class II, Priority Action) (A-89-127)

Modify Air Carrier Operations Bulletin (ACOB) distribution procedures to expedite the approval and transmission of ACOB's to the principal inspectors and airline officials. (Class II, Priority Action) (A-89-128)

Direct principal operations inspectors to inspect their air carriers operating under 14 CFR Parts 121 or scheduled 135 as to procedures for refueling with an inoperative fuel quantity gauge and require, as necessary, that these air carriers modify their refueling procedures to require dipsticking, dripsticking, or have other appropriate measurements of fuel quantity taken, with consideration given to the level of the airplane. (Class II, Priority Action) (A-89-129)

Initiate a joint airline industry force to develop a directed approach to the structure, functions, and responsibilities of airline flight safety programs with the view toward advisory and regulatory provisions for such programs at all Part 121 airlines. (Class II, Priority Action) (A-89-130)

--to the American Association of Airport Executives and the Airport Operations Council International:

Inform your membership of the aircraft rescue and fire fighting efforts in this accident and of the benefits of using automated voice notification systems for emergency response/mutual aid notifications. (Class II, Priority Action) (A-89-131)

Recommend that member airports equip all of their emergency vehicles with bolt cutters. (Class II, Priority Action) (A-89-132)

--to the National Fire Protection Association:

Inform the members of the Technical Committee on Aircraft Rescue and Fire Fighting (ARFF) of the ARFF efforts in this accident and of the benefits of using automated voice notification systems for emergency response/mutual aid notifications. (Class II, Priority Action) (A-89-133)

Recommend to the Technical Committee on Aircraft Rescue and Fire Fighting (ARFF) that the appropriate manual be modified to include bolt cutters as recommended equipment for ARFF vehicles. (Class II, Priority Action) (A-89-134)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ James L. Kolstad
Acting Chairman

/s/ Jim Burnett
Member

/s/ John K. Lauber
Member

/s/ Joseph T. Nall
Member

/s/ Lemoine V. Dickinson, Jr.
Member

Jim Burnett, Member, filed the following concurring/dissenting statement:

I concur with the facts and findings of this accident report; however, I dissent from the probable cause statement. I believe that the Federal Aviation Administration (FAA) and Delta Air Lines, Inc. (Delta) were direct causes of the accident.

The accident report documents factually that the FAA and Delta were aware, a year before the accident, of serious deficiencies in Delta's flight operations and training programs. Despite this knowledge, both failed to correct the deficiencies until after the accident occurred. For example, one of the report's findings, which was adopted by all five Board Members, concludes that "neither the FAA nor Delta took sufficient corrective action to eliminate known flightcrew performance deficiencies." Many of these same deficiencies were evident in the behavior and performance of the accident flightcrew. As the memorandum to the Board from the Chief of the Aviation Accident Division pointed out, "this particular crew was operating essentially in accordance with the same procedures and cockpit discipline concepts that the FAA had chastised earlier and that Delta was defending as adequate." I believe that had the FAA and Delta addressed and corrected these known deficiencies in an aggressive, effective and timely manner, the

accident would have been prevented. Their failure to do so, in my view, links them directly to the probable cause of the accident.

Following an unprecedented number of flightcrew-related operational incidents during June 1987, the FAA's Acting Administrator announced a national special emphasis surveillance of Delta. The Acting Administrator stated in a press release dated July 15, 1987, that "each incident apparently involved human error and this is a matter of great concern to us"...; and that the FAA will initiate immediate action to correct any deficiencies uncovered during the course of the inspection. The ten-member national inspection team assembled in Atlanta, Georgia on July 24, 1987, and spent six weeks conducting an indepth inspection of Delta's flight operations and training programs.

The report of the national inspection team dated September 4, 1987, contained over 40 findings of serious deficiencies in Delta's flight operations and training programs. In my view, several of the findings constitute noncompliance with specific Federal Aviation Regulations; however, no enforcement actions were taken as a result of the violations. The report listed some 55 recommendations for corrective actions. FAA and Delta senior management staff were briefed on the results of the inspection.

In a written response to the national inspection team's report dated November 12, 1987, Delta stated that "many of the conclusions drawn were incorrect." In many instances Delta defended the observed crew behavior as company approved procedure. On several findings that Delta agreed with, Delta's response letter did not include a description of how they intended to deal with the problem. As a result of Delta's disagreement and FAA's apparent indifference, many of the recommendations remained in abeyance and no corrective action was implemented.

A year after the national inspection was completed, Delta was involved in the fatal accident at Dallas. It was apparent that meaningful changes had not been made following the national inspection, because many of the deficiencies that had been observed a year previously were evident in the accident crew's performance. These deficiencies included a lack of cockpit discipline and flightcrew coordination, improper checklist use, and an absence of overall flightcrew professionalism. These deficiencies were causal to the accident and, as a result, the aircraft was not configured properly for takeoff.

Subsequent to the accident, FAA conducted a follow-up survey of Delta's flight operations and training programs to determine the adequacy of corrective actions taken as a result of the national inspection team's recommendations. The team's report dated November 10, 1988, stated that while many improvements had been made, numerous deficiencies identified during the national inspection a year previously had not been corrected. The survey found that "fundamental changes to checklists and procedures are still pending."

The Acting Manager of the Georgia Flight Standards District Office informed the NTSB in a memorandum dated August 8, 1988, that "a major revision of Delta Air Lines aircraft crew checklists for all Delta aircraft began after the flight 1141 accident." The FAA suggested additional changes to this revision in a memorandum to Delta dated December 13, 1988. Delta's new B-727 pilot's checklist and revised pilot's operating manual received final FAA approval and became effective on February 20, 1989. The new checklist included changes to designate critical items that require dual crewmember response, to identify items that require challenge and response, and to establish specific crewmember responsibilities for each checklist item. Flaps are required to be checked and verified twice: first, on the taxi checklist by the first officer; and second, on the before takeoff checklist by the captain and first officer. The revised pilot's operating manual contains new sections emphasizing cockpit checklist philosophy and crew duties. Many of these changes incorporate actions recommended by the national inspection team. Following introduction of these changes, every Delta crewmember received a line check to assure his familiarization with and use of the new checklists and operating procedures.

In summary, I believe that Delta senior management and FAA were causal to the accident because they failed to assure that the known serious deficiencies in Delta's flight operations and training programs were addressed and corrected in an effective and prompt manner. Both were sufficiently knowledgeable concerning the problems, had the opportunity and responsibility to correct them, but failed to do so. And yet, in hindsight after the accident occurred, comprehensive changes were made in six months. I believe that had this same level of commitment and change been made after the national inspection of Delta, the accident would have been prevented.

At the time of announcing its 1987 special emphasis surveillance of Delta, the FAA, in an apparent move to reassure the flying public, promised immediate action to correct any deficiencies uncovered. One year and one accident later is not immediate. The public deserves protection, not mere reassurance.

I support our staff's proposal to include the corporate actions and policy of Delta Air Lines as being directly causal, and join with the proposals by the Chief of Aviation Accident Division and the Chief of the Operational Factors Division to include the FAA's failure to take immediate corrective action as being directly causal. I cannot support the language in the Board-adopted probable cause which suggests that Delta, one of the major players in the airline industry and the aviation economy, was somehow victimized by the circumstances of its economic environment. I see no support in the record for such a position.

Therefore, I would favor a probable cause statement which would read as follows:

> The National Transportation Safety Board determines that the probable cause of this accident to be (1) the Captain and first officer's inadequate cockpit discipline which resulted in the flightcrew's attempt to takeoff without the wing flaps

and slats properly configured; and (2) the failure of the takeoff configuration warning system to alert the crew that the airplane was not properly configured for the takeoff. Also causal to the accident was the failure of Delta Air Lines' management to provide leadership and guidance to its flightcrews through its training and check airmen programs to promote and foster optimum cockpit management procedures, and the failure of the Federal Aviation Administration to correct known deficiencies in the training and check airmen programs of Delta Air Lines.

/s/ Jim Burnett
Member

September 26, 1989

5. APPENDIXES

APPENDIX A

INVESTIGATION AND PUBLIC HEARING

1. Investigation

The Safety Board was notified of the accident about 10:30 a.m. eastern daylight time, August 31, 1988. A team of investigators was dispatched from Washington, D.C., and arrived on the scene that afternoon. Investigative groups were formed of operations, air traffic control, witnesses, meteorology, survival factors, structures, powerplants, systems, flight data recorder, maintenance records, cockpit voice recorder, airplane performance, and human performance.

The parties to the investigation were the Federal Aviation Administration, Delta Air Lines, the Boeing Commercial Airplane Company, the Air Line Pilots Association, Pratt & Whitney Division of United Technologies Corporation, the Dallas/Fort Worth International Airport, and the Midland, Texas Fire Department.

2. Public Hearing

A 4-day public hearing was held in Irving, Texas, beginning November 29, 1988. Parties represented at the hearing were the Federal Aviation Administration, Delta Air Lines, the Boeing Commercial Airplane Company, the Air Line Pilots Association, Pratt & Whitney Division of United Technologies Corporation, and the Dallas/Fort Worth International Airport.

APPENDIX B

PERSONNEL INFORMATION

Captain Larry Lon Davis

Captain Larry L. Davis, 48, was hired by Delta Air Lines on October 18, 1965. The captain holds airline transport pilot (ATP) certificate No. 1518525 with B 727, DC-9, and airplane multiengine land ratings and commerical privileges in airplane single engine land and sea. He was issued a first class medical certificate on June 7, 1988, with a limitation to have corrective lenses in his possession for near vision when exercising the privilege of his certificate.

On July 27-28, 1988, the captain completed recurrent training on the Boeing 727. On July 29, 1988 and August 9, 1988, he received a proficiency check and an en route check, respectively. He had flown approximately 17,000 hours, 7,000 of which were in the Boeing 727. During the last 90 days, 60 days, and 30 days before the accident, he had flown 119 hours, 27 minutes; 99 hours, 56 minutes; and 61 hours, 56 minutes, respectively.

The captain had been off duty 27 hours 27 minutes before reporting for duty on the day of the accident. At the time of the accident, he had been on duty 2 hours 35 minutes, of which 1 hour and 13 minutes was flight time.

First Officer Carey Wilson Kirkland

First Officer Cary W. Kirkland, 37, was hired by Delta Air Lines on January 26, 1979. He holds ATP certificate 1904535, with airplane multiengine land rating and commerical privileges in airplane single engine land. He was issued an FAA first class medical certificate with no restrictions on January 18, 1988. Since more than 6 months had elapsed since the issuance of his medical certificate, the certificate had been downgraded to a second class medical certificate. Pursuant to applicable regulations, he was qualified to exercise his commerical privileges and was qualified to serve as first officer on the flight.

He qualified as a Boeing 727 first officer on December 9, 1987. His last proficiency check was completed on November 20, 1987, and his last en route check was on December 6, 1987. At the time of the accident, he had flown 6,500 hours, 4,000 of which were in the Boeing 727. During the last 90 days, 60 days and 30 days before the accident, the first officer had flown 160 hours, 23 minutes; 123 hours, 57 minutes; and 60 hours, 43 minutes, respectively.

The first officer's off-duty time before reporting for duty on the day of the accident and his on-duty and flight hours on the day of the accident were the same as those listed for Captain Davis.

Second Officer Steven Mark Judd

Second Officer Steven M. Judd, 30, was hired by Delta Air Lines on November 20, 1987. He holds ATP certificate 520723890, with airplane multiengine land rating and commerical pilot privileges in airplane single engine land. He additionally holds flight engineer certificate 520723890 with a turbojet powered rating. He was issued an FAA first class medical certificate with no restrictions on October 27, 1987. Since more than 6 months had elapsed since the issuance of his medical certificate, the certificate had been downgraded to a second class medical certificate.

The second officer qualified as a Boeing 727 second officer on January 20, 1988. At the time of the accident, he had flown 3,000 hours, 600 of which were in the Boeing 727. During the last 90 days, 60 days, and 30 days before the accident, he had flown 128 hours, 22 minutes; 51 hours, 56 minutes; and 1 hour, 7 minutes, respectively.

The second officer's off-duty time before reporting for duty on the day of the accident and his on-duty and flight hours on the day of the accident were the same as those listed for the captain and the first officer.

APPENDIX C

COCKPIT VOICE RECORDER TRANSCRIPT

TRANSCRIPT OF A FAIRCHILD A-100A COCKPIT VOICE RECORDER, S/N 51362, REMOVED FROM DELTA AIR LINES B727 WHICH WAS INVOLVED IN AN ACCIDENT AT DALLAS-FT. WORTH INTERNATIONAL AIRPORT ON AUGUST 31, 1980

LEGEND

CAM	Cockpit area microphone or sound source
RDO	Radio transmission from accident aircraft
PA	Public address system
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Flight Engineer
-4	Voice of flight attendant in cockpit
-?	Voice unidentified
XXX	Miscellaneous aircraft
APP	Approach Control
CTR	Center
GPWS	Ground Proximity Warning System
UNK	Unknown
*	Unintelligible word
#	Nonpertinent word
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause
Note:	All times are expressed in central daylight time.

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0828:33	((start of recording))
0828:43 CAM-3	I sure hate goin' with one knee I'd appreciate getting it fixed
0828:47 CAM-1	it's kinda of a weak point on the seven twenty seven fuel gage! *
0828:51 CAM-2	yeah
0829:00 CAM-6	thank you
0829:01 CAM-3	thanks very much
0829:02 CAM-6	did we get the sign off
CAM-3	*
0829:05 CAM-1	yeah yeah signed and delivered
0829:12 PA-6	((cabin departure anouncement by gate agent))
0829:22 CAM-6	see you later

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0829:45 CAM-2	did you get anything *-
0829:55 CAM-2	did you get anything
0829:58 CAM-2	for tomorrow
0830:00 CAM-2	put in a white slip

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0829:30 RDO-2	ramp Delta eleven forty one ready to push fifteen
0829:32 RAMP	eleven forty one off of fifteen let's go tail straight back and call me your taxi instructions
0829:37 RDO-2	okay
0829:46 INT -7	oh you can release brakes and give them a call
0829:49 INT -1	brakes off tail straignt back
0829:50 INT -7	roger

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0830:01 CAM-1	I got a thing I got to look it up and see if I want I want to look at the rotation and see what it is
CAM-1	I may put in one when I get back
0830:09 CAM-?	if you can
0830:13 CAM-1	- I forgot to get my pay check did you get yours
CAM-2	yeah I got mine
0830:17 CAMA-2	there been so much happen ***
0830:26 CAM	((sound of trim in motion horn))
0830:29 CAM-2	we generally require a fresh infusion along about the end of the month and in the middle
0830:33 CAM-2	in order to keep everybody happy

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0830:37 INT -7	alright engines are cleared to start
0830:41 INT -1	okay

INTRA-COCKPIT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0830:43 CAM-3	beacon
0830:44 CAM-2	it's on
0830:46 CAM-3	parking brake
CAM-2	it's off
0830:47 CAM-3	forty psi
0830:49 CAM-2	guys like @ you know can put twenty six thousand down on a house you know and not even bat an eye
0830:55 CAM-3	((sound of laugh)) lifes savings
0831:01 CAM-1	well he has been diligent in his savings
0831:04 CAM-2	that's right
0831:06 CAM-2	he diligently dumped it there
0831:07 CAM	((sound of engine igniter starts))
CAM-3	I was a homebody in the Navy

INTRA-COCKPIT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0831:13			
CAM-2	batchin' it batchin' it makes it did you live in the "Q"		
0831:17			
CAM-3	I lived in the "Q" rat as a ensign but I lived in a - start valve closed - forty psi		
0831.19			
CAM	((sound of engine igniter stopped))		
0831:20			
CAM-3	start valve open		
0831:24			
CAM-1	It's interesting you know they're pushin' this guy back and that tug driver can't begin to see em - *		
CAM-2	*		
CAM-1	- gettin' out		
0831:37			
CAM	((sound of engine igniter starts))		
0831:39			
CAM-3	oil pressure's up		
0831:48			
CAM	((sound of ingition stopped))		
0831:49			
CAM-3	start valve's closed forty psi		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0831:50 CAM-2	you want all of 'em
CAM-1	yeah
0831:54 CAM-3	start valve open
0832:00 CAM-3	oil pressure rising
0832:08 CAM	((sound of engine igniter starts))
0832:17	((sound of engine igniter stopped))
0832:19	
CAM-3	start valve closed forty psi
0832:24 CAM	((sound of three generators coming on the line))
0832:29 CAM-3	engine instruments
CAM-2	checked normal

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0831:51 INT -7	alright brakes set you guys have a great trip
0831:57 INT -1	brakes are set you have a good day thank you

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0832:32 CAM-3	engine anti-ice
0832:33 CAM-2	closed
0832:46 CAM-2	yeah it look's like they're homin' in on that thing over there - puttin' the jetways in today
0832:50 CAM-3	alright
0832:54 PA	((sound of flight attendents cabin briefing starting))
CAM-3	look's like they'll be ready before long
0833:17 CAM	((sound of two clicks))
0833:24 CAM	((sound of click))
0833:33 CAM	((sound of trim in motion))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0832:58 RDO-2	ramp Delta eleven forty one's ready to taxi
0833:03 RAMP	eleven forty one give me a right turn bring it between south ramp and thirty hold short of inner
0833:10 RDO-2	eleven forty one roger

INTRA-COCKPIT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0834:51 PA	((cabin briefing stops))
0835:00	((Recording interruption sound))
0835:31 CAM-1	how about lookin' down here at Delta's now and then
CAM	((sound of laugh))
CAM-?	yeah *
0835:43 CAM-3	while we're still young
0835:48 CAM-3	how about lookin' down here while we still have teeth in our mouths
0835:35 CAM	what's that
0835:52 CAM-3	how about lookin' down our way while we still have teeth in our mouths
0835:55 CAM	((sound of laugh))
0835:57 CAM-2	growing gray at the south ramp is Delta
CAM-?	*

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0836:09 CAM-1	I guess we oughta shut down number three save a few thousand dollars		
0836:13 CAM-2	I'll I'll call and ask ground if we can if we just like to shut down over here		
0836:24 CAM-2	ask him if he can give us give us a two minute warning to start our engines		
0836:36 CAM-3	okay		
0836:50	((sound of scraping noise on tape))		
		0837:20 GND	Delta at thirty make a left turn say your number
		0837:24 RDO-2	that's ah eleven forty one
		0837:26 GND	Delta eleven forty one okay give way to company to your left the seven two join the inner for standard taxi one eight left
		RDO-2	ah seven thirty one roger
0837:38 CAM-1	we're gunna wait for him		
0837:40 CAM-2	yeah		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0837:53 CAM-1	where is he		
0837:57 CAM-2	he's right there		
CAM-1	*		
0838:21 CAM-2	just now comin' out		
0838:22 CAM-1	we certainly taxiied out before he did		
0838:26 CAM-1	did he say standard to one eight		
0838:53 CAM-3	take off data has been computed for one eight left		
CAM-2	okay		
0838:57 CAM-3	auto pack trip light is not required - pitot heat		
0838:59 CAM-2	it's on		
0839:00 CAM-3	airspeed and epr bugs		
0839:01 CAM-2	thirty one and forty five on both sides and alternate epr set		
0839:05 CAM-3	airspeed warning switches		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0839:06 CAM-2	three A's
0839:08 CAM-3	altimeter and flight instruments
0839:09 CAM-2	set cross checked
0839:11 CAM-3	stab trim
0839:12 CAM-2	ah five point six
0839:36 CAM-4	a lotta people goin' out this morning
0839:40 CAM-3	yeah big push
	((7 minutes and 42 seconds of nonpertinent conversation between the flight crew and a flight attendent))
0847:28 CAM-1	don't we have to change to ground here
0847:30 CAM-2	yeah I'm sorry I'm sittin' here talking to the flight attendent

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0847:53 CAM-2	I said thirtyone I meant eighteen
0847:59 CAM-1	I think he knows
0848:09 CAM-2	transition at twentyone hold short of nineteen
0848:12 CAM-1	okay

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0847:41 RDO-2	ground Delta eleven forty one's with ya on top of the thirtyone bridge
0847:45 GND	eleven forty one come south on the inner until taxiway twenty one then move to the outer hold short of nineteen
0847:56 GND	say this again for a second so I can hear his answer Delta eleven forty one come south on the inner till taxiway twenty one then move to the outer
0848:02 RDO-2	eleven forty one roger

INTRA-COCKPIT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

((1 minute and 18 seconds of non-pertinent conversation between the Flight crew and a flight attendent))

0850:01 CAM-4	are we gunna get takeoff or are we just gunna roll around the airport
0850:04 CAM-2	well we we thought we were gunna have to retire sittin' there waitin' for taxi clearance
0850:21 CAM-4	my gosh we've got a long taxi to do
0850:24 CAM-1	yeah we are gettin' down here where we let all the Americans get off first
0850:34 CAM-1	once they're all gone we can go

((1 minute and 22 seconds of non-pertinent conversation between the flight crew and a flight attendent))

0853:12 CAM-2	what kinda birds are those
0853:16 CAM-'	Egrets or what ever they call 'em
0853:18 CAM-4	yeah Egrets -

IntRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-2	are they		
CAM-4	I think so		
0853:21 CAM-4	Are they a cousin to the ones by the sea		
0853:25 CAM-1	I don't know they whenever I mow grass out in my pasture they come in and it stirs up the grasshoppers and everything -		
0853:34 CAM-3	boy they just flock here		
0853:36 CAM-2	I've seen them all over the place out around here		
CAM-1	grasshoppers *		
CAM-4	real *		
0853:41 CAM-1	they ah in fact they sit on the back of our horse now and then you see one out there just sittin' on the back of the horse		

INTRA-COCKPIT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0853:45 CAM-4	oh is that right
0853:46 CAM-2	I've seen them sittin' on the back of a lot of cows
CAM-1	yeah
0853:50 CAM-4	are they the ones that pick the bugs off of them and stuff
0853:53 CAM-1	I guess and they hang around them because while they're grazing you know they stir up the insects and they can get 'em easier
0853:58 CAM-4	uh huh
0854:00 CAM-4	they're pretty birds
0854:07 CAM-2	they got one more American and I think we'll be able to go here - start clearin' some of this -

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0854:18 CAM-1	It's interesting how they sit around the airport like this without being afraid		
0854:25 CAM-4	didn't we taxi		
0854:26 CAM-2	I'm surprised they're not complainin' about the noise		
0854:28 CAM-4	all the way around		
0854:30 CAM-4	we go to the other side		
0854:33 CAM-1	all the way around down here over back up here		
0855:10 CAM-3	boy this is somethin'-		
CAM-3	if this is how it is on a severe clear vfr day --		
0855:15 CAM-4	can you imagine-(laugh)		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-4	imagine --
0855:16 CAM-2	imagine what it would be like if we had weather today
0855:20 CAM-2	I tell you what Dallas Fort Worth Center is ah hundred percent better than it was three years ago -
0855:25 CAM-4	is it really
0855:26 CAM-2	with its with regard to weather gettin' in and gettin' out and all
0855:33 CAM-2	if it clouded up and even looked like there was going to be weather it I useta think it backed up you'd be holdin' slowin' down doin' all kinds of stuff
0855:41 CAM-?	ugh
0855:59 CAM-1	did you see that bird

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
CAM-4	yes
0856:02 CAM-1	he got the jet blast
0856:03 CAM-4	yeah he did he got it
0856:04 CAM-2	ah what a crash
0856:08 CAM-4	he said what in the world was that
0856:09 CAM-2	ever go out to Midway and see the gooney birds they're somethin' to watch
0856:15 CAM-3	they crash and look around to see if any body saw 'em you know
0856:17 CAM-2	yeah
0856:19 CAM-2	they would they you know if you'd do a runup the flight would come up and do a runup and the gooney birds would be back there in the prop wash just hangin' in the air you know and then they shut pull pull the power back and then they'd just *

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM	((sound of laugh))
0856:35 CAM-2	hit the ground you know -- they were hilarious
0856:38 CAM-2	they'd send a truck out you'd get ready to take off they'd send a pickup truck out and they'd go move the birds off the runway so you could takeoff
0856:44 CAM-4	oh really oh how funny where are they where was that
0856:47 CAM-2	Midway Midway Island
0856:48 CAM-4	Midway Island
0856:49 CAM-2	they come back and they nest in exactly the same spot that they were born
0856:52 CAM-4	on the runway

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0856:53 CAM-2	yeah whether it was a runway or what it was they come back to the exact same spot and eh so there's some kind of a law or somethin' that you can't build anything on the island anymore because --		
0857:04 CAM-4	uh huh		
0857:07 CAM-2	it's a sanctuary for the birds or somethin'		
0857:08 PA-3	good morning ladies and gentleman we're number four for departure, flight attendents prepare the cabin please		
0857:22 CAM	((flight switched to tower frequency))		
0857:32 CAM-4	we're ready		
0857:33 CAM-3	thank you		
0857:35 CAM	((sound similar to cockpit door being closed))		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0857:42 CAM-1	might as well start
0857:49 CAM-3	forty psi
0857:51 CAM-2	number three
0857:54 CAM-3	start valve open
0858:07 CAM	((sound of engine igniter starts))
0858:09 CAM-3	oil pressure
0858:16 CAM	((engine igniter stops))
0858:17 CAM-3	start valve closed forty psi
0858:23 CAM	((sound of generator coming on line))
0858:24 CAM-3	engine instruments

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0858:26 CAM-2	checked normal
0858:30 CAM-3	engine anti-ice
0858:31 CAM-2	it's closed
0858:46 CAM-3	shoulder harness
0858:47 CAM-2	they're on
CAM-3	flaps
0858:48 CAM-2	fifteen fifteen green light
0858:49 CAM-3	flight controls

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0858:38 TWR	eleven for-ty one taxi position runway one eight left and hold the Bandit will cross ahead
0858:44 RDO-2	okay eleven forty one's position and hold

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0858:56 CAM-2	tops and bottoms are checked		
0858:53 CAM-3	nav instruments		
0858:54 CAM-2	they're set		
0858:57 CAM-3	takeoff briefing		
0858:58 CAM-2	is complete		
0858:59 CAM-3	flight attendents have been notified - and acknowledged		
0859:00 CAM-3	anti-skid		
0859:01 CAM-2	on		
0859:02 CAM-3	continuous ignition		
0859:04 CAM-2	on		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0859:05 CAM-3	nav lights		
0859:06 CAM-2	on		
0859:07 CAM-3	transponder		
CAM-2	on		
0859:08 CAM-3	before takeoff checklists complete		
CAM-2	thank you		
		0859:17 TWR	Delta eleven forty one fly heading one eight five runway one eight left cleared for takeoff
		0859:20.4 RDO-2	eleven forty one one eight five cleared to go
0859:35 CAM	((sound of increasing engine noise))		
0859:48.4 CAM-2	power's set		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0859:49.8 CAM-2	engine instruments look good
0859:51.4 CAM-2	airspeed's comin' up both sides
0859:53.5 CAM-2	eighty knots
0900:05.5 CAM-2	vee "R"
0900:06.5 CAM	((sound similar to nose strut extension))
0900:10.7 CAM-2	vee two
0900:12.5 CAM	((sound of snap))
0900:15.1 CAM	((sound of stick shaker starts and continues until end of tape))
0900:15.5 CAM-1	(somethin's wrong/ooh)
0900:17.6 CAM	((sound of compressor stall))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

TIME &
SOURCE CONTENT

0900:18.3
CAM ((sound of compressor stall))

0900:19.1
CAM-2 engine failure

0900:19.9
CAM ((sound of compressor stall))

0900:20.4
CAM ((sound of compressor stall))

0900:21.1
CAM ((sound of compressor stall))

0900:21.7
CAM-2 we got an engine failure

0900:22.9
CAM ((sound of momentary power interruption
to the cvr))

0900:26.9
CAM-1 we're not gunna make it

AIR-GROUND COMMUNICATIONS

TIME &
SOURCE CONTENT

0900:19.5
RDO ((sound of microphone key for 6.6 seconds))

0900:28.9
RDO-2 eleven forty one's-

INTRA-COCKPIT

TIME & SOURCE	CONTENT
0900:34.7 CAM-1	full power
0900:34.9 CAM-2	* *
0900:35.3 CAM	((sound of first impact))
0900:37.1 CAM	((sound of second impact))
0900:37.4 CAM	((sound of third impact))
0900:37.4 CAM	((sound of scream))
0900:38.5 CAM	((sound of fourth impact))
0900:39.4	((end of tape))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
0900:33.4 RDO	((sound of microphone keying for 0.3 seconds))
0900:36.6 RDO	((sound of microphone keying for 0.3 seconds))
0900:37.3 RDO-?	send the - call the equipment

APPENDIX D

DELTA AIR LINES' B727 PILOT'S CHECKLIST

■ INTERMEDIATE STOP ITEMS
▲ S/O'S FUNCTION NO CHALLENGE

B-727 PILOT'S CHECKLIST (-232 & -247 Modified)

FAA APPROVED DATE 3-15-84

FIRST FLIGHT OF DAY CHECK THE FOLLOWING

STANDBY RUDDER — FLIGHT DIRECTORS
ANTI-SKID — STAB TRIM
ANTI-ICE — AUTOPILOT
PITOT HEAT

BEFORE START

■ A/C STATUS & LOGBOOK ..... CK
■ FUEL REQD ..... ——ON BOARD——
OXY MASK/MIC/INTERPHONE ..... CK
STANDBY RUDDER ..... OFF
FLIGHT CONTROL SWITCHES ..... ON
ANTI-SKID ..... OFF
STALL WARNING ..... CK
INSTRUMENT COMPARATOR ..... CK
EMERGENCY EXIT LIGHTS ..... ARMED
#2 ENG ACCESS DOOR LIGHT ..... OFF
ENGINE START SWITCHES ..... OFF
■ SEAT BELT & NO SMOKING ..... ON
■ WINDOW HEAT ..... ON
ANTI-ICE ..... CLOSED
PITOT HEAT ..... OFF
INTERIOR & EXTERIOR LIGHTS ..... SET
■ NAVIGATION LIGHTS [247] ..... ON
■ ENGINE FIRE WARNING SYSTEMS ..... CK
ALT & FLT INSTS ..... SET/CROSSCK
COMPASS SELECTORS ..... SLAVED
GPWS ..... CK
STATIC SOURCE SELECTORS ..... NORMAL
MACH AIRSPEED WARNING ..... CK
INDICATOR LIGHTS & APD ..... CK
ENGINE INSTRUMENTS ..... CK
LANDING GEAR ..... DOWN, IN, 3 GREEN
■ RADAR & TRANS ..... CK & SET
FLIGHT DIRECTORS ..... STBY
SPEED BRAKE ..... DETENT
REV THROTTLES & START LEVERS ..... DOWN, CLOSED & CUTOFF
FLAPS ..... UP
STAB TRIM ..... NORMAL
AUTOPILOT ..... OFF
■ RADIOS & NAV INSTS ..... CK & SET
■ RUDDER & AILERON TRIM ..... ZERO
STANDBY POWER ..... CK
■ CABIN & S/O PREFLIGHT ..... COMPLETE
■ ▲ AUTOPILOT TEST SW ..... NORMAL
■ ▲ CIRCUIT BREAKERS ..... CK
■ DEPARTURE BRIEFING ..... COMP

BEFORE DISPATCH

▲ #2 SYS B HYD PUMP ..... ON
▲ APU & BATT CHARGER ..... START & CK
▲ PACK(S) ..... AS REQD

ENGINE START

▲ DOOR WARNING LIGHTS ..... CK
▲ PACKS ..... BOTH OFF
▲ GALLEY POWER ..... OFF
▲ FUEL SYSTEM ..... SET
BEACON ..... ON
PARKING BRAKE ..... AS REQD
PNEUMATIC PRESSURE ..... ——PSI

AFTER START

▲ ELEC SYSTEM ..... CK & SET
▲ EXTERNAL POWER & AIR ..... REMOVE
▲ GALLEY POWER ..... ON
▲ FUEL SYSTEM ..... SET
▲ SYS A & B HYD PUMPS ..... CK & ON
▲ ENG 2/APU BLEEDS ..... AS REQD
▲ PACKS ..... AS REQD
▲ COCKPIT DOOR ..... LOCKED (PRIOR TO T/O)
ENGINE INSTRUMENTS ..... CK
ENGINE ANTI-ICE ..... AS REQD

TAXI

T/O DATA COMPUTED RWY——USING RWY——
AUTO PACK TRIP LT ..... REQD OR NOT REQD
PITOT HEAT ..... ON
AIRSPD & EPR BUGS ..... SET/CROSSCK
AIRSPD WARN SWS ..... SET, 3——(A OR B)
ALT & FLT INSTS ..... SET/CROSSCK
STAB TRIM ..... ——UNITS

When Delayed Start is Desired

DELAYED ENGINE START

▲ PACKS ..... BOTH OFF
▲ GALLEY POWER ..... OFF
▲ FUEL SYSTEM ..... SET
PNEUMATIC PRESSURE ..... ——PSI

DELAYED AFTER START

▲ ELEC SYSTEM ..... CK & SET
▲ GALLEY POWER ..... ON
▲ FUEL SYSTEM ..... SET FOR TAKEOFF
▲ SYS A HYD PUMPS ..... CK & ON
▲ ENG 2/APU BLEEDS ..... CLOSE
▲ PACKS ..... ON
ENGINE INSTRUMENTS ..... CK
ENGINE ANTI-ICE ..... AS REQD

TAXI (CONTINUED)

▲ FUEL HEAT ..... AS REQD
▲ FLT/GRD SWITCH ..... FLT
▲ F/O ALT VIBRATOR C/B [232] ..... IN
SHOULDER HARNESS ..... ON
FLAPS ..... ——— GREEN LIGHT
FLIGHT CONTROLS ..... CK
NAV INSTRUMENTS ..... SET

BEFORE TAKEOFF

TAKEOFF BRIEFING ..... COMP
FLIGHT ATTENDANTS ..... NOTIFIED/ACKD
ANTI-SKID ..... ON
CONTINUOUS IGNITION [232] ..... ON
START SWITCHES [247] ..... FLT/START
NAV LIGHTS [232]/STROBE[247] ..... ON
TRANSPONDER ..... ON
▲ APU MASTER SWITCH ..... OFF
▲ FUEL HEAT ..... OFF
▲ APU LIGHT ..... OFF
▲ AUTO PACK TRIP SWITCH ..... NORMAL
▲ C/SD OIL COOLER [247] ..... GROUND OFF

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END

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