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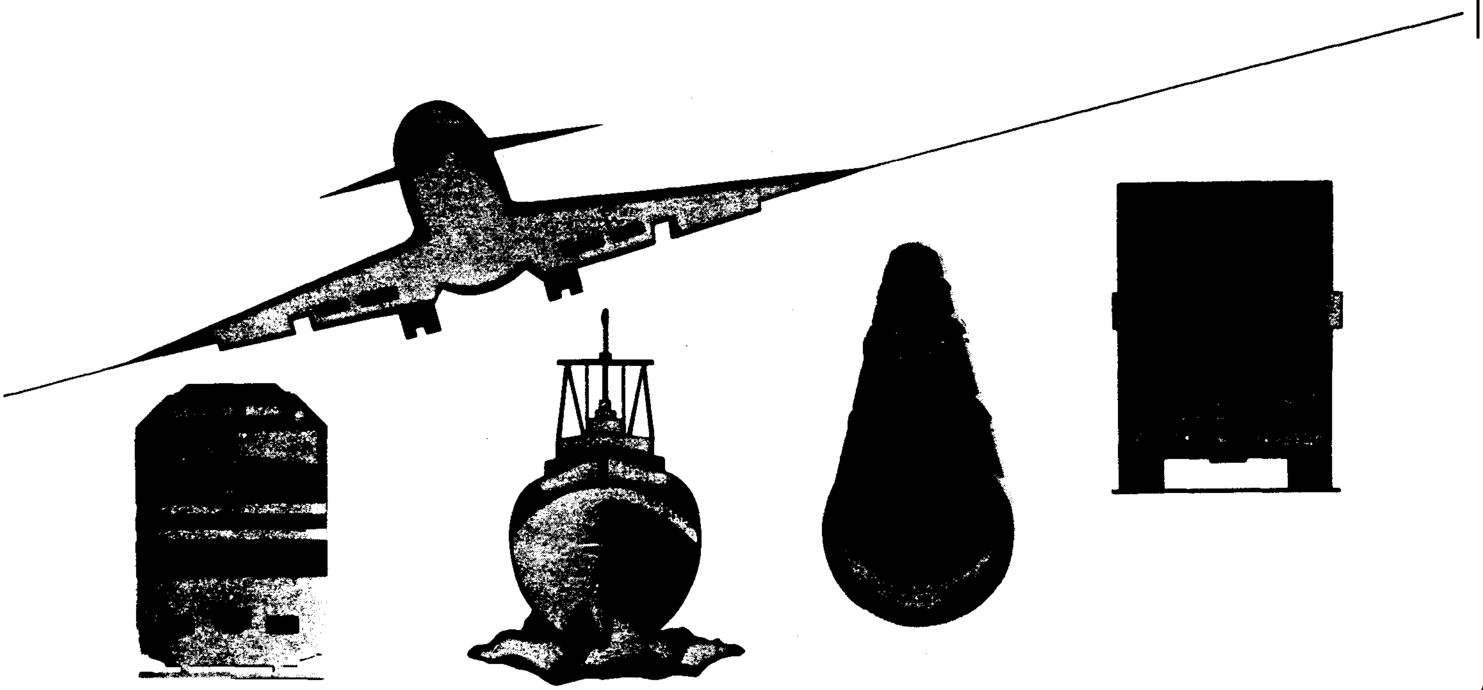
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

**IN-FLIGHT FIRE/EMERGENCY LANDING
FEDERAL EXPRESS FLIGHT 1406
DOUGLAS DC-1 0-10, N68055
NEWBURGH, NEW YORK
SEPTEMBER 5, 1996**



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SEPTEMBER 5, 1996

Adopted: July 22, 1998
Notation 6800B

Abstract: This report explains the accident involving Federal Express flight 1406, a Douglas DC-10-10, which made an emergency landing at Stewart International Airport on September 5, 1996, after the flightcrew determined that there was smoke in the cabin cargo compartment. Safety issues in the report include flightcrew performance of emergency procedures, undeclared hazardous materials in transportation, dissemination of hazardous materials information, airport emergency response, and adequacy of aircraft interior firefighting methods. Safety Recommendations concerning these issues were made to the Federal Aviation Administration, the Department of Transportation, and the Research and Special Programs Administration.

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CONTENTS

ABBREVIATIONS

AFFF	aqueous film-forming foam
AFIP	Armed Forces Institute of Pathology
ANG	Air National Guard
ARFF	aircraft rescue and firefighting
ARTCC	air route traffic control center
ATA	Air Transport Association
ATC	air traffic control
ATP	airline transport pilot
CDL	configuration deviations list
CFR	Code of Federal Regulations
CRM	crew resource management
CVR	cockpit voice recorder
DEC	Department of Environmental Control
DEGMBE	diethylene glycol monobutyl ether
DOT	Department of Transportation
EOC	emergency operations center
FAA	Federal Aviation Administration
FL	flight level
FDR	flight data recorder
FS	fuselage station
FTIR	Fourier Transform Infrared
GC/MS	gas chromatography/mass spectrometry
GOCC	Global Operations Command Center
HMIS	Hazardous Materials Information System
HMRT	Hazardous Materials Response Team
LOFT	line oriented flight training
MEL	minimum equipment list
mL	milliliter
NASA	National Aeronautics and Space Administration
NYSP	New York State Police
PBE	protective breathing equipment
pH	hydrogen-ion concentration
POI	FAA principal operations inspector

psi	pounds per square inch
RSPA	Research and Special Programs Administration
SN	serial number
SPAAT	skin penetrator agent application tool
STC	supplemental type certificate
THF	tetrahydrofuran
TRACON	terminal radar approach control
µl	microliter

EXECUTIVE SUMMARY

About 0554 eastern daylight time, on September 5, 1996, a Douglas DC-10-10CF, N68055, operated by the Federal Express Corporation as flight 1406, made an emergency landing at Stewart International Airport, Newburgh, New York, after the flightcrew determined that there was smoke in the cabin cargo compartment. The flight was operating under the provisions of Title 14 Code of Federal Regulations Part 121 as a cargo flight from Memphis, Tennessee, to Boston, Massachusetts. Three crewmembers and two nonrevenue passengers were aboard the airplane. The captain and flight engineer sustained minor injuries while evacuating the airplane. The airplane was destroyed by fire after the landing.

The National Transportation Safety Board determines that the probable cause of this accident was an in-flight cargo fire of undetermined origin.

Safety issues discussed in this report include flightcrew performance of emergency procedures, undeclared hazardous materials in transportation, dissemination of hazardous materials information, airport emergency response, and adequacy of aircraft interior firefighting methods. Safety recommendations concerning these issues were made to the Federal Aviation Administration, the Department of Transportation, and the Research and Special Programs Administration.

NATIONAL TRANSPORTATION SAFETY BOARD
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AIRCRAFT ACCIDENT REPORT

IN-FLIGHT FIRE/EMERGENCY LANDING FEDERAL EXPRESS FLIGHT 1406 DOUGLAS DC-10-10, N68055 NEWBURGH, NEW YORK SEPTEMBER 5, 1996

1. FACTUAL INFORMATION

1.1 History of Flight

About 0554 eastern daylight time,[1] on September 5, 1996, a Douglas DC-10-10CF, N68055, operated by the Federal Express Corporation (FedEx) as flight 1406, made an emergency landing at Stewart International Airport (Stewart), Newburgh, New York, after the flightcrew determined that there was smoke in the cabin cargo compartment. The flight was operating under the provisions of Title 14 Code of Federal Regulations (CFR) Part 121 as a cargo flight from Memphis, Tennessee, to Boston, Massachusetts. Three crewmembers and two nonrevenue passengers were aboard the airplane. The captain and flight engineer sustained minor injuries while evacuating the airplane. The airplane was destroyed by fire after the landing.

The accident occurred on the first leg of a scheduled two-leg sequence from Memphis to Boston with a return to Memphis. The flight engineer stated that before departing Memphis, he received a hazardous materials briefing from a FedEx dangerous goods specialist.[2] This briefing included discussions about the locations of hazardous materials that were on board the airplane (in cargo containers 1L/1C and 3R[3]) and about the Halon[4] hose connections to container 1L/1C (which was designated for flammable dangerous goods). The dangerous goods specialist then gave the captain the Notification of Dangerous Goods Loading Form (Part A)

[1] Unless otherwise indicated, all times are eastern daylight time, based on a 24-hour clock.

[2] FedEx dangerous goods specialists are responsible for verifying that shipments of declared hazardous materials are properly packaged, identified, labeled and marked. They also inspect hazardous materials packages for signs of damage or leakage, and ensure that all hazardous materials packages have been properly loaded. Dangerous goods specialists are assigned to those stations in which hazardous materials are accepted and loaded for transportation.

[3] For cargo container locations, see figure 1.

[4] An inert chlorofluorocarbon gas used to extinguish fires.

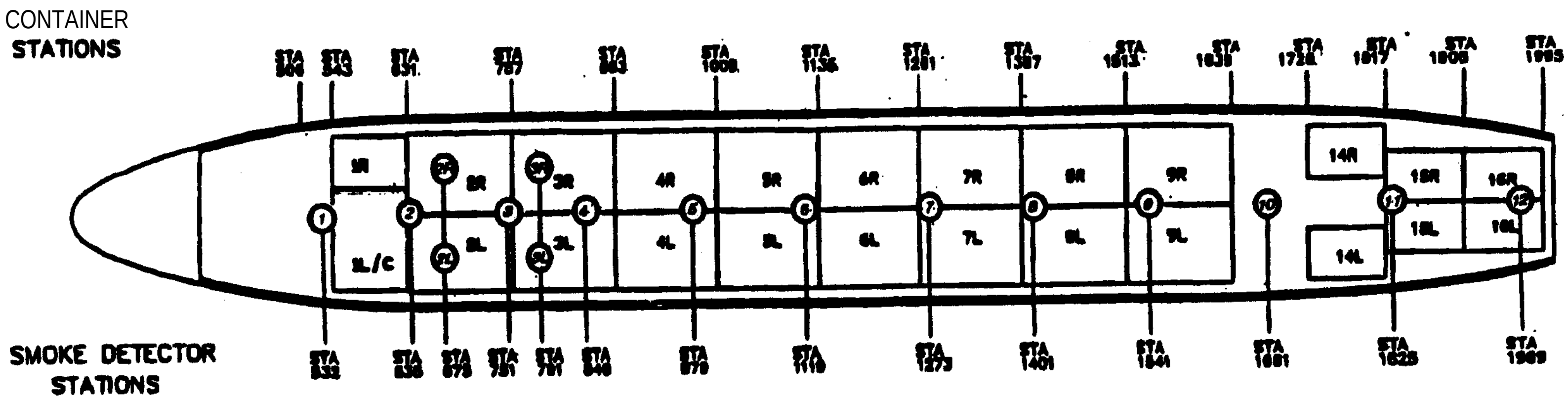

Figure 1.—DC-10-10, N68055, upper cabin cargo container positions and smoke detector locations.

containing required hazardous materials information,[5] which the captain signed.[6] Flight 1406 departed Memphis at 0242 central daylight time (CDT); the flightcrew stated that the engine start, taxi, takeoff, and climb were normal. The first officer was the pilot flying, and the captain performed the duties of the nonflying pilot.

The airplane's upper cargo deck was loaded with 23 cargo containers and 1 cargo pallet. The lower forward cargo compartment contained six cargo containers; and the lower aft cargo compartment contained seven containers.

At 0536:23, when the airplane was at flight level (FL) 330,[7] the cockpit voice recorder (CVR) recorded the captain asking, "what [ ]'s that?"[8] Two seconds later, both the first officer and the flight engineer said, "cabin cargo smoke." At 0536:27, the captain stated, "You see that…we got cabin cargo smoke…cabin cargo smoke." The flight engineer then stated, "cabin cargo smoke, oxygen masks on." The CVR indicates that the crew then donned oxygen masks and established crew communications, as required by the first two steps on the "Fire & Smoke" checklist (see figure 2).[9]

During postaccident interviews and in his deposition, the captain stated that he initially donned his smoke goggles, but had to remove his eyeglasses to do so. During the landing phase of the flight, he removed his goggles so he could replace his glasses. The captain also said that the goggles were dirty and scratched. The first officer stated that he elected not to wear his smoke goggles because he felt that they would unduly restrict his peripheral vision. The flight engineer initially donned his smoke goggles, but then removed them after noting that no smoke was entering the cockpit. At 0536:40, the flight engineer said, "okay it's number nine

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[5] The Department of Transportation (DOT) hazardous materials regulations require the aircraft operator to provide the pilot-in-command with certain information about hazardous materials on board the flight (including proper shipping name, hazard class, identification number, total number of packages, net quantity or gross weight per package, and location aboard the aircraft), in writing, before departure.

[6] According to the FedEx Flight Operations Manual, "Appropriate parts (A; B and/or BR; C and/or CR) of the Notification of Dangerous Goods Loading form, FEC-M-390 are required for each departure." The Part A forms list the class of hazardous materials and where they are on the airplane, and serves as the required written notification to the pilot-in-command. The Part B forms are the individual shipping documents for each shipment of hazardous materials, other than radioactive materials. The Part BR forms are for shipments of radioactive materials. The Part C and CR forms are comparable to the Part B and BR forms, respectively, but are used for domestic shipments only. Parts A and B are discussed in greater detail in section 1.15.2.1.

[7] 33,000 feet mean sea level, based on an altimeter setting of 29.92 inches of mercury (Hg).

[8] See appendix B for a complete transcript of the CVR.

[9] Cockpit emergency equipment also included a portable oxygen cylinder with attached smoke mask and a protective breathing equipment (PBE) smoke mask and hood, neither of which were used during the emergency.

FEDERAL **DC-10 FLIGHT MANUAL**

FIRE & SMOKE

1. **Oxygen Mask & Smoke Goggles (All Required)** .... **ON, 100%**
2. **Crew & Cockpit Communications** .... **ESTABLISH**
   Check Mike switches set to MASK, place cockpit speaker ON, place MIC SEL switch to FLT INT, and establish crew communication.
3. **Cockpit Door & Smoke Screen** .... **CLOSED**
   Close the cockpit door & smoke screen to exclude heavy concentrations of smoke. Leave door closed unless opening it is dictated by a greater emergency, and then at Captain's discretion.

or
4. **If Descent is required** .... **PROCEED TO STEP 6**
5. **If Descent is NOT Required** .... **PROCEED TO STEP 14**

WARNING

Should structural damage be suspected, limit airspeed. Gear and / or Speed Brakes may be used depending on type of damage.

6. **Autopilot** .... **AS REQUIRED**
7. **Throttles** .... **IDLE**
8. **Speed Brake** .... **FULL**
9. **Airspeed** .... **MACH .82 TO .85 (320 TO 350 KIAS)**

NOTE
If structural damage is known or suspected, use appropriate turbulence penetration speed.

10. **ATC** .... **NOTIFY**
11. **Transponder (if no contact with ATC)** **7700**
12. **Tank Pumps** .... **ALL ON**
13. **Altimeter** .... **SET**
14. **Type Of Smoke Or Fire** .... **DETERMINE & PROCEED TO APPROPRIATE PROCEDURE, THIS CHAPTER**

    A. ELECTRICAL FIRE & SMOKE : **Can best be determined by smell or visible smoke from electrical components (e.g., circuit breaker, radio)**

    B. AIRCONDITIONING SMOKE : **Can best be recognized by smoke emanating from overhead air conditioning outlets.**

    C. CABIN CARGO SMOKE : **Can best be recognized by checking smoke detectors on the Second Officers panel, or by observing smoke or fire in the main deck cargo area.**

(End of Procedure)

20 March 1994 **2-8-1**

Figure 2.—FedEx DC-10 "Fire & Smoke" checklist.

smoke detector."[10] (See figure 1 for location of smoke detectors.) Upon the first officer's suggestion, the nonrevenue passengers (who had been seated in the foyer area in the cabin directly behind the cockpit) came into the cockpit, where they donned their oxygen masks. During postaccident interviews, the passengers stated that at that point they had been unaware of the developing emergency; they had both been reading magazines, and neither saw nor smelled smoke in the foyer area (see figure 3 for a diagram of the foyer).

At 0537:56, the captain stated, "okay it's moving forward whatever it is…it's up to seven." According to the CVR, at 0539:13, the captain asked the flight engineer to test the smoke warning system, which he did. During the test, several lights came on blinking, rather than steadily.[11] At 0539:28, the captain said, "that's seven and eight." At 0539:31, the flight engineer stated, "those others may be failing in the blinking mode." At 0539:52, the captain said, "I got ten now."[12] At 0540:07, the captain stated, "we've definitely got smoke guys…we need to get down right now, let's go." At this time, according to postaccident interviews, the captain decided that the first officer should continue flying the airplane while he coordinated with air traffic control (ATC) and worked with the flight engineer on the checklists. At 0540:43, the captain informed the Boston air route traffic control center (ARTCC) of the emergency. The flight was immediately cleared to descend to 11,000 feet. The captain told investigators that he did not call for the emergency descent checklist but said that he thought he had completed all of the items from memory.

ARTCC informed the pilots that the Albany County Airport, New York, was approximately 50 miles ahead of them and that Stewart was about 25 miles behind them. The captain selected Stewart, and the flightcrew began to divert the flight there.

At 0541:41, the flight engineer began the "Cabin Cargo Smoke Light Illuminated" checklist (see figure 4), in accordance with the last step of the "Fire & Smoke" checklist. At 0542:21, he stated, "and now we have 8, 9, and 10…we've lost detector 7…it's gone out." He

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[10] In postaccident interviews conducted before the CVR transcript was available, the captain and flight engineer stated that the first lights they saw illuminated were the master caution light and the No. 7, No. 8, and No. 9 smoke warning lights. (These smoke warning lights corresponded with smoke detectors installed overhead in the upper cabin of the airplane, slightly forward of cargo container rows 7, 8, and 9, respectively.) During the deposition proceeding, the captain and the flight engineer again stated that they first saw the No. 7, No. 8, and No. 9 smoke detectors illuminated simultaneously, and the flight engineer stated that he did not recall the No. 9 smoke detector being illuminated alone.

[11] The FedEx DC-10 Flight Manual states, "If a flashing [cargo fire/smoke detector] indicator light is observed during the normal test procedure of the cargo fire/smoke detector units, the crewmember is alerted that the detector unit connected to the flashing light is beginning to deteriorate. **A flashing indicator light does not signify an inoperative fire/smoke detector.** However, a log book entry must be made noting the position of the flashing detector light, whereby maintenance is given a timeframe in which to replace the deteriorating fire/smoke detection unit. The fire/smoke detection system will perform all fire/smoke detection functions normally. A totally inoperative fire/smoke detector unit will not illuminate during the normal test procedure." (Emphasis in original.)

[12] During his deposition, the captain said that this comment referred to the number of lights illuminated during the test of the smoke detector system, and not to smoke detector No. 10. Although there are 16 smoke detector lights, it could not be determined whether all 16 lights in fact illuminated during the test.

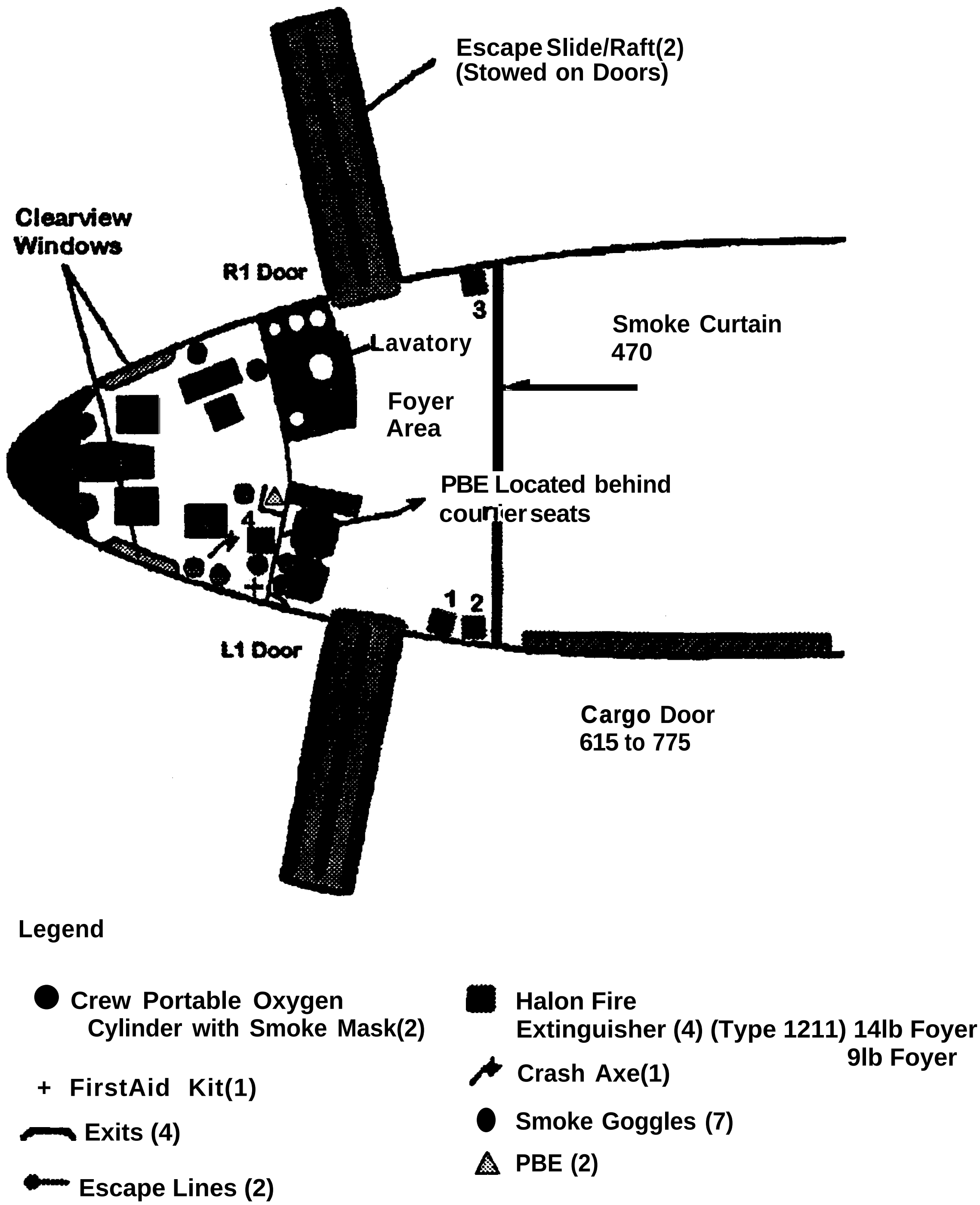

Figure 3.—Diagram of the DC-10-10, foyer area.

FEDERAL EXPRESS

DC-10 FLIGHT MANUAL

CABIN CARGO SMOKE LIGHT ILLUMINATED

1. **Pack Function Control Selectors** .... TWO PACKS OFF

NOTE
Operate the No. 1 Pack only, if available.

2. **Cockpit Air Outlets** .... OPEN
3. **Courier Masks & Goggles** .... VERIFY ON/100%
4. **Airplane Altitude** .... CAPTAIN'S DISCRETION
   - A. Land as soon as possible.
   - or
   - B. If above FL 270, consider descent to FL 270. Manually raise cabin altitude to 25,000 ft.
   - or
   - C. If below FL 270, and an immediate landing is not possible, climb to FL 270. Manually raise cabin altitude to 25,000 ft. using the MANUAL CAB ALT control wheel.
5. **If unable To Extinguish Fire/Smoke** .... MANUALLY RAISE CABIN ALTITUDE TO 25,000 FEET
6. **Cabin Air Shutoff T-Handle** .... PULL
7. **Maintain 0.5 PSI Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270.**
8. **Fire** .... CHECK EXTINGUISHED

NOTE
Restricted articles container is designed to be "relatively" air tight so that any fire which may start inside will quickly consume all available oxygen. Depressurizing airplane will further deny oxygen to fire and should result in adequate fire control.

CAUTION
No crewmember should leave the cockpit to fight a fire except when it is determined that the fire is accessible and then only when measures already taken have not been effective. In addition, do not open restricted articles container during flight when a fire within is known or suspected.

9. **If It Is Necessary To Leave The Cockpit To Fight A Fire:**
   - A. Protective Breathing Equipment .... DON/ACTIVATE

NOTE
The PBE is located in a container in the coat closet and should be worn when fighting an actual fire. The walk-around O_2 bottle is also available in the cockpit.

   - B. Fire extinguisher .... OBTAIN
   - C. Fire or smoke source .... EXTINGUISH
10. **Land At Nearest Suitable Airport.**

(End of Procedure)

Figure 4.—FedEx DC-10 "Cabin Cargo Smoke Light Illuminated" checklist.

then stated at 0543:02, "I'm manually raising the cabin altitude…there is smoke in the ah cabin area." During postaccident interviews, the flight engineer said that he felt rushed with the workload during the descent, and that he felt he had spent too much time trying to find the correct station identifier for Stewart on the airport performance laptop computer.[13] The CVR transcript records the flight engineer asking what the three-letter identifier for Stewart was five times between 0543:22 and 0549:09. At 0548:29, he announced that the "Cabin Cargo Smoke Light Illuminated" checklist was complete.

During postaccident interviews, the flight engineer told Safety Board investigators that he was confused by some items on the "Cabin Cargo Smoke Light Illuminated" checklist and acknowledged that he did not accomplish step No. 6, "Cabin Air Shutoff T-Handle," (when the T-handle is pulled, airflow is maintained to the cockpit area, but all airflow is shut off to the main deck cargo area). Regarding step No. 7, "Maintain 0.5 Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270," he acknowledged that he did not attempt to maintain 0.5 pounds per square inch (psi) differential pressure, but said that he had selected "manual" on the outflow valve control and "cranked it open a couple of times." (For more information on the cabin outflow valve control, see section 1.6.2.)

At 0546:56, the flight was handed off from Boston ARTCC to New York terminal radar approach control (TRACON) controllers, who provided assistance until the airplane landed. During postaccident interviews, the flight engineer said that during this portion of the flight, he opened the cockpit door several times and saw grayish smoke accumulating in the foyer area.

At 0547:27, the captain advised the first officer, "keep the speed up man, don't slow to two-fifty…we're in an emergency situation here." At 0550:41, after about 3 minutes of assisting the crew with the Stewart approach, the New York TRACON controllers asked if any hazardous materials were on board, and the captain replied affirmatively.

The captain stated that as the airplane approached the airport, visibility remained good in the cockpit, even though he could smell smoke through his oxygen mask. The airplane was cleared to land on runway 27, and the first officer landed the airplane at 0554:28. The captain then took control of the airplane and brought it to a stop on taxiway A3, where airport aircraft rescue and firefighting (ARFF) trucks were waiting.

The flight engineer said that when he opened the cockpit door after landing, he saw that the foyer area was full of smoke, and he could not see the smoke barrier[14] at the aft end of the foyer. The captain later told investigators that both he and the flight engineer called for an emergency evacuation. The CVR indicates that at 0555:07, the captain stated, "we need to get the [ ] out of here," and that 12 seconds later the flight engineer said, "emergency ground egress." The captain told investigators that he then pulled all three engine fire handles and attempted to

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[13] The airport performance laptop computer provides takeoff and landing performance data.

[14] The smoke barrier is a curtain that separates the cockpit and foyer area from the cabin cargo area.

discharge the engine fire agents (he was unsure whether all bottles discharged).[15] After the accident, the captain said that the "Emergency Evacuation" checklist had not been read. The flight engineer confirmed that the "Emergency Evacuation" checklist had not been read, but he stated that he had turned off the battery switch (which is item No. 18 on that checklist). (See appendix C for the "Emergency Evacuation" checklist.)

The flight engineer attempted to open the primary doors (doors L1 and R1),[16] but the doors would not immediately open. Meanwhile, the captain attempted to open his cockpit window and felt resistance, and when he broke the air seal he heard air escape with a hissing noise. He shouted to the others that the airplane was still pressurized. The flight engineer then rotated the outflow valve control to the open position (thereby depressurizing the airplane), and again attempted to open the L1 and R1 doors. Both of the evacuation slides deployed; however, the L1 door only partially opened. After the airplane was depressurized, both the captain and first officer opened their cockpit windows. The captain said that at that point the smoke was colored gray to black, and then turned black and had a "horrible acrid" smell. He said he had to hold his breath until his window opened and the smoke "billowed out the window like a chimney."

Smoke coming out of the cockpit windows and evacuation doors was immediately visible to the firefighters. After the captain and first officer opened their respective sliding windows, they positioned their upper bodies outside the airplane. The captain knelt on his seat with his upper body outside the window. The first officer was seated on the window sill with his feet on his cockpit seat and his upper body outside. They remained in these positions until after the flight engineer and the jumpseat riders had evacuated the airplane (via the R1 evacuation slide) and called to them from the ground beneath their windows. The captain and the first officer then evacuated the airplane using the cockpit windows' escape ropes. During the evacuation, the captain sustained rope burns on his hands, and the flight engineer received a minor cut to his forehead.

The flight engineer said that while he was in the airplane, the smoke was "oily and sooty" and acrid smelling, and that it made breathing unpleasant and difficult. He said that before he left the cockpit, he used his oxygen mask to fill his lungs with oxygen and then entered the foyer area. He stated during his deposition that he did not consider using the PBE that was available in the cockpit because he was anxious to open the exit doors, and he thought this could be accomplished relatively quickly. He also indicated that he forgot that the PBE was available in the cockpit.

As soon as he evacuated the airplane, the flight engineer gave the top sheet of Part A of the "Notification of Dangerous Goods Loading" form to a firefighter, who radioed the

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[15] For more information about the fire protection system on the DC-10, see section 1.6.3.

[16] The L1 door is the forward door on the left side of the airplane, and the R1 door is the forward door on the right side of the airplane. (See figure 3.) These doors were the only doors available to the crew because the other doors had been blocked by cargo modifications.

information contained on that sheet (the classes and locations of the declared hazardous materials on board the airplane) to the incident commander. The flight engineer also told firefighters that the cargo containers holding hazardous materials were located in cargo containers 1L/C and 3R and recommended that the firefighters discharge the airplane's Halon bottles that were connected to those containers, even though the fire appeared to be aft of the hazardous materials containers. The flight engineer also indicated that he told firefighters that the more detailed Part B shipping papers were in a plastic folder on the outside of the cockpit door.

As soon as the occupants had evacuated the airplane, the firefighters punctured the slide at the L1 door and used a ladder to enter the foyer area. They attempted to fight the fire from there using handheld hose lines, but the cargo net and the forward cargo containers blocked their access to the cargo compartment. The flight engineer then provided instructions to the firefighters on how to open the fuselage cargo door using the door controls located on the floor of the foyer area. During these efforts, one of the firefighters broke off the control handle. However, they were able to open the cargo door with the damaged control by using pliers to grip and position the control valve.[17]

After the cargo door was opened, firefighters began attempting to fight the fire by aiming handheld hose lines through the cargo door into the cabin. Within approximately 5 minutes after the cargo door was opened, flames burned through the top of the fuselage. (The airport operations log recorded that flames breached the crown of the fuselage about 0655.) In postaccident interviews, many of the eyewitnesses who described seeing the flames coming through the fuselage did not specify the portion of the fuselage where they saw the first flames. Some of the witnesses, who did specify a location, and video footage taken by firefighters of the right side of the airplane, indicate that early visible flames came through the top of the fuselage at a point approximately even with the trailing edge of the wings (in the area roughly corresponding to the junction of cargo container rows 8 and 9). However, a FedEx mechanic who had assisted firefighters in opening the cargo door said that just before observing the fire erupting through the top of the fuselage he saw paint bubbling, aluminum melting, and "fingers" of fire coming from the left side of the fuselage 5 to 8 feet back from the leading edge of the left wing (which roughly corresponds to the forward portion of cargo container position 6L). One other eyewitness, the ATC tower operator,[18] described the location where he first saw flames appearing as "the first third of the fuselage."

After the flames began venting through the fuselage, the incident commander withdrew the firefighters from the interior of the airplane and reassessed his tactical approach to fighting the fire. Shortly after the fire first burned through the crown of the fuselage, firefighters began using truck-mounted turrets aimed at the breached areas of the fuselage. These firefighting

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[17] According to section 8-18-2 of the FedEx DC-10 Flight Manual, the cargo "door is manually controlled and hydraulically operated…. Pressure for the [door's hydraulic] system is supplied by an electrically operated pump. If electrical power is not available, the door may be operated by hydraulic pressure from a hand pump, or by manually unlatching and opening with a crane."

[18] From the tower, he would have had a view of the left side of the airplane.

efforts continued until approximately 0925, when the fire was extinguished and cleanup operations began.

The accident occurred during the hours of darkness. Stewart is at 41°30.25' north latitude and 74°06.29' west longitude.

1.2 Injuries to Persons

Injuries	Flightcrew	Cabin Crew	Passengers	Other	Total
Fatal	0	0	0	0	0
Serious	0	0	0	0	0
Minor	2	0	0	0	2
None	1	0	2	0	3
Total	3	0	2	0	5

1.3 Damage to Airplane

The airplane was destroyed by fire after landing. The estimated replacement cost of the airplane is about $95 million.

1.4 Other Damage

Most of the cargo was destroyed by fire and smoke and by the firefighting agent applied during the emergency response operation. Insurance estimates of the value of the destroyed cargo totaled about $300 million.

1.5 Personnel Information

The captain, first officer, and flight engineer were certificated in accordance with Federal Aviation Administration (FAA) regulations. A search of FAA records indicated no history of accidents, incidents, or enforcement actions; a search of the National Driver Register indicated no history of driver's license suspension or revocation for the three crewmembers.

1.5.1 The Captain

The captain, age 47, was hired by FedEx on October 8, 1979. He held an airline transport pilot (ATP) certificate with airplane multiengine and single-engine land and commercial pilot ratings, and type ratings in the Boeing 727 (B-727), Cessna 500, Douglas DC-10, and Lockheed L-382.

His first-class medical certificate was issued on August 8, 1996, with the restriction, "must wear corrective lenses." Company records indicate that at the time of the accident, he had accumulated approximately 12,344 total flying hours. He had logged 883 hours in the DC-10 as first officer and 1,621 hours as captain.

The captain's most recent pertinent ground training, flight training, and checks, according to FedEx records, were as follows:

June 6, 1996	Single visit proficiency check (simulator)
June 5, 1996	Recurrent ground training/special purpose operational training (simulator)
June 4, 1996	Recurrent emergency equipment drills/recurrent line oriented flight training (LOFT) [19]
January 26, 1996	Recurrent crew resource management (CRM) LOFT (simulator)
December 15, 1995	Aircraft line check—observed by FedEx check airman
August 24, 1994	FAA en route cockpit surveillance
June 7, 1994	DC-10 transition oral examination
May 25, 1994	DC-10 transition ground training
November 12, 1992	CRM awareness training
November 6, 1990	Initial firefighting with PBE

Before his employment at FedEx, the captain was briefly employed as an air taxi pilot, flying light twin-engine airplanes. Before that, beginning in 1971, he served in the U.S. Air Force as a C-130 pilot.

The captain described his activities for the 72-hour period before the accident. Regarding his sleep cycles, he said he went to bed at 2350 central daylight time (CDT) on September 1, 1996, and awoke at 0900 CDT on September 2. He was off duty on September 2 and 3. He said he went to bed at 2230 CDT on September 2 and awoke at 0700 CDT on September 3; he went to bed at 2000 CDT on September 3 and awoke at 0015 CDT on September 4. On September 4, he served as captain on a flight from Memphis to Boston, which was scheduled to leave Memphis at 0245 CDT. He slept at Boston for approximately 1 hour 45 minutes and arrived back at Memphis at 1116 CDT. He arrived home at 1215 CDT, ate lunch, and ran some household errands. He slept from 1400 CDT until 1800 CDT and had dinner at 1830 CDT. He went to sleep at 2100 CDT.

He awoke at 0015 CDT on September 5, 1996, and checked in for the accident flight at 0125 CDT.

1.5.2 The First Officer

The first officer, age 41, was hired by FedEx on December 27, 1989. He held an ATP certificate with airplane multiengine and single-engine land, commercial pilot, rotorcraft–helicopter, and instrument helicopter ratings, and a type rating in the Douglas DC-9 airplane.

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[19] The captain told Safety Board investigators that during his last flight training session in June 1996, he was given a scenario that involved a cargo fire on a flight from Boston to Newark. He said that the scenario was almost identical to the emergency on flight 1406.

His first-class medical certificate was issued on July 29, 1996, with the restriction, "must wear corrective lenses." The first officer indicated that he was wearing his glasses throughout the accident flight. Company records indicate that at the time of the accident, the first officer had accumulated 6,535 total flying hours. He had logged 1,101 hours in the DC-10 as flight engineer and 237 hours as a first officer.

The first officer's most recent pertinent ground training, flight training, and checks, according to FedEx records, were as follows:

February 28, 1996	DC-10 LOFT simulator training
February 23, 1996	DC-10 upgrade simulator training/check
February 2, 1996	Upgrade DC-10 oral exam
February 1, 1996	Upgrade DC-10 ground training
January 24, 1996	Initial DC-10 emergency equipment drills
March 12, 1995	Aircraft line check—observed by FedEx check airman
July 8, 1992	CRM awareness training
January 9, 1990	Initial firefighting with PBE

Before being employed by FedEx, the first officer served in the U.S. Navy as a naval aviator flying fixed-wing airplanes and helicopters. He began pilot training with the Navy in November 1979.

The first officer described his activities for the 72-hour period before the accident. Regarding his sleep cycles, he said he went to bed at 2030 CDT on September 1, 1996, and woke up at 0830 CDT on September 2. He was off duty on September 2 and 3. He said that he went to bed at 2245 CDT on September 2 and awoke at 0600 CDT on September 3; he went to bed at 2130 CDT on September 3 and awoke 2½ hours later, at 2400 CDT. He left home at 0040 on September 4 and flew on the same flight sequence as the captain. He arrived home on September 4 at 1215 CDT, had lunch, and went to bed at 1245 CDT. He woke up at 1830 CDT, had dinner, and picked up his son from football practice. He went to bed at 2030.

He awoke at 2350 CDT on September 5, 1996, and checked in for the accident flight at 0125 CDT.

1.5.3 The Flight Engineer

The flight engineer, age 45, was hired by FedEx on March 20, 1996. He held an ATP certificate with airplane multiengine and single-engine land and commercial pilot ratings, and a type rating in the B-737 airplane.

His first-class medical certificate was issued on March 11, 1996, with the restriction, "must wear corrective lenses." The flight engineer stated that his glasses are only for distance vision, and that he removes them periodically when he does not need them. He stated that he was not wearing them during the emergency portion of the accident flight.[20] Company records indicate that at the time of the accident, the flight engineer had accumulated 3,704 total flying hours. He had logged 188 hours in the DC-10 as flight engineer.

The flight engineer's most recent ground training, flight training, and checks, according to FedEx records, were as follows:

June 11, 1996	Aircraft line check—observed by FedEx check airman
June 2, 1996	Simulator LOFT training
May 27, 1996	DC-10 simulator training/check
April 29, 1996	DC-10 initial oral examination
April 25, 1996	DC-10 initial oral examination
April 17, 1996	DC-10 emergency equipment drills
April 8, 1996	CRM awareness training
March 25, 1996	Initial firefighting with PBE

From October 1995 until his time of employment with FedEx, the flight engineer was employed as a DeHavilland DHC-8 (Dash-8) first officer by Horizon Air. He flew the Cessna 310 for Copper State Air Service from February 1995 until October 1995. He also flew jet trainers and fighters in the U.S. Air Force.

The flight engineer described his activities for the 72-hour period before the accident. Regarding his sleep cycles, he said he went to bed on September 1, 1996, at 2100 CDT and awoke at 0600 CDT on September 2. He was off duty on September 2 and 3. He said that he went to sleep at 2100 CDT on September 2 and awoke at 0600 CDT on September 3; he went to sleep at 1830 on September 3 and awoke at 2400 CDT. On September 4, he flew on the same flight sequence as the captain and first officer. After he arrived home, he exercised, ate lunch, and took a 2-hour nap. He awoke and had dinner at 1700 CDT. After dinner, he went to bed, sleeping approximately 6 hours.

He awoke at 2400 CDT on September 5, 1996, and checked in for the accident flight at 0115 CDT.

1.6 Airplane Information

N68055, a DC-10-10CF, serial number (SN) 47809, was manufactured by the Douglas Aircraft Company and was issued an airworthiness certificate on January 21, 1975. The airplane was originally operated by Continental Airlines; FedEx acquired the airplane on May 14, 1980. In May 1989, the airplane underwent supplemental type certificate (STC) modifications to its cabin interior, changing its configuration from a passenger-carrying to a cargo-only full

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[20] The Safety Board understands that the FAA is aware of, and is taking action to address, this issue.

freighter airplane. These STC modifications included changes to the overhead cabin ventilation ducting, and installation of smoke detectors, cabin floor pallet tiedown and movement systems, and panels covering the interior walls.

A review of the airplane records revealed that a possible hazardous materials spill (of an unknown white powder) was reported on August 5, 1996, and was cleaned up on August 23, 1996. The spill occurred on the right side and at the rear of the main cargo deck areas at cargo container positions 14R, 15R, and 16R. Testing at that time found the spilled substance not to be corrosive, and no further action was taken. No other pertinent discrepancies were noted in the maintenance logs, the minimum equipment list (MEL),[21] or the configuration deviations list (CDL).[22]

As of September 5, 1996, N68055 had been flown 38,271 hours, with 17,818 cycles. Three General Electric CF6-6D engines powered the airplane. The takeoff gross weight of the airplane was 364,144 pounds. The maximum allowable takeoff gross weight was 446,000 pounds.

1.6.1 Air Ventilation System

The air conditioning/ventilation system on the DC-10 consists of three environmental control units (air conditioning packs) located beneath the main cabin floor. The three packs feed conditioned air through a distribution system for cooling/heating the airplane's cockpit and cabin compartments. (The system also provides pressurized air for cabin pressurization.) On the accident airplane, air entered the main cabin from an overhead duct just aft of the cockpit in the foyer area.

The STC modifications to the accident airplane in 1989 included modifications to the overhead cabin ventilation ducting. No tests of upper cabin airflow patterns have been conducted on this airplane configuration or with cargo pallets in place. A Boeing systems engineer with Douglas Products Division who is familiar with the DC-10 ventilation system testified at the Safety Board's deposition proceeding that although there is an attempt to minimize axial airflow[23] on passenger airplanes as much as possible, axial flow can and does occur in cargo configurations. A FedEx engineer who is familiar with the accident airplane's configuration testified that he had observed axial (aft-flowing) airflow in an empty cargo airplane (i.e., without any cargo containers in place).

Safety Board investigators considered conducting smoke/fire tests to observe what the airflow patterns would have been during the accident sequence. However, because any such

[21] The MEL lists items of aircraft equipment that may be deferred when inoperable. The MEL is developed by each operator of an aircraft and must be equivalent to or more conservative than the master MEL, which is developed by the manufacturer and approved by the FAA.

[22] The CDL lists changes to the aircraft configuration that may be deferred.

[23] Airflow along the airplane's longitudinal axis (fore and aft).

test would have had to include a re-creation of the heat produced by the fire (and not just the smoke) and also the effects of the airplane's maneuvering at altitude, the members of the fire group determined that no meaningful tests could be done safely.

To further study the ventilation system, on January 30, 1998, Safety Board investigators examined an undamaged FedEx DC-10 with the same configuration as the accident airplane. From the initial entry point behind the cockpit, air was routed both into the cockpit area and into the main cargo cabin. The main cargo cabin ducting consisted of a 12-inch diameter fiberglass duct installed in the crown of the cabin. Eight outlets from the main overhead duct (the first of which was installed at fuselage station (FS) [24] 700 and the last at 1740) directed conditioned air into the cabin. (The outlets were 4-inch tubes that extended about 4 inches down into the cabin from the main duct.)[25] The air exited the cabin through a series of metal floor vents installed in the cabin floor where the floor abutted the cabin walls. The floor vents were 9.48 inches high and between 10.5 and 16.25 inches long. The floor vents were not evenly distributed; more were installed in the aft portion than in the forward portion of the main cargo cabin. (See figure 5 for the arrangement of floor vents.) After exiting the floor of the main cargo cabin, the air passed through holes, known as cusp holes,[26] and exited the airplane from the outflow valve, which was located on the left side of the airplane forward of the wing.

The accident airplane's pneumatic systems were examined for abnormal conditions or malfunctions. The pneumatic lines from the engines and the auxiliary power unit were found attached to the airframe except in the areas where the aft fuselage had separated during the postlanding fire. The pneumatic lines from the environmental control units were examined. They remained attached to the airframe throughout the lower portion of the airplane.

1.6.1.1 Cabin Air Shutoff

According to the March 20, 1994, edition of FedEx's DC-10 Flight Manual, page 8-2-1:

> Three shutoff valves are installed, one in each cabin conditioned air supply duct…. A single handle recessed in the cockpit ceiling above the second observer [flight engineer] operates the three shutoff valves in the cabin conditioned air manifolds and the overpressure relief valve in the main conditioned air manifold.

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[24] See figure 1 for fuselage station locations.

[25] The main cabin smoke detectors, most of which are mounted on the main overhead air duct, are also suspended about 4 inches beneath the duct.

[26] Cusp holes allow air to flow from the upper cabin to below the floor and eventually to the outflow valve.

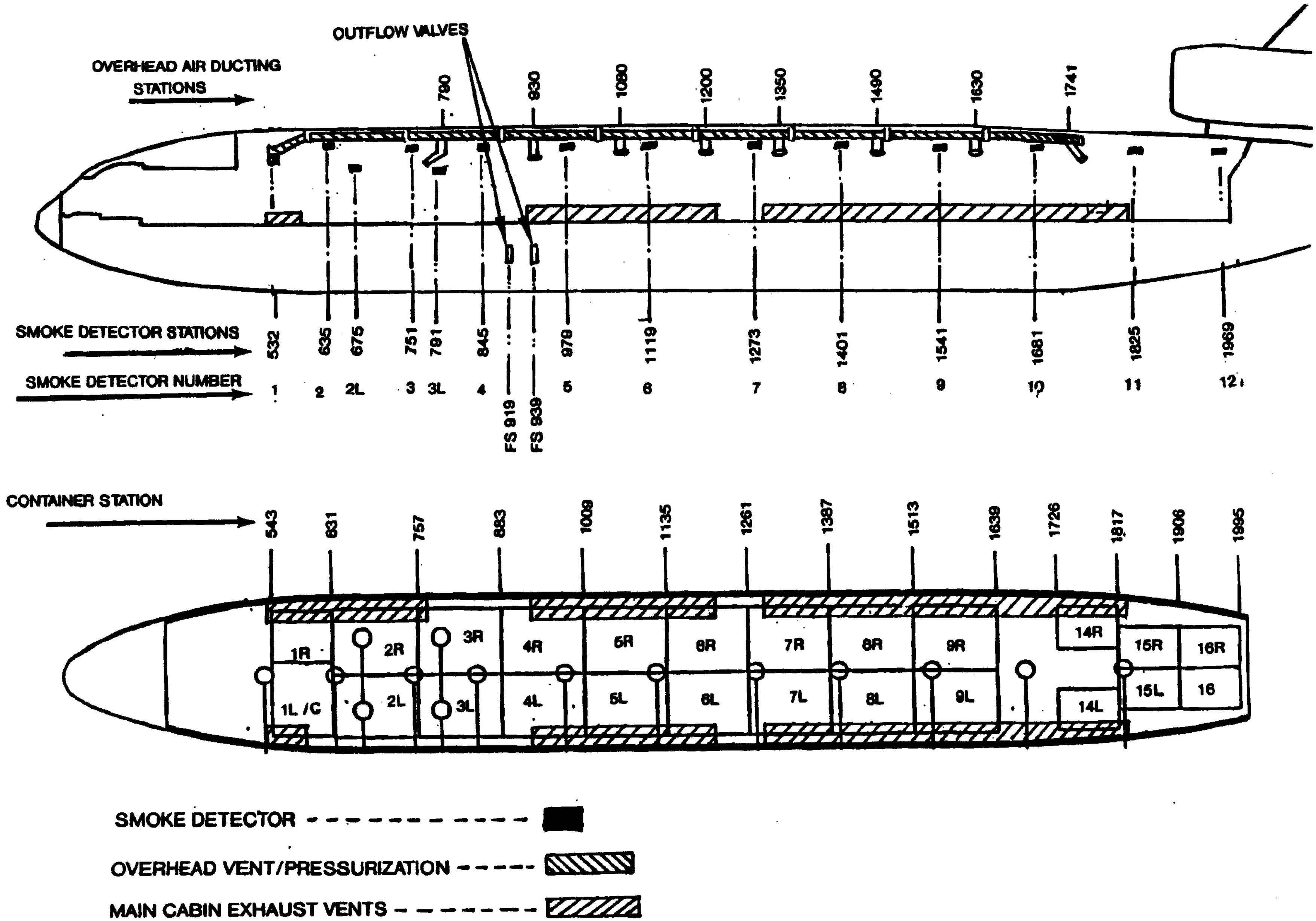

Figure 5.—DC-10-10, N68055, cargo container, smoke detector, and main cabin overhead ducting locations.

> In the event of smoke indication in the cabin cargo compartment, pulling the handle shuts off all air to the cabin and opens the relief valve under the floor to dump excess air directly to the pressure control outflow valves.

1.6.2 Cabin Pressurization System—Cabin Outflow Valve Control

According to the March 20, 1994, edition of FedEx's DC-10 Flight Manual, page 8-2-2/8-2-3:

> Cabin pressure is controlled and maintained by metered release of conditioned air in either an AUTO, SEMI-AUTO, or MANUAL mode…. The cabin pressure controller maintains the desired cabin pressure in relation to the altitude set…. In the AUTO mode, cabin pressurization is automatically controlled during takeoff, climb, cruise, and descent conditions to the lowest cabin altitude compatible with aircraft and flight requirement.
>
> When MANUAL control is selected, the control wheel engages a locking mechanism to secure the outflow valve in its existing position. After selection, manual control is achieved by pressing the control wheel inward (to disengage the control wheel locking device) and rotating the wheel to position the outflow valve to attain the desired cabin altitude. When the control wheel is released, the outflow valve is again locked in its existing position. Selecting the valve at more than two-thirds open can cause a negative pressure and create a noise in the cabin. At touchdown, the Second Officer [flight engineer] must manually depressurize the aircraft.

In the DC-10, the manual cabin outflow valve control wheel projects vertically through the flight engineer's panel. Approximately one-third of the wheel projects through the panel. During a ground test conducted by a Safety Board investigator on a similar DC-10, two full manual cranks of the outflow valve control wheel in the cockpit did not perceptibly open the outflow valve from the full-closed position. (During the test, a full "crank" of the control was considered to be the most rotation of the wheel that could be obtained with one hand motion.) During the test, the valve began to perceptibly open after about 3 full cranks and was completely open after about 16 full cranks.

1.6.3 Fire/Smoke Detection System

Smoke detection systems were installed in the main cargo cabin and lower cargo areas. The smoke detection system consisted of 16 main deck smoke detectors suspended from the cabin ceiling, each of which was connected to an indicator light in the cockpit, and 4 lower forward cargo compartment detectors. Postaccident examination of the smoke detection systems in the upper cabin cargo area revealed that they had been destroyed by fire. The lower cargo compartment detectors were in place and were not damaged. The system could not be functionally tested because of the damage to the upper cabin system and the associated wiring bundles.

The airplane had fire extinguishing systems for each of the three engines (two bottles for each engine) and one bottle for the forward lower cargo compartment. In addition, three Halon fire extinguishers were installed in the forward portion of the main deck cargo compartment connected to cargo container 1L/1C.

Examination of the engines' fire extinguishing systems revealed that on some of the bottles, the squibs (discharge devices that rupture to discharge the fire extinguishing agent in the bottle) had discharged. The No. 1 and No. 3 engines each had bottle 1 fired, and the lower cargo compartment had its bottle fired. None of the three main deck Halon bottles had been used. Neither of the No. 2 engine squibs had discharged.

1.6.4 L1 Forward Passenger Door Design and Operation

The L1 and R1 cabin doors are plug-type doors that are normally powered up and down by an electric motor through a gearbox, cable drums, sprockets, and torque tube, and 1/8-inch nylon-coated drive cables that are attached to the door. During emergency operation, an air motor drives the door open through the same electric motor gearbox, cable drums, sprockets, torque tube, and drive cables. The air motor supply is provided by an air bottle charged with nitrogen to 1,500 psi. When the door handle is moved to the emergency position, the air motor opens the door within 9 seconds. A fully charged bottle is capable of providing air pressure for up to approximately 30 seconds. The door is designed to open when activated when the cabin pressure differs by less than approximately 0.5 psi from the external pressure. If an attempt to open the door is made with the pressure differential greater than 0.5 psi, the bottle pressure will bleed off and the door will not open. A ratchet-type lock prevents the door from closing all the way if it is only partially opened.

1.7 Meteorological Information

The weather logged by the Stewart tower when flight 1406 landed was as follows:

> Wind from 280^{o} at 4 knots; surface visibility 2 statute miles restricted by mist; a broken layer of clouds at 3,000 feet above the ground and an overcast layer of clouds at 7,000 feet above the ground; temperature 64°F (18°C); dew point 63°F (17°C); altimeter setting 30.18 inches of Hg.

1.8 Aids to Navigation

No problems with aids to navigation were reported.

1.9 Communications

No communications difficulties were reported.

1.10 Airport Information

Stewart is located approximately 3.5 miles northwest of Newburgh, New York, and has a published elevation of 491 feet above sea level. The airport has two intersecting runways oriented approximately east-west (runway 9-27, which is 11,818 feet by 150 feet) and northwest-southeast (runway 16-34, which is 6,006 feet by 150 feet). The airport is certificated under 14 CFR Part 139 and is an Index C aircraft ARFF facility.[27]

1.11 Flight Recorders

A digital flight data recorder (FDR) and a CVR were installed in the airplane. The FDR was a 37-parameter Sundstrand Model UFDR (SN 2783). The CVR was a Fairchild Model A100 (SN 4225). Both recorders were removed from the airplane by investigators and sent to the Safety Board's laboratory in Washington, D.C., for readout.

1.11.1 CVR

The four channels of the CVR contained information from the cockpit area microphone, the captain's position, the first officer's position, and the flight engineer's position. Although the top of the CVR unit was lightly coated with a soot-like substance, it did not show evidence of either fire or structural damage. The quality of the recording was excellent.[28] A transcript was prepared and is included as appendix B.

1.11.2 FDR

The FDR showed evidence of slight thermal damage and sooting, but the recording medium was undamaged.

1.12 Wreckage and Impact Information

The upper cargo containers and fuselage were destroyed by fire. The fuselage had separated in two places: at FS 1531, just aft of the rear wing spar, and at FS 1986, just forward of the aft pressure bulkhead. Several areas of the fuselage were consumed by fire. (See section 1.14.) Examination of the L1 and R1 doors found that the doors were seized in their respective

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[27] 14 CFR Sections 139.319 and 139.315 require, for scheduled air carrier service with aircraft at least 126 feet long but less than 159 feet long, that the airport be equipped with a minimum of two ARFF vehicles with a total quantity of water of at least 3,000 gallons for foam production.

[28] The Safety Board uses the following categories to classify the levels of CVR recording quality: excellent, good, fair, poor, and unusable. Under the recently revised definitions of these categories, an "excellent" recording is one in which virtually all of the crew conversations can be accurately and easily understood. The transcript that was developed may indicate only one or two words that were unintelligible. Any loss in the transcript is usually attributed to simultaneous cockpit/radio transmissions that obscure each other.

tracks with severe heat damage around the door jambs and their drive cables. (See figure 3 for location of L1 and R1 doors.)

The nose of the airplane was lightly sooted above both cockpit windows. The area above the L1 door was burned and sooted. The fuselage above the L1 and R1 doors was heavily sooted, with soot trailing outwards from inside the airplane. The top two-thirds of the R1 door was also heavily sooted. The window in the R2 door was ruptured inwards. No smoke, soot, or fire damage was observed in or around the ruptured portion of the door.

A light residue of soot and oil was observed trailing aft from both air conditioning pack cooling outlets on the left side of the fuselage. There was a 6-inch diameter hole on the left side of the airplane, forward of the main cargo door, slightly below the window line. Heavy soot trailed approximately 2 feet aft of the outflow valve along the left side of the fuselage. The cargo door's hydraulic line remained attached at the lower right side of the fuselage and at the upper fuselage crown at the centerline attachment. No evidence of soot or fire damage was found on the lower fuselage and belly of the airplane.

The vertical stabilizer, rudder, horizontal stabilizers, and elevators were intact and free of fire damage. The No. 2 engine nacelle was sooted about 4 feet aft of the engine intake and was burned through the lower nacelle at four locations that corresponded to the consumed fuselage below the nacelle. The right side of the No. 2 engine pylon and exterior fuselage were sooted and burned from the top of the engine pylon to fuselage longeron[29] 13 at the right horizontal stabilizer fairing. (See figure 6 for a diagram of longeron locations.) The tailcone and lower fuselage skin were compressed vertically along its bottom surface, and there was a vertical wrinkle 2 feet from the end of the tailcone.

The lower cargo compartments, wings, landing gear, and No. 1 and No. 3 engines were undamaged and free of soot or fire damage.

At the separated empennage section, the upper interior fuselage crown and the canted area of the aft pressure bulkhead were heavily sooted between longeron 15 left and longeron 23 right. Four of the upper fuselage ring frames were burned and melted between longeron 1 left and the upper canted bulkhead, parallel to longerons 18 left and right. The No. 2 engine bleed air duct was separated about 3 feet forward of the bulkhead. Electrical wires protruded about 20 feet from the aft pressure bulkhead and had cut and separated ends. The wire insulation remained intact on the wires that protruded from the left side of the aft pressure bulkhead, and the wire insulation was burned around the wires that protruded from the right side of the aft pressure bulkhead. No evidence of arcing of airplane wiring was seen. The lower section of the aft pressure bulkhead that was common to the lower cargo area was undamaged and had no soot or fire damage.

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[29] Longerons are the principal longitudinal structural members in an aircraft fuselage.

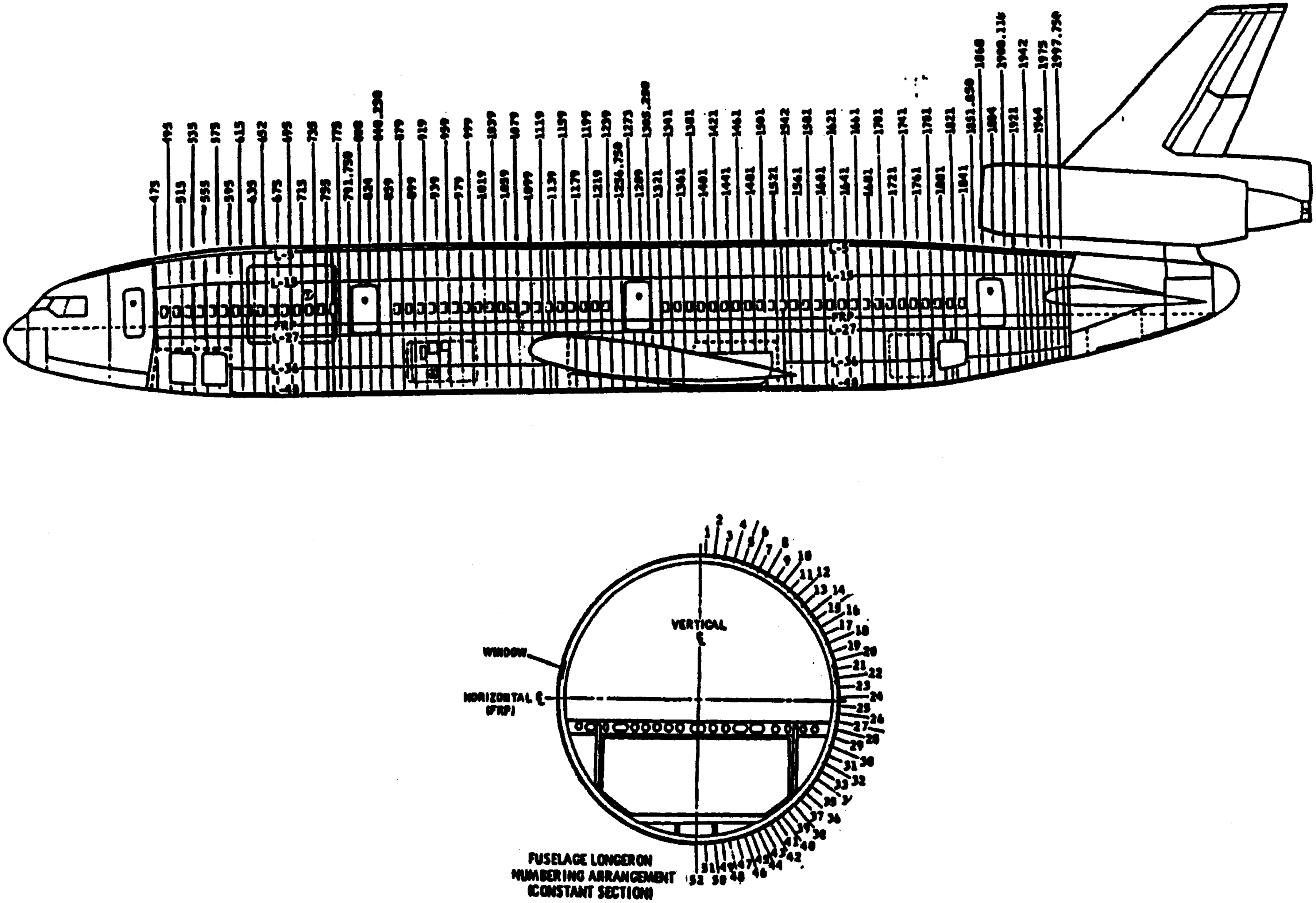

Figure 6.—DC-10-10, N68055, fuselage station and longeron number locations.

The left No. 1 engine and its engine pylon and the right No. 3 engine and its engine pylon were structurally intact and were attached to the fuselage. Neither of these engines or their pylons had any sooting or heat damage.

1.13 Medical and Pathological Information

The captain, first officer, and flight engineer submitted urine specimens approximately 25 hours after flight 1406 landed. The specimens were analyzed and found to be negative for THC,[30] cocaine, phencyclidine (PCP), amphetamines, and opiates. The results of the postaccident breath alcohol tests conducted approximately 25½ hours after flight 1406 landed were invalid under DOT regulations because of the elapsed time since the accident.

1.14 Fire

1.14.1 Fire Damage to Lower Cargo Compartment

No evidence of smoke or fire was observed on any of the cargo containers from the lower forward and lower center cargo compartments (the lower aft cargo compartment was empty). The undersides of the main deck cabin flooring, above the center accessory compartment, had several areas where the bottom fiberglass face of the main cabin flooring was scorched. Two larger scorched areas were found near the forward inboard side near FS 1149, below the 6R container position. A smaller scorched area was found under the forward outboard side of FS 1515 (at the interface of container positions 8L and 9L), and another smaller scorched area was found between FS 1641 and 1661 (under the vacant area aft of cargo container row 9). There was some melting of the insulation blanket cover under the cabin return air grills in the right forward corner of the center cargo compartment. Burned debris from the cabin had also fallen through the return air grills in that area.

1.14.2 Fire Damage to Upper Cargo Compartment

There were melted and partially consumed aluminum fuselage skin, longerons, and frames[31] throughout the interior fuselage. The cabin interior of the forward fuselage was burned and sooted between FS 470 and 765. The cabin sidewall panels in that area were destroyed by fire on the right side of the fuselage, exposing the burned and melted fuselage ring frame flanges. The center of the fuselage crown was consumed by fire from FS 515 through 575, above container row 1. (See figure 7.) Two small areas of fuselage crown were consumed by the fire between FS 595 and 615 on the right side of the fuselage and between FS 615 and 635 on the left side of the fuselage, also above container row 1. The center of the fuselage crown was consumed in the area of the main cabin cargo door from FS 635 through 735, above the location of cargo container row 2.

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[30] Delta-9-tetrahydrocannabinol (marijuana).

[31] The frames run laterally every 20 inches along the airplane fuselage and provide support for the longerons.

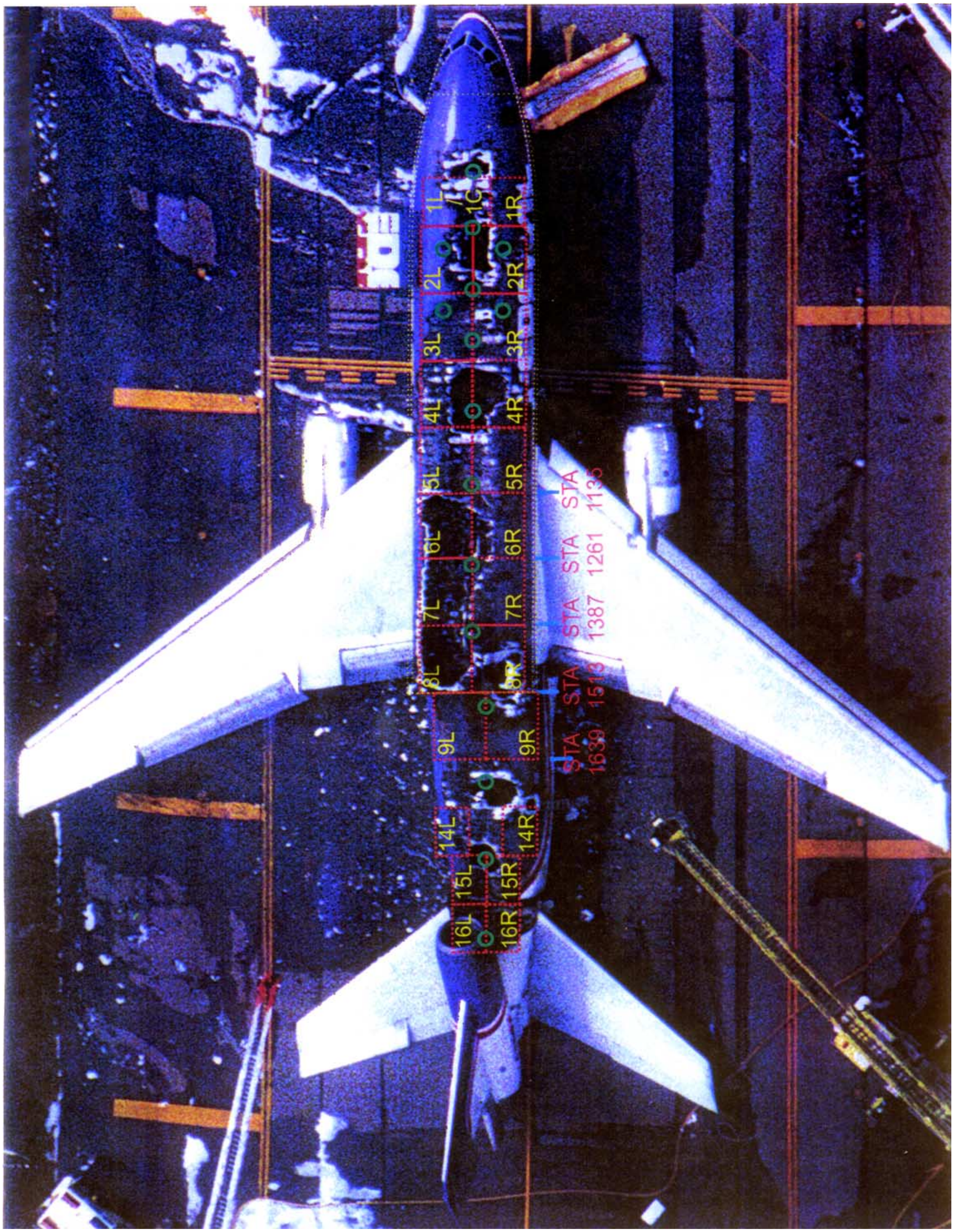

Figure 7.—DC-10-10, N68055, airplane with overlaid cargo container positions

The cabin sidewall panels were lightly sooted and remained attached to the left side of the fuselage between FS 450 and 840, above container position 3L. Burned and sooted upper sidewall panels hung down directly above the attached lower sidewall panels. The right side of the fuselage between FS 808 and FS 919, next to container position 3R, exhibited severe heat and fire damage, along with melted fuselage frame flanges. The airplane's exterior paint was scorched and bubbled on the left side, next to the first two windows between FS 859 and 899, near the aft of container row 3 and the front of container row 4.

The fuselage crown was consumed by the fire between FS 939 and FS 1039, from approximately the middle of container row 4 to the middle of container row 5. The frame flanges on either side of this consumed area of the fuselage crown were burned and melted. The left side of the fuselage crown was also consumed by fire between FS 1179 and FS 1531, an area corresponding to approximately the middle of cargo container 6L to the middle of cargo container 9L.

Light soot deposits were found on the cusp holes under the cabin floor vents and on floor structural components on the right side of the cabin between FS 1039 and FS 1099, outboard of the 5R position (on the accident flight, position 5R was occupied by a loaded cargo pallet, not a cargo container). A floor vent panel at FS 1119 was melted. Intense heat and fire damage was observed in the area of container position 6R at the level of the cabin cargo deck floor on the right side of the fuselage. Three floor vent panels outboard of container 6R were melted or fire damaged, including a floor vent panel between FS 1199 and 1219, which was melted on the corner near FS 1199 and at FS 1139, where the baffle and floor vent grill were melted. The bottom surface of cargo container 6R was melted through the bottom of the container onto a seat track and through the cargo compartment floor into the lower cargo compartment. No other cargo container floors or bottom surfaces were breached.

Examination of the section of the fuselage that separated at FS 1531 and FS 1986 revealed interior skin sooted throughout the crown. Soot deposits on the left side of the cabin interior just forward of FS 1531 (which was at the front of cargo container row 9) were in a "V" pattern with the lowest point of the "V" being on the floor level at the fuselage separation point. At this separation, there was no evidence of thermal damage to the cabin floor or to the fuselage structure. The fiberglass floor board on the left side outboard between the interface of containers 8L and 9L was burned. Examination of the left outboard airplane structure just aft of the separation showed soot deposits on the lower outboard floor panel between FS 1561 and FS 1581, adjacent to cargo container position 9L. There was no evidence of soot deposits on the floor beam lightening holes[32] between FS 1541 and FS 1561. The left side blow-out panel[33] between FS 1561 and 1581 showed no evidence of heat damage.

[32] Lightening holes are areas of the aircraft structure left out (by the manufacturer) to reduce weight without compromising the strength of the aircraft.

[33] Blow-out panels are small areas of the floor designed to fail at certain pressure differentials to provide in-flight decompression venting (to prevent overall failure of the floor structure).

There was a melted aluminum shield (a small wall panel that abuts the floor) between FS 1581 and 1601 (outboard of 9R). The ventilation grill at this point was intact. There was no evidence of soot flow along the left or right side tunnel in the area of the blow-out panel or on the cusp holes under the floor. The binder in the fiberglass floor board on the outboard left side of FS 1641 was burned away, leaving only the fiberglass strands. (No containers were in this area [FS 1639-1728] on the accident flight.) There was some scorching of the underside of the floor panel between FS 1641 and 1661. This heat damage was about 24 inches to the right of the airplane centerline. Cabin sidewall panels on the left side of the cabin between FS 1621 and 1851 were burned and sooted throughout the upper half of the panels (this area began above container 9L and extended through the forward portion of container 15L). A portion of the seat track in the cabin floor was melted between FS 1641 and 1656. The fuselage skin and frames between FS 1900 and 1986 were undamaged.

The center of the fuselage crown was consumed by fire between FS 1741 and 1781, above container row 14. The fuselage crown frames forward and aft of FS 1741 and 1781 were melted, and the fuselage skin was consumed on the right side of the fuselage between FS 1781 and 1821. The area surrounding the consumed skin was free of soot. Light sooting was observed above the horizontal stabilizer between FS 1986 and 2163. The center of the fuselage crown was also consumed by fire between FS 1868 and 1942, above container rows 15 and 16.

Three cabin fluorescent light ballasts were recovered. One ballast was found in container 6R, one in container 4L, and one next to the forward cargo door near FS 695. All were fire damaged but showed no evidence of arcing or internal failure. The switch for the cabin fluorescent lighting, which was installed on a control panel aft of the L1 door, was found in the "off" position. A FedEx representative reported that the main cargo compartment fluorescent lights are normally turned on during cargo loading at night and are turned off before flight.

During the on-scene portion of the investigation, four aerosol cans were found in the debris on the main cabin floor. Two of them were found in the area between cargo containers 6R and 7R. The tops of both of these cans were intact. The propellant filling port plug on the bottom of one was missing; the plug on the bottom of the other one was present. Two additional cans were found in the area of container 9L. The tops of both of these cans were missing, and the metal bodies where the tops attached were unfolded (uncrimped).

A specially trained accelerant residue detection K-9 Labrador retriever (trained to detect ignitable vapor residues from petroleum products, alcohol, and other common accelerants), was brought into the main cargo compartment a few days after the accident to check for accelerant residue. No accelerant residue was detected.

1.14.2.1 Damage to Cargo Containers and Contents[34]

After the accident, the cargo containers that had been in the main cabin were removed from the airplane and arranged in the same order in which they had been in the airplane. The bottom surface of each container was examined and photographed as the containers were removed. None of the container bottom surfaces exhibited evidence of fire damage except for container 6R. The forward inboard corner (as viewed from aft looking forward with container 6R in its original position in N68055) of container 6R's bottom surface was melted.

The cargo containers were arranged with a 10-foot wide center walkway and about 2½ feet between the forward and aft sides of the containers for walkaround space. Orange rubber traffic cones were placed along the center walkway to simulate the positions of the cargo compartment smoke detectors in relationship to the individual positions of the cargo containers. One-inch wide orange plastic surveyor's tape was connected to cornerposts of each cargo container, front to rear, on both sides to trace the height of the burned and melted container corner posts. A conical "V" burn pattern was observed from right to left and from forward to rear with the lowest (deepest burned) area centered over container 6R.[35] It was observed that the cargo in containers surrounding 6R (position 6L, 7R, and 5R) was burned to a greater depth along the sides next to container 6R than in the other areas of those containers. For example, the cargo in container 6L was burned to the floor along the inboard (right) side of the container, which bordered on 6R. Likewise, the cargo in container 7R was burned deeper along the container's forward edge (next to the aft of container 6R). An overhead view of the cargo containers also showed that the deepest (lowest level of consumed wreckage) fire damage had occurred at container 6R.[36]

Container 6R's aluminum roof, three Lexan[37] walls, and nylon roll-up curtain (the fourth wall) were completely consumed by fire, except for a small portion at the bottom center of

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[34] The Safety Board's fire group was assisted with the examination and documentation of the fire-damaged cargo containers by investigators from the New York State Office of Fire Prevention and Control Arson Bureau (who conducted an independent examination a few days after the initial investigative team), and a safety specialist from FedEx.

[35] According to basic fire science, a "V"(cone-shaped) burn pattern usually narrows at the point or area of the fire's origin; as the fire propagates, the cone widens as the fire spreads out to reach fuel. See, e.g., National Fire Protection Association's *Guide for Fire and Explosion Investigations*, NFPA 921, 1995, "The analysis of fire patterns is performed in an attempt to trace fire spread, identify areas and points of origin, and identify the fuels involved." [Par. 4-1]; "The angled lines of demarcation, which produce the 'V' pattern, can often be traced back, from the higher to lower levels, toward a point of origin. The low point or vertex of the 'V' may often indicate the point of origin." [Par. 4-17.1]

[36] The row of cargo containers on the left side of the airplane exhibited a similar burn pattern to that seen on the right side, except that generally less fire damage was observed on the left side cargo containers and their contents, and the melted cornerposts on the left side were taller than the cargo container posts on the right side of the airplane.

[37] Lexan is a polycarbonate product manufactured by General Electric Plastics. It is easily molded and is typified by its high-impact resistance.

the aft Lexan wall.[38] The outboard forward cornerpost was completely consumed. The outboard aft cornerpost measured 3 feet 9 inches, the inboard forward cornerpost measured 1 foot 2 inches, and the inboard aft cornerpost measured 3 feet 6 inches. The roll-up door spring assembly, including the spring cover, was melted to the floor near the inboard forward cornerpost. Solidified melted aluminum was puddled on the container floor along the inboard side of the container floor. Portions of the container's 8-inch high aluminum lower sidewall had melted along the outboard, inboard, and forward sides of the container.

Other containers that sustained significant fire damage were those in positions 6L, rows 7 and 8, and 9R. Appendix D describes in detail the damage to each of the cargo containers from the main cabin, except for containers 1L/1C and 3R, which contained declared hazardous materials and are described below.

Containers in positions 1L/1C and 3R contained declared hazardous materials. The container in position 1L/1C was a full-contour aluminum container designed for hazardous materials. The container, when viewed from the side with its access door facing forward, had soot in varying degrees of thickness on the outside of the upper half of the container. The roof of the container had a hole approximately 12 inches left of its center and about 4 inches in from the edge of the door side. The hole was 16 to 18 inches long (left to right) and 12 inches deep (forward-aft dimension) and was centered in an area that had been dented inward. FedEx reported that the hole had been caused by the equipment used to remove the container from the airplane after the fire. No soot was observed on the container's interior surfaces. A small amount of water was present on the floor of the container.

The contents of container 1L/1C were secured by netting, and the packaging was tight and in place. No discrepancies were noted during the postaccident examination regarding the separation, segregation, and orientation of the packages in the container. On September 8, 1996, each package within the container was also inspected. The package containing a vial of an infectious substance (HIV) appeared to be undamaged and was opened and examined. The inner contents were intact and undamaged. One package containing a flammable liquid showed signs of wetness along the bottom of the package, even though this box was on top of another box within the container. When the wet box was opened, a cooler pack was found to be the source of the wetness; the glass bottle of flammable liquid within the box was not damaged and did not leak. Other than the light sooting of some packages, there was no evidence of damage or leakage from any of the other packages in this cargo container.

The container in position 3R was a full Lexan container. It had an aluminum floor, roof, frame, Lexan sides, and a draw-down nylon curtain to cover the door or opening of the container. Eighty percent of the roof, 100 percent of the rear wall opposite the door, 75 percent of the left side, and 75 percent of the right side were consumed by fire. The floor area of the container was intact. The inboard cornerposts were intact; the outboard cornerposts were slightly burned at the top.

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[38] This portion of the remaining wall had pieces of a cardboard box imbedded in it.

The cargo container was emptied and its radioactive contents inventoried. All of the inner containers for the radioactive materials were found intact. Ten separate shipments of radioactive materials were found in the container. All other recognizable shipments declared as hazardous materials were also unloaded from 3R and inventoried. Some contents were consumed by fire; others had sustained some level of water and/or fire damage. Excluding the 10 radioactive shipments, 36 packages were identified and inventoried as hazardous materials.

1.14.2.1.1 Contents of Cargo Containers in Position 6R and in Rows 8 and 9

Each of the containers was inspected to assess the degree of its fire damage and the depth to which its contents were burned.[39] A layered inspection of the debris in each cargo container[40] was initiated starting with the top, outermost layer of burned cargo and working inward and down towards the center of the cargo. The examination revealed that container 6R was the only cargo container that exhibited fire damage throughout its debris and down to the container floor. The investigation found four cargo shipments in container 6R:[41] one consisting of industrial metal valves, one consisting of a DNA synthesizer, and two separate computer shipments. All of the contents of 6R were removed and examined.

The metal valves were found in the aft outboard corner of 6R. The various-sized valves were stacked on top of cardboard on a single wooden pallet, wrapped in newspaper, and banded with steel bands. Some of the newspaper wrapping was slightly discolored by heat but had not been impinged by flames. Other portions of newspaper and cardboard were charred. The aft part of the pallet was unburned under the cardboard, but the forward part of the pallet was charred and burned. A variety of electronic equipment was also found in the remains of container 6R: a Texas Instruments Extensa laptop computer; two Power Station power servers; a

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[39] During the on-scene portion of the investigation, no separate search was conducted specifically for undeclared hazardous materials. However, investigators were told that any items discovered during the search that appeared to be potentially hazardous were to be provided to the hazardous materials group for further evaluation. Also, as discussed below, in November 1997, the debris stored in boxes labeled 9L and 9R was examined in detail. During this examination a hazardous materials investigator searched specifically for undeclared hazardous materials. Further, in March 1998 all of the stored cargo debris was searched for possible undeclared hazardous materials.

[40] Some items might have come to rest in cargo containers other than those in which they were originally loaded. Firefighters reported that some cargo debris had been spread around from the force of the water being sprayed on the fire.

[41] The FedEx cargo manifest indicated the shipments (identified by airbill number) that were loaded into each cargo container, but did not include descriptions of the contents of each shipment. The manifest listed only airbill numbers and information about the shipper and receiving party. The nature of the shipments in container 6R was determined by inspecting the contents of the container and by information obtained by FedEx when it contacted the four shippers of the items in 6R. Although FedEx made the cargo manifest for the accident flight available to the Safety Board, it was not considered useful to the Safety Board's investigation and it was not provided to the other parties to the investigation. FedEx indicated that the manifest is "proprietary, confidential, and contains information about FedEx customers which we do not ordinarily release to third parties." (January 22, 1998, letter from FedEx to the Safety Board.)

computer manufactured by Power Computing Company; and a DNA synthesizer Expedite Model 8909 manufactured by PerSeptive Biosystems. Investigators examined all of this equipment to assess internal and external fire damage and to search for possible ignition sources.

The Extensa plastic computer case was partially melted and burned along its left side, but the remainder of the case was undamaged and remained encased in its Styrofoam and plastic packaging materials. The computer was pried open, and a service invoice was found between the keyboard and computer screen. The invoice revealed that the computer had been repaired by Texas Instruments on the day before the accident. When questioned by investigators, the Texas Instruments technician who repaired the computer stated that the computer's connectors to the hard drive had been upgraded. According to the technician, the computer's battery had not been recharged before it was shipped to its owner. Further examination of the computer components and its battery pack found that the left side of the plastic computer case was burned and melted, exposing the end of the battery pack. (The Extensa laptop is equipped with two rows of seven nickel metal hydride batteries mounted to a plastic circuit board.) The plastic covering on two of the outboard batteries in the pack was burned and melted, exposing the metal cases, which were undamaged. The remainder of the batteries and the circuit board were intact and showed no further fire damage. A voltage check across the positive and negative battery leads measured 0.26 volt. No other fire damage was noted on the interior of the computer.

On the two Power Station power servers, the plastic external surfaces were melted and charred. No batteries or other power source was found in the power servers. No fire damage was found inside the units.

The outer case of the Power Computing Company computer was burned on the front of the case. No evidence of internal fire damage was found in the unit. No batteries were found inside the computer. Several coils of burned and charred computer connection cables were found near the power server and the computer monitor.

The following additional items, some of which were burned, were found among the debris in 6R:

- Packages labeled Warrick Pharmaceutical Albuterol Sulfate USP Inhalation Solution .083 percent, and packaging and products labeled Sodium Chloride Inhalation Solution.
- A partially melted plastic bottle labeled ICE P___, empty B___, Contain water on___[42]
- A box labeled Texas Instruments Computer Box.
- Pieces of broken glass bottles (similar to wine bottle glass).
- Pieces of broken, flat, clear glass.
- Various unidentified electronic/electric components imbedded in melted and solidified aluminum.
- Pieces of copper wire conductor of various gauges with many areas of melted copper.

[42] "___" indicates illegible/melted lettering on the plastic bottle.

- An unknown green, red, and cream-colored material on the inboard side of the container floor.
- Fluid that leaked from a large, silver-colored valve.

(An analysis and identification of the unknown green, red, and cream-colored material and the fluid sample are discussed in section 1.16.1.)

After removing the burned debris from container 6R, the container floor was examined. It consisted of an aluminum top skin covering an aluminum framework that was on top of another aluminum bottom skin. Most of the top skin of the flooring was melted and had sagged down between the supporting framework underneath it. In several areas, the flooring had melted through the bottom skin as well. Along a portion of the inboard edge of the container (beginning approximately 3 feet aft of the front wall) molten aluminum had flowed through the container floor onto the cargo tracks on the cabin floor in that area and had resolidified. The floor along the aft edge of the container under the three wooden pallets that had supported the industrial valves, computer equipment, and the DNA synthesizer, respectively, was not melted.

Because of the comments on the CVR regarding the smoke detector activation sequence and because of the early fuselage crown burnthrough observed by ground witnesses in the area of cargo rows 8 and 9, investigators also focused on the containers and cargo located in this area. At the request of a party to the Safety Board's investigation, the stored contents of containers 9L and 9R were examined by members of the fire group on November 7, 1997. After the accident, FedEx had hired a contractor to clean out the cargo containers from the accident airplane and store the contents at Stewart. One large box labeled 9L was found in the storage area. In addition to miscellaneous debris, this box contained some unburned computer parts and some burned and unburned cardboard packaging material. A Packard Bell laptop computer was found burned with a melted case and exposed internal circuit boards, but the circuit boards were unburned and showed no heat damage. A substantial amount of material in the box was unburned, including material with a low melting point, such as polyurethane, polystyrene, and polyethylene. Ten plastic bottles containing liquid were found undamaged by heat. The caps were tightly secured on the bottles. Analysis of the liquid in these bottles indicated that the liquid was aqueous, rather than organic. The aqueous liquid in one of the bottles had a pH of 2.0 (acidic) and the liquid in the other nine bottles had a pH of 0.5 (also acidic).

A wooden pallet with the number 9L written on it was also found in the storage area. It contained a computer tower and some pieces of aluminum structure that appeared to be from an aluminum cargo container. There was a large piece of resolidified aluminum with two bottle caps melted into it with what appeared to be sample bottle impressions. The smaller cap had parts of the cardboard seal still inside of the cap, although it showed darkening/charring.

A small cardboard box labeled "Special, Hold for Security-Fire Investigation, 9L #400," which contained miscellaneous material, was also found in the storage area. The box contained a 1-gallon paint-type can with a heavily carbonized lightweight solid inside. The can was not distorted, and some of the black carbonized material was found over the edge of the can inside the lid groove. The box also contained what appeared to be part of a microscope and two parts of starter motor housing, a paint can cover, and what looked like an ashtray lid (undamaged).

Another wooden pallet labeled 9L had miscellaneous parts stuck to burned debris, including microscope slides, open sample bottles (about 2 inches high) and crimp-style closures, main automotive engine bearings, an automotive seat track, and spools of magnetic tapes.

Nine large cardboard boxes were found in the storage area numbered 66 through 74 and labeled “9R.” The contents are listed in appendix E.

An additional examination of the stored cargo took place from March 24 through 26, 1998. The salvaged cargo (from containers other than 6R and the hazardous materials containers), which had been packed and stored in approximately 122 large cardboard boxes, was searched for aerosol cans and other items that might have constituted undeclared shipments of hazardous materials. Seven aerosol cans and various other items were retrieved. Because all the aerosol cans were breached, it was determined that their testing would not be of value because it would not reveal their original contents. Testing of the other items revealed that the liquids in four plastic bottles and several milliliter (mL) vials had a hydrogen-ion concentration (pH) of 1.0; the liquid in another plastic bottle had a pH of 1.8; the liquid in a plastic cylinder had a pH of nearly 9.0. There were also two containers of liquid with flash points of 60ºC (140ºF) and 65ºC (149ºF), respectively.

1.14.2.1.2 DNA Synthesizer Found in Container 6R

The Expedite Model 8909 DNA synthesizer was found in the center of container 6R lying on its left side with the top facing forward (as viewed from aft looking forward), the front towards the right side of the airplane, and the bottom facing aft (see figure 8 for a diagram of the synthesizer). The unit contained several bottles with labels that included flammability symbols, and some of the bottles contained liquid. One large bottle in the aft row had a very strong odor when it was removed from the unit. Because this unit was found at the lowest point of the "V" burn pattern, the Safety Board investigation evaluated and analyzed the liquids contained in this unit.

The synthesizer, which was designed to produce synthetic DNA from a variety of chemical reagents,[43] was owned by the Chiron Corporation of Emeryville, California, and was being shipped to Chiron Diagnostics, a subsidiary company in East Walpole, Massachusetts. The manufacturer of the synthesizer was PerSeptive Biosystems, Inc., headquartered in Framingham, Massachusetts.[44]

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[43] A reagent is a substance used in a chemical reaction to detect, measure, examine, or produce other substances.

[44] According to Chiron, it purchased the synthesizer new on December 29, 1994, and the synthesizer was installed in Chiron’s research laboratory in California on January 17, 1995. Chiron indicated that the synthesizer was last used on February 5, 1996, and that Chiron employees did not flush or decontaminate the instrument between the time it was last used and the time it was prepared for shipment.

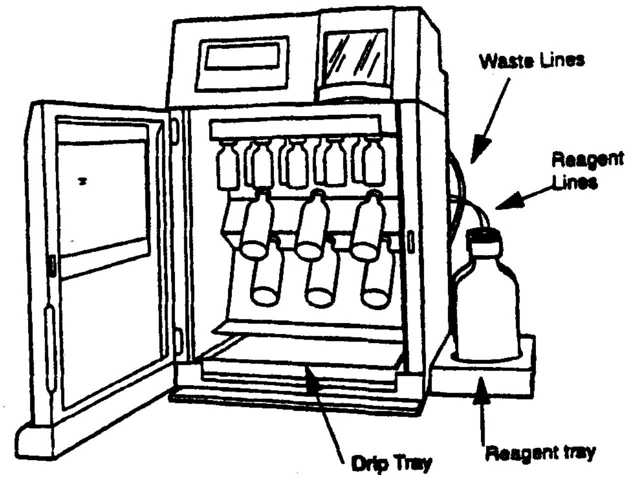

Figure 8.—Expedite Model 8909 DNA synthesizer instrument cabinet.

According to PerSeptive, when the synthesizer is set up for normal operation, the reagent bottles contain a variety of liquid reagents, several of which are regulated as hazardous materials, including acetonitrile[45] and tetrahydrofuran[46] (THF), both of which are classified as flammable liquids under the DOT hazardous materials regulations. Acetonitrile is the primary reagent and solvent used in the machine.

The synthesizer was housed in a metal cabinet about 2½ feet high. An access door on the lower portion of the front was designed to include a glass panel in the top half. Fifteen brown glass reagent bottles, ranging in size from 25 mL to 250 mL, were installed

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Chiron noted the following operational problems with the synthesizer from its installation date to its shipment date: the trityl monitor was replaced because it was not functioning properly when the unit was first installed; blockage of the flow lines occurred on August 7, 1995, and on September 1, 1995; a leaking valve was replaced in 1995 (the exact date is not known).

PerSeptive's maintenance records reflect the replacement of the trityl monitor in February 1995 and five undated field service reports to repair blocked flow lines or low flow rates. The field service reports indicate that the problems were resolved by flushing the flow lines and/or replacing the solenoids that operate the valves.

The Chiron research scientist in charge of the laboratory where the synthesizer was located stated that he was not aware of any problems with the instrument when it was prepared for shipment on August 28.

[45] Acetonitrile has a flash point of 42ºF and a flammability limit of 4.4 to 16 percent by volume in air. (Flash point of a liquid is the lowest temperature at which it produces sufficient vapors to sustain a momentary flame across the surface of the fuel. Standard methods for measuring flash point are ASTMD93 and ASTMD92. Flammability limits are the concentration limits of a combustible fuel in an oxidant (usually air) through which a flame, once initiated by a spark, will continue to propagate.) Acetonitrile vapors are heavier than air and may cause a flame to travel back from a source of ignition to the source of the fuel.

[46] THF has a flash point of -4ºF and a flammability limit of 1.8 to 11.8 percent by volume in air. After prolonged exposure to air, THF can form peroxides, which can explode on contact with strong bases or metal or spontaneously if the peroxide concentration is greater than 0.5 percent. The THF supplied by PerSeptive for use in its synthesizers contains a stabilizer to prevent the formation of peroxides. Because the stabilizer is consumed over time, it has a recommended shelf life of 3 to 5 years, with the precaution that it should be discarded sooner if the liquid is exposed regularly to air or moisture. The PerSeptive Nucleic Acid Synthesis System Service Guide states that opened bottles of amidite solution containing THF should be discarded if "over six months old."

internally in four rows and screwed into caps attached to the synthesizer. Each cap had a hole in it, which allowed a tube to extend from inside of the synthesizer into each bottle. (When it was set up for operation, the unit also included two external 4-liter reagent bottles and two external waste bottles for spent reagents from the synthesis process. These four external bottles were not shipped with the accident unit.) The unit weighed approximately 97 pounds.[47]

The bottom portion of the exterior of the synthesizer had areas of undamaged gray paint. A substantial amount of solidified melted aluminum debris had adhered to the top of the unit, and there was solidified melted aluminum vertically along the right side of the unit. The glass panel was missing from the lower access door. The inside of the lower portion, when viewed through the access door, revealed the four rows of brown glass bottles. The bottles were found intact with a strip of shipping tape placed across the front of each row of bottles. The back of the synthesizer was fire damaged.

Loose debris from the bottom of the synthesizer consisted of broken glass (the unit's access door window was made of glass) and other loose debris. A plastic drip tray had some heat damage and was melted along the left side. A paper diagram on the inside of the large access door was sooted but otherwise intact.

At the accident site, the glass bottles were removed one at a time along with portions of the tubes extending into the bottles. The bottles were individually identified, capped, and placed in plastic bags for further examination. The individual "O" rings for the bottles were intact and in place. The tightness with which each bottle had been screwed into the machine was assessed by the position that the shipping tape had been secured across each of the bottles. A chemical analysis and testing of the fluids found in the bottles were conducted at the National Aeronautics and Space Administration (NASA) Kennedy Space Center, the results of which are discussed in section 1.16.1.

Investigators packaged the synthesizer in new shipping materials supplied by PerSeptive and transported the package to Safety Board headquarters for further examination. The synthesizer was then sent to PerSeptive Biosystems' manufacturing facility, where, on February 18, 1997, investigators further examined and documented the accident DNA synthesizer. During that examination, an undamaged synthesizer provided by PerSeptive was examined for comparison purposes.

(See appendix F for a detailed description of the fire damage to the DNA synthesizer.)

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[47] The airbill for the package containing the synthesizer listed its weight (including packaging materials) as 145 pounds.

1.14.3 Significance of Location of First Fuselage Burnthrough and Smoke Detector Activation Sequence

At the Safety Board's deposition proceeding several witnesses commented on the usefulness of the location of the first fuselage burnthrough and the smoke detector activation sequence in determining the origin of the fire. An FAA fire expert, who took part in the investigation and has participated in numerous other Safety Board accident investigations, testified that experience has shown that the location of first burnthrough is not always above the point of the fire's origin. He also testified that because of the many unknown factors at work during a cargo fire (such as temperature, smoke buoyancy, tightness of cargo door seals, and the effects of ventilation) the sequence in which smoke detectors activate cannot be correlated to the location of the source of the fire. He stated that the purpose of smoke detection systems is to detect the presence of fire, not to indicate the location of a fire. A Boeing engineer with the Douglas Products Division, who also took part in the investigation, testified that smoke detectors are installed to detect smoke, not to indicate the location of the fire's origin.

A Boeing engineer, who participated in the design and development of the DC-10 airplane, testified that smoke tests conducted on passenger airplanes showed that the smoke detectors closest to the source of smoke were not always the first detectors to activate.

A fire consultant to one of the parties stated in written reports and in his deposition testimony that Safety Board accident reports show that the location of first burnthrough does occur above the point of the fire's origin. He also indicated that he believed there was minimal axial flow in the DC-10; therefore, the first smoke detector to activate would necessarily be directly above the source of the fire. Another fire consultant hired by the same party indicated agreement with the first consultant's conclusions; however, he also acknowledged in his deposition testimony that smoke detector activation sequence is not necessarily an indicator of the fire's origin.

1.15 Survival Aspects

1.15.1 Use of Smoke Goggles and Oxygen Masks

The FedEx Aircraft Operating Manual for the DC-10 outlines emergency procedures for use in the event of fire and smoke, and contains additional checklists for specific types of smoke (electrical smoke, air conditioning smoke, or cabin cargo smoke). All of these procedures call for the immediate donning of the oxygen masks and smoke goggles, if required, by the cockpit crew followed by a series of steps including (for cabin cargo smoke) depressurizing the airplane by manually opening the outflow valve.

In an informal survey of air carriers conducted by the Safety Board during its investigation of the May 11, 1996, accident involving ValuJet Airlines flight 592,[48] pilots from several air carriers indicated that they would not don oxygen masks and smoke goggles for situations such as reports of a galley fire, smoke in the cabin, or a slight smell of smoke in the cockpit. Based on the circumstances of that accident and the results of its survey, the Safety Board concluded that air carrier pilots had inadequate guidance about the need to don oxygen masks and smoke goggles immediately in the event of a smoke emergency. Thus, the Safety Board issued Safety Recommendation A-97-58 to the FAA, asking it to issue guidance to air carrier pilots about the need to don oxygen masks and smoke goggles at the first indication of a possible in-flight smoke or fire emergency. In a November 17, 1997, letter, the FAA responded that it agreed "with the intent of this safety recommendation and will issue a flight standards handbook bulletin…contain[ing] guidance on procedures to don protective breathing equipment for smoke and fume protection."

Title 14 CFR Part 121.333 requires that pilots of pressurized airplanes operating above FL 250 be provided a "quick donning type of oxygen mask that…can be placed on the face from its ready position, properly secured, sealed, and supplying oxygen upon demand, with one hand and within five seconds." This regulation also requires that the mask can be "put on without disturbing eyeglasses and without delaying the flight crewmember from proceeding with his assigned emergency duties." The Safety Board notes (as it did in its ValuJet Miami accident report) that FAA regulations do not establish any similar performance requirements for smoke goggles.[49] In that report, the Board issued Safety Recommendation A-97-59, which asked the FAA to establish a performance standard for the rapid donning of smoke goggles and then ensure that all air carriers meet this standard through improved smoke goggle equipment, improved flightcrew training, or both.

In its November 17, 1997, response to this recommendation the FAA stated that it believed this issue was addressed by 14 CFR 121.337, which establishes standards for PBE, and 14 CFR 121.337(8), which requires that such equipment be conveniently located and easily accessible. The FAA further stated that a "preliminary review of industry practices concerning equipment and carrier procedures indicate a need for further guidance on the location and donning of this equipment. The FAA will issue a flight standards handbook bulletin to provide additional guidance on the location and donning of this equipment. The bulletin will also include equipment and procedural guidance on flightcrew training requirements."

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[48] National Transportation Safety Board. 1997. *In-flight Fire and Impact with Terrain, ValuJet Airlines Flight 592, DC-9-32, N904VJ, Everglades, near Miami, Florida, May 11, 1996.* NTSB/AAR-97/06. Washington, DC.

[49] The Safety Board has expressed its concerns to the FAA about the performance of smoke goggles beginning in 1974, as a result of its investigation of the Pan American World Airways B-707 freighter accident at Boston and in 1983, as a result of the Air Canada DC-9 accident at Cincinnati. The Board recognizes that the FAA currently has design requirements for smoke goggles in 14 CFR Part 25.1439 and Technical Standard Order C99. However, none of these requirements establishes minimum performance standards for donning time or difficulty.

1.15.2 Emergency Response

ARFF at Stewart is primarily provided by the New York Air National Guard (ANG). Pursuant to mutual assistance agreements, municipal fire departments also responded and provided assistance during this accident. Other state and local agencies that responded to the accident included the New York State Emergency Management Office, the New York State Police (NYSP), the New York Department of Environmental Conservation (DEC), the New York Department of Health, the Orange County Office of Emergency Management, and the Orange County Hazardous Materials Response Team (HMRT).

At 0545, about 10 minutes before the airplane landed at Stewart, the ATC tower at Stewart notified the airport operations department and the ANG fire department about the inbound DC-10 and its emergency and advised them that hazardous materials were on board the airplane. About the same time, the NYSP detail at Stewart was also notified of this information. No details about the specific hazardous materials or the quantities on board were provided.

Six trucks from the ANG fire department responded and were in standby position when the airplane landed. The assistant fire chief on duty assumed the role of incident commander. Airport operations and NYSP personnel were also on scene when the airplane landed. After the airplane landed on runway 27 and stopped on taxiway A3, the ANG fire trucks were positioned around the airplane to fight the fire.

About 0600, the Stewart FedEx station manager was advised by his ramp personnel that a FedEx DC-10 was on the runway and that smoke was coming from the airplane. The station manager arrived about 0603 at the ramp facility, where ramp personnel were on the telephone with the FedEx Global Operations Command Center (GOCC) in Memphis. Approximately 0615 or 0620, an airport operations employee arrived at the ramp facility and transported a FedEx ramp agent and an aircraft mechanic to the accident scene to provide assistance to the firefighters in opening the cargo door.

About 0630, an off-duty assistant fire chief, who had been called from his home by the incident commander, arrived on the scene. He suggested the use of a skin penetrator agent application tool (SPAAT)[50] to puncture the fuselage. During his deposition, the assistant fire chief, who was at that time serving as the incident commander, testified that at the flight engineer's suggestion,[51] they attempted (without success) to call Douglas to find out if there were alternate methods for entering the airplane without damaging it. He acknowledged that this effort delayed the use of the SPAAT tool somewhat. Before the SPAAT was rigged and ready to use, and just as the firefighters succeeded in opening the cargo door, flames were observed venting through the fuselage. Accordingly, the SPAAT tool was never used. The fire chief

[50] The SPAAT is a penetration-type firefighting tool used to puncture the fuselage and introduce extinguishing agent into the interior.

[51] During his deposition, the flight engineer indicated that he was unaware that firefighters wanted to cut a hole in the airplane fuselage.

testified that, based on “lessons learned” from this accident, if a similar situation were to arise again they would immediately employ a penetrator tool with a firefighting agent.

About 0700, the ANG fire chief arrived on scene and took over as the incident commander, relieving the assistant fire chief who had until then been serving in that role. The fire chief continued to serve as the incident commander until approximately 1430 or 1445 when he turned command of the scene over to the joint control of the State DEC and the Orange County HMRT.

By 0730, an emergency operations center (EOC) had been activated in building 110 of the airport operations department, staffed by representatives from airport operations, the NYSP, and the Orange County Office of Emergency Management. About 0925, officials from the FedEx corporate office in Memphis advised airport operations that a team from Memphis was en route to Stewart.

After this accident, the Stewart Airport emergency plan was revised to provide for enhanced coordination with state and local agencies. (For more information about emergency response, see Section 1.1, History of Flight.)

1.15.2.1 Dissemination of Hazardous Materials Information

FedEx uses multiple forms for documenting the shipment of hazardous materials on board its cargo airplanes. The “Notification of Dangerous Goods Loading (Part A)” is completed for all flights, including those without hazardous materials on board. The Part A is an envelope with a multicopy form on the front that identifies the cargo containers by their positions on the airplane and the classes of hazardous materials (such as flammable liquids or corrosives) in each container. The Part A envelope contains copies of all shipping documentation about the hazardous materials on the airplane, and the top form is signed by a hazardous materials specialist and the captain of the airplane.

A “Dangerous Goods Separation Pouch” for each cargo container that transports a declared hazardous materials package is inserted into the Part A envelope. The separation pouch is also an envelope with a multicopy form on the front that identifies the various classes of hazardous materials in a specific cargo container. A copy of the form on the separation pouch is also affixed to both ends of each hazardous materials cargo container. The Part A and the separation pouch do not indicate the specific hazardous materials and the quantities on board the airplane.

Specific information about the hazardous materials in a given package, such as the proper shipping name, United Nations identification number, and hazard class, quantity, and 24-hour emergency telephone number, is found on the “Notification of Loading of Dangerous Goods (Parts B or C)” or, if applicable, a “Notification of Loading of Dangerous Goods Radioactive Materials (Parts BR or CR).” This form, which is affixed to a package containing hazardous materials, also has the FedEx tracking number and remains on the package throughout shipment.

Copies of these forms (Parts B, C, BR, or CR) are placed in the separation pouch for the appropriate cargo container.

The assembled Part A, separation pouches, and copies of the Parts B, C, BR, or CR forms are carried in the cockpit so they can be available to the flightcrew. Copies of the Parts B, C, BR, or CR forms for each shipment of hazardous materials are also retained at the originating station where the shipment is accepted. Further, copies of these forms and the Part A and the separation pouches for a given flight are retained at the departing hub of the flight. The DOT hazardous materials regulations require that the proper shipping name, hazard class, identification number, packaging group, and total quantity of the material appear on the shipping papers for hazardous materials. Further, the regulations require an operator to provide this information in writing to the pilot-in-command and also require that a copy of the shipping papers accompany the shipment on board the airplane.

Both the initial incident commander and the ANG fire chief (who took over at 0700 as incident commander) indicated that they were concerned about the safety of the firefighters and the possible exposure of personnel at the scene to the hazardous materials or their combustion byproducts.[52] Consequently, both requested (but did not receive) copies of what they referred to as "manifests" from the flightcrew and other FedEx representatives so they could identify the specific hazardous materials on board and their quantities and locations on the airplane. The ANG fire department log had entries at 0730, 0815, and 1125 logging ANG personnel's efforts to have FedEx fax copies of the "manifest" to airport operations or to the FedEx ramp facility at Stewart. The fire chief also stated that he gave a local FedEx employee two fax numbers at the ANG command center, and he assigned two ANG personnel to stand by those machines. However, no faxes from FedEx were received at those machines.

According to FedEx personnel, the FedEx dangerous goods hub in Memphis and the GOCC faxed several copies of the Part A, Parts B, BR, or CR, the dangerous goods loading pouches, and the weight and load plans throughout the morning to various fax numbers at Stewart. Although the receipt of the faxes by the facilities to which they were sent could not be verified in most instances, the faxes appear to have been transmitted to the fax numbers located at the FedEx ramp facility at Stewart, the airport operations office, and the NYSP barracks at Stewart. The airport operations log contained entries at 0635 that the FedEx "manifest" had arrived by fax, and, at 0656, that additional hazardous materials "manifest" information had been received. Airport officials who received those faxes indicated that they were of poor quality and therefore did not provide them with the needed information. Twenty-eight partially legible Part B forms were received by 0733 by the Orange County HMRT coordinator. Additional Part Bs were faxed from the GOCC from 0858 and throughout the morning, with the last fax transmitted by 1340.

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[52] During postaccident interviews, the HMRT coordinator said that he had also been concerned about the potential threat to the surrounding communities be posed by the release of any of the hazardous materials on board.

According to postaccident interviews, many of the Parts B, BR, and CR forms containing the specific information sought by the incident commander were seen by airport operations staff, the NYSP personnel, New York DEC law enforcement officers and spill technicians, and the Orange County HMRT coordinator and team members. Representatives from airport operations, the NYSP, and the Orange County HMRT indicated that the information they received was forwarded to the incident command post. The ANG fire department log did not contain any entries of faxes received from FedEx about the hazardous materials on the airplane.

Of the shipping documentation carried on board the airplane, only the original form on the Part A envelope was retrieved by the flightcrew before the evacuation (the flight engineer had placed the form in his pocket). Immediately after evacuating (about 6 minutes after the airplane had landed), the flight engineer provided the Part A form to one of the ANG firefighters. The firefighter immediately read the information on the Part A[53] over the radio to the incident commander and then placed the Part A in his fire vehicle where it remained until the fire was extinguished, when another firefighter recovered it. Some time before 0700, the initial incident commander received a one-page typewritten sheet from the FedEx station at Stewart containing the same information.

The flight engineer stated that he told firefighters that the Part Bs and other shipping documents were located on the back of the cockpit door. However, they were not retrieved until the day after the accident when the burned and water-soaked remains of the shipping documents were recovered. During the deposition proceeding, the ANG fire chief stated that about 1 hour and 15 minutes after the firefighting operation began, FedEx employees advised that the Part Bs were on the aircraft. The fire chief indicated that no attempt was made to retrieve the Part Bs at that time because of the severity of the fire.

About 0915, the HMRT coordinator gave the fire chief (who was by then serving as the incident commander) a handwritten list of chemicals and United Nations identification numbers provided by local FedEx personnel. The local FedEx personnel also gave the fire chief a copy of the weight and load plan. During postaccident interviews, the fire chief acknowledged receiving the handwritten list, but noted that the list did not specify the amounts of the hazardous materials on board.

About 1200, the ANG base commander received a call from FedEx's vice president for security in Memphis. According to the base commander, the vice president called to provide the ANG with what information he could about the hazardous materials on board the airplane, but he indicated that hazardous materials were not his area of specialty. The base commander provided the vice president with a fax number located in the ANG incident

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[53] The Part A indicated that (1) the hazardous materials were carried in the cargo containers in positions 1L/1C and 3R; (2) the container in 1L/1C was carrying flammable liquids, corrosive materials, infectious substances, materials that were spontaneously combustible, and magnetized materials; and (3) the container in 3R contained radioactive materials, shipments with dry ice, and "ORM-D. [a material that presents a limited hazard during transportation because of its form, quantity, and packaging (49 CFR 173.144)]."

command post. When checked an hour later, no information had been received at the command post. Shortly before 1300, the base commander directed the chief of the ANG command post to contact the FedEx vice president for the information. According to the ANG command post chief, the vice president advised the command post chief that he could not provide the information because the Safety Board had taken over the investigation.

In a January 27, 1997, letter of explanation to the Safety Board, FedEx stated that the vice president's actions were consistent with company policy, which dictates that once the Safety Board has taken control of an aircraft accident investigation, all information pertaining to that investigation is to be forwarded to the Board. The FedEx letter also stated that at the time of the ANG request, the senior DEC law enforcement officer, the NYSP, and other appropriate state officials already had copies of documents listing the hazardous materials on board.

1.15.2.1.1 Other FedEx Accidents Involving Dissemination of Hazardous Materials Information

In the July 31, 1997, postcrash fire involving a FedEx MD-11 operating as flight 14 at Newark International Airport, Newark, New Jersey (still under investigation), the shipping papers were destroyed. The flight had originated in Narita, Japan, and copies of the shipping documentation for the hazardous materials had been retained there. Approximately 1½ to 2 hours after the accident, FedEx provided the incident commander with information about the quantity and identification numbers for the hazardous materials on board, including a notation that there were "maybe 36 pounds of an unknown haz.mat."

On March 5, 1998, a Cessna 208B owned by FedEx and operated by Baron Aviation Services, Inc., crashed near Clarksville, Tennessee. Information from the ongoing investigation indicates that the Part B hazardous materials shipping papers on board the airplane and on file at FedEx's Memphis hub did not accurately reflect what was on board the airplane[54] and include an emergency response telephone number.

On April 7, 1998, another Cessna 208 operated by FedEx crashed near Bismarck, North Dakota. Preliminary information indicates that, although no declared hazardous materials were on board that flight, it took 2 hours and 49 minutes from the time the information was requested for FedEx to answer the question about whether hazardous materials were on board. (The accident is still under investigation.)

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[54] Although the Part A was accurate in that it properly listed the classes of hazardous materials that were on board, one of the Part Bs did not accurately reflect the hazardous materials on board. The Part B in question listed a total of 31 packages of flammable liquids; however, only 5 of the 31 packages were on board the aircraft. The remaining 26 packages had been part of the airplane's cargo on a previous flight, but were subsequently removed from the airplane and transported via ground transportation.

1.15.2.1.2 Postaccident Actions by FedEx

Safety Board investigators surveyed seven other operators who carry cargo[55] to determine whether they had the ability to quickly retrieve and produce complete information about hazardous materials carried on board a particular flight. They found that only one carrier (SwissAir) had a computerized capability to provide information about the declared hazardous materials on board its airplane. The remaining carriers, like FedEx, keep track of this information only by retaining at the departing station paper copies of the hazardous materials shipping documentation carried on board the airplane.

During an April 1998 meeting with the Chairman of the Safety Board, FedEx officials indicated that FedEx intended to develop and implement an improved system for tracking and retrieving information about hazardous materials being carried on board FedEx flights. In a May 5, 1998, letter, the President and Chief Executive Officer confirmed that FedEx was committed to developing "systems and procedures which will reduce substantially the length of time required to provide firefighters and other emergency responders with detailed information concerning [hazardous materials] shipments aboard FedEx aircraft." He indicated that FedEx planned to phase in the new system, first creating an "intermediate solution" consisting of an "electronic notification system upon which basic [hazardous materials] information of interest to fire fighters will be entered by a DG [dangerous goods] specialist at airport ramps at departure of FedEx aircraft." This system would include information on hazard class, quantity, and location of all hazardous materials on the airplane, excluding dry ice. This information would be available on computer terminals at FedEx facilities worldwide.

The May 5 letter indicated that the "permanent solution" envisioned by FedEx would "allow the tracking, by container and aircraft, of [hazardous materials] shipments throughout the shipping cycle. Completed [hazardous materials] information, including inbound and outbound [hazardous materials] manifests, will be available on an immediate basis at the FedEx GOCC, which is manned 24 hours-a-day, 7 days a week, and all FedEx facilities." A FedEx dangerous goods technical advisor explained during the deposition proceeding that FedEx hoped that the development of this new system would prompt a regulatory reexamination of information that needs to be immediately available to emergency responders. Specifically, he indicated that the proper shipping names of a hazardous material would not be relevant to emergency responders.

The letter further indicated that "[t]his solution will require extensive system development efforts, along with scanning technologies which are currently under development. This effort is estimated to be at least 18 months away from testing." Finally, the letter indicated that the current regulatory scheme, which requires that detailed shipping documents be maintained by the operator and carried on board the aircraft, would need to be adjusted to permit electronic documentation of this information in place of the currently required paper records.

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[55] The carriers surveyed were Airborne Express, United Parcel Service, Northwest Airlines, SwissAir, United Airlines, British Airways, and Delta Air Lines.

1.16 Tests and Research

1.16.1 Chemical Analysis of Substances Found in Container 6R

On December 16 and 17, 1996, at the NASA Kennedy Space Center, investigators documented and analyzed the fluids and debris recovered from the DNA synthesizer; fluid removed from the industrial valves; green, red, and cream-colored material found on the inboard side of the container floor; and burned debris that had been removed from cargo container 6R.

Gas chromatography/mass spectrometry (GC/MS) was used to analyze the residues left in the bottles on the accident synthesizer. Specifically, investigators looked for the presence of the 15 chemicals used in the DNA synthesizer and for the presence of aqueous film-forming foam (AFFF), a firefighting agent that was sprayed on the accident airplane. Calibration information was collected through the GC/MS analysis of standard solutions containing known concentrations of AFFF and the other 15 chemicals. Three concentrations (1 percent, 0.1 percent, and 0.01 percent) of a mixture of each of the 15 chemicals were prepared by dilution for calibration of the GC/MS system.

Visual inspection of each of the bottles from the accident synthesizer showed that some bottles had liquid in the bottoms. These liquids were poured into glass vials and sealed with Teflon-lined (airtight) caps with septums. The bottles from the accident synthesizer that did not show evidence of liquid in the bottoms were rinsed with methanol, and the methanol rinse was transferred into glass vials and sealed for injection into the gas chromatograph. The NASA laboratory provided clean, clear glass bottles for the methanol rinse. The amount of methanol rinse used differed depending on the conditions of the sample. The rinse procedure and the quantities of fluid rinsed from each bottle are detailed in appendix G.

Each of the samples were analyzed by injecting 0.1 (microliter) µl of each fluid into the GC/MS system. The following table shows, for each bottle identification, the estimated quantity of fluid in each bottle and the identity and amount of each chemical identified in that sample. The vials containing the methanol/residue solutions were retained for later use. More definitive quantitative results of some of the chemicals were determined in a reanalysis discussed in section 1.16.3. (See appendix H.)

Bottle Identification	Approximate Quantity of Fluid in Bottle	Chemicals Identified (Approximate Quantity)
AUX 3	4-5 mL (yellowish)	• acetonitrile[56] • THF (.01%) • DEGMBE[57] (.03%)

[56] No percentages are given on this chart for acetonitrile because this test did not produce an accurate measurement of the amount of acetonitrile left in the bottles. Because of the relatively large quantities of acetonitrile in most of the bottles (as compared with the other substances found to be present), the quantity of acetonitrile in the sample used for this test exceeded the calibration limits of the GC/MS. The samples were subsequently diluted and retested.

ACT 4	less than 1 mL	• acetonitrile • DEGMBE (<1%) • 1-chloro-octane (trace) • 1-bromo-octane (trace)
7	50 to 100 µl[58]	• acetonitrile • DEGMBE (<1%)
8	methanol rinse (added 200 µl)	• acetonitrile • DEGMBE (<1%) • hexanedinitrile (trace) • aminocaproic acid (trace)
OX 2	methanol rinse (added 500 µl)	• acetonitrile • THF (>1%)
WSH 1	methanol rinse (added 1 mL)	• acetonitrile • chloroform (~15ppm)
CAP B6	methanol rinse (added 1 mL)	• acetonitrile • THF (~0.03%) • pyridine (~0.03%) • 1-methylimidazole (~0.01%) • DEGMBE (<<0.01%)
5	methanol rinse (500 µl)	• acetonitrile (>1%) • DEGMBE (0.01%)
T/U	methanol rinse	• acetonitrile
A	methanol rinse	• acetonitrile
CAP A5	methanol rinse	• acetonitrile • THF (~1%) • 4-chloro-butanoic acid
9	methanol rinse (500 µl)	• acetonitrile • DEGMBE
G	methanol rinse (500 µl)	• acetonitrile • DEGMBE
C	methanol rinse (500 µl)	• DEGMBE
6	undiluted	• acetonitrile • DEGMBE

The results of the analysis of other fluids found in cargo container 6R were as follows:

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[57] DEGMBE (Diethylene glycol monobutyl ether) is the principal ingredient in the firefighting agent AFFF.

[58] It is generally accepted that 50 µl (or 0.050 mL) is equal to one drop. (1 µl = 0.001 mL.)

Description of Fluid in Bottle	Chemicals Identified (Approximate Quantity)	Sample Preparation
AFFF (Sample provided by NASA)	• DEGMBE • 1-chloro-octane • 1-bromo-octane • 1-chloro-decane	0.1 µl injection
methanol extraction of synthesizer spill; tray debris	• AFFF (trace)	0.1 µl injection
Valve liquid	• H_20 • DEGMBE	0.1 µl injection
Re-methanol extracted from cargo container floor	• DEGMBE	0.1 µl injection

Fourier Transform Infrared (FTIR) spectroscopy was used to identify the solid materials found in cargo container 6R.[59] The red, green, and cream-colored materials were separated under a microscope. Each of the materials was prepared in a diamond cell[60] and transferred to the microscope of the FTIR apparatus for the infrared spectrum. The infrared spectrum of the red, green, and cream-colored material was consistent with a substance used for packing material.

1.16.2 Procedures Used to Prepare the Synthesizer for Shipment

According to the PerSeptive field engineer who prepared the instrument for shipment, a few days before he came to Chiron to prepare the instrument, he called the Chiron research scientist and asked that the reagent bottles be emptied and filled with acetonitrile before he arrived, and the research scientist agreed to do so. According to a laboratory technician who helped prepare the synthesizer for shipping, the research scientist directed her to empty old reagents from all the reagent bottles for the synthesizer. In a September 16, 1996, interview, the technician stated that on the morning of August 28, 1996, she emptied all of the internal reagent bottles of the synthesizer and filled them about one quarter full with clean acetonitrile. However, in a document submitted to the Safety Board on October 31, 1996, Chiron indicated that "[a]ll reagent bottles, except DBLK 8 and AUX 3[61] were emptied, rinsed, and refilled partially with acetonitrile on August 28, 1996, before [the PerSeptive field engineer] arrived." That document, which also listed the chemicals Chiron believed were contained in each of the reagent bottle positions after the unit was last used for synthesis and on the morning of August 28, 1996, characterized the status of the AUX 3 bottle at the time of the PerSeptive field engineer's visit as "inconclusive." During the deposition proceeding, the Chiron research scientist and laboratory technician and Chiron's Director of Environmental Health and Safety indicated, when asked

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[59] The FTIR analysis identifies functional groups (groups of atoms in a molecule that give that molecule its unique physical and chemical properties) and molecular structure based on a library of known absorption bands.

[60] A diamond cell is used to make a solid sample into a thin film for analysis.

[61] Chiron stated that the reagent bottle in position AUX 3 was not generally used in the synthesis process.

about the meaning of the "inconclusive" characterization, that the AUX 3 bottle was either empty or contained acetonitrile.

The PerSeptive field engineer arrived at the Chiron laboratory on the afternoon of August 28. According to the research scientist, he told the field engineer that the bottles had been emptied of old reagents and partially filled with acetonitrile. The research scientist then left the field engineer alone to decontaminate and package the unit for shipment. In a postaccident interview, the field engineer said that he determined that all of the internal bottles (which are brown-colored glass) had acetonitrile in them by using smell and visual examination, but also stated "it depends on the customer's word." However, he acknowledged that he would not be able to determine by his sense of smell whether the acetonitrile had been contaminated with other chemicals. The field engineer said that he noted one of the two external reagent bottles, DBLK 8, (which was made of clear glass) had some old reagent in it. The field engineer removed this bottle and replaced it with a bottle partially filled with acetonitrile.

In a September 16, 1996, interview 11 days after the accident, the field engineer described the next steps he took to prepare the machine for shipment as follows. He ran the "prime all" function[62] three times on each column position, and then emptied all of the bottles by turning them upside down until they stopped dripping. He then replaced the bottles so that the filter at the bottom of the tubes came into contact with the outer edge of the bottom of the bottle.[63] He then ran the "prime all" function again three times on each column position to dry the instrument. (When the "prime all" function runs without liquid in the bottles, a dry, inert gas is pumped through the flow paths and bottles.) He said that he did not remove the internal reagent bottles after these drying cycles, but that he visually inspected them and they appeared dry. He said that he then depressurized the synthesizer by disconnecting the inert gas supply and loosening each internal reagent bottle to relieve the internal pressure.

On April 4, 1997, Chiron forwarded to the Safety Board a computer disk containing a data file named "history.log" that contained a record of manual inputs to the synthesizer made at the time of the field engineer's visit and other operating data.[64] A printout of this file showed a total of 59 entries between 1603 and 1708 on August 28, 1996. The first

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[62] The "prime all" cycle function draws some liquid from every reagent bottle so that every flow path in the machine is flushed. During this function, a fixed volume of liquid is pumped from each internal and external reagent bottle through the flow paths and column positions before it is discharged into one of the two waste bottles. The elapsed time for one "prime all" cycle to run on a given column position is about 3 minutes. The "prime all" cycle must be manually activated from the menu display and control panel on the front of the synthesizer.

[63] He stated that the filter "acts like a sponge," so that any remaining fluid in the bottle would "get sucked up into the tubing."

[64] The disk was found at the Chiron Diagnostics facility in East Walpole, Massachusetts, the destination of the accident synthesizer. According to Chiron, the research scientist in charge of the synthesizer at Chiron's California laboratory packed the disk in a box with copies of the user manual for the synthesizer and four other 3.5-inch disks. According to Chiron, the scientist in East Walpole had stored the disks and not used them while they were in his possession. Before sending the disk to the Safety Board, Chiron had examined all five disks and found that only one (the one forwarded to the Board) had files with any activity in 1996.

and second entries indicated “power restored” and “instrument diagnostic run.” The remaining 57 entries indicated “manual function invoked.”

A followup interview with the PerSeptive field engineer was conducted on August 28, 1997. He acknowledged that the “history.log” file was a record of the functions and operations he performed on August 28, 1996. The field engineer stated that before he began flushing the synthesizer, he ran a test to confirm that the inert gas used to pressurize the system was not leaking. The field engineer further explained that the first 7[65] and the last 6 of the 37 “manual function invoked” entries represented the “prime all” functions that he ran on each column position to flush and dry the instrument. (The “history.log” times indicated that the amount of time that elapsed after each of these entries before the next entry was recorded ranged from 2½ minutes to 7 minutes.)

The field engineer explained that the remaining 44 “manual function invoked” entries in the “history.log” file (those recorded between the first 7 and the last 6 entries) were the result of his having invoked the “prime individual”[66] function a number of times for each reagent position on each of the two columns. (The “history.log” files file indicated that the amount of time that elapsed after each of these entries before the next entry was recorded ranged from 4 seconds to 17 seconds.) He acknowledged that these additional functions were not prescribed by PerSeptive as part of the normal purging procedure, but indicated that he took these additional steps to ensure that fluid from each reagent position was being properly delivered. (He stated that he did not have written guidance with him when he purged the accident synthesizer, but that he based the purging on Service Note 89-006, “Preparing An Expedite System For Storage Or Transport” (see appendix I).) The field engineer stated that he saw liquid coming out of the waste line during the “prime individual” functions, indicating to him that the fluid was flowing properly. The field engineer indicated that it was his standard practice to take these additional “prime individual” steps when purging instruments not in his normal service territory.

The field engineer again stated (as he had at his earlier interview) that before running the last 6 “prime all” functions (to dry the machine), he emptied all of the reagent bottles and held them upside down until they stopped dripping. At the conclusion of his August 28, 1997, interview, the field engineer stated that he was “100 percent certain” that no visible fluids remained in the instrument when he completed the purging procedure. The field engineer stated that he saw no leakage, malfunction, or operational problems and that he did not observe anything unusual about the instrument during the purging and drying process.

During both his September 1996 and August 1997 interviews, the field engineer described the remainder of the steps he took to prepare the instrument for shipment as follows.

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[65] He stated that when he started the flushing cycles, he inadvertently ran “prime all” on column 2 instead of beginning with column 1, and thus 13 (rather than 12) of the entries recorded on the data file were attributable to the “prime all” functions.

[66] The field engineer stated that invoking the “prime individual” function for a particular bottle position would cause the machine to make between 10 and 20 pulses, each of which would pump some fluid from the selected bottle. He further stated that each pulse would contain between 15 and 19 microliters of fluid.

He placed the plastic flow lines for the two external reagent bottles and the two waste lines in a plastic zip-lock bag that was sealed with a clear, plastic shipping tape, and then taped it to the outside of the synthesizer. He stated that the reagent bottles that were external to the unit, WSH A 7 and DBLK 8, were not shipped with the synthesizer or in an accompanying package. The field engineer stated that he left the two external reagent bottles and the two waste bottles in Chiron's lab on a laboratory bench under a ventilation hood. After the accident, Chiron located the two external reagent bottles in its lab and accounted for the two waste bottles. The field engineer stated that he packaged the unit for shipment using a PerSeptive-supplied wooden pallet with a foam support, cardboard container, and other shipping materials that were provided previously to Chiron. He placed the synthesizer on the pallet, positioned the foam supports at the bottom and top of the synthesizer, used an empty box to fill in space, and then slid the outer cardboard container over the top of the synthesizer. He said that he left the packaged synthesizer in the laboratory and departed from Chiron about an hour and a half after he had arrived.

The Chiron research scientist completed and signed an internal Chiron form titled, "Outgoing Procedure Checklist," which was dated August 30, 1996. The form provides information to Chiron's shipping department about the contents of the package and other shipping information, such as the recipient's address and telephone number. The entry to indicate if the package contained hazardous materials was marked "N" (for "No") and had a handwritten entry reading, "Instrument was thoroughly decontaminated of all chemicals." The research scientist acknowledged that he did not verbally confirm with the PerSeptive field engineer that the synthesizer had been decontaminated. The checklist was left on top of the packaged synthesizer.

Personnel from Chiron's shipping department transferred the packaged synthesizer from the laboratory to the shipping department and loading dock, where two synthetic straps were placed around the boxed unit. The shipping department employee who handled the synthesizer reviewed the information on the internal checklist, including the entry about hazardous materials and decontamination, but stated that he had no reason to suspect that anything was amiss. Shipping department personnel did not have a written record of when the synthesizer was picked up from the laboratory and could not recall the date. The shipping manager at Chiron indicated that he was aware of only one synthesizer that had been shipped (the accident synthesizer).

Chiron's shipping manager acknowledged that 20 to 30 infectious substance shipments are made each day from Chiron. The shipping manager further stated that research personnel do receive awareness training on the handling and transportation of hazardous materials. Excerpts from Chiron's Chemical Safety Manual instruct employees to consult with the shipping department before preparing any hazardous materials for shipment or transporting hazardous materials off site. According to the shipping manager, shipping department personnel complete hazardous materials training required under the DOT hazardous materials regulations. Training courses taken by Chiron shipping personnel were conducted by FedEx.

A FedEx courier who picked up the synthesizer from Chiron's loading dock on September 4 stated that he did not ask any Chiron shipping department personnel whether any of the packages he picked up from Chiron contained any hazardous materials, nor did the Chiron employees comment on the contents of the packages. The courier delivered the packaged synthesizer to the FedEx Oakland terminal for air transport to Memphis on flight 1200. (Flight 1200 departed at 1921 on September 4 and arrived at 0107 on September 5.) On September 5, it was loaded on flight 1406 to Boston.

1.16.3 Reanalysis of Fluids Found in DNA Synthesizer

Demonstrations of PerSeptive's purging and drying procedures were conducted on February 18, 1997, at PerSeptive's manufacturing facility,[67] and on June 17, 1997, at the Armed Forces Institute of Pathology (AFIP). The residues left in the bottles after the AFIP demonstration were then analyzed to determine the concentrations of any chemicals in the residues. The results of the analysis were compared with the results of the analysis of the concentrations of chemicals in the residues found in the accident synthesizer.

Investigators convened at NASA on July 23, 1997, to reanalyze the concentrations of liquids found in the accident synthesizer and to compare the results with the concentrations of liquids left in the synthesizer that were purged at AFIP in accordance with PerSeptive’s procedures. A reanalysis of the residues of selected bottles was undertaken with increased dilution to prevent instrument saturation (the concentration of relevant chemicals had exceeded the calibration during the November 1996 tests). The bottles reanalyzed were taken from positions AUX 3, CAP A5, CAP B6, and OX 2. These bottles were chosen for reanalysis because the first analysis found that they contained residues of THF (a chemical used in the synthesis process), which was the most volatile of the chemicals found in the accident synthesizer. Table 1 shows the amount of chemical residue left after the purging at AFIP, and table 2 shows the amount of chemical residue left in bottles from the accident synthesizer as determined in the reanalysis.

Table 1. Quantitative GC/MS Analysis of Bottles from the DNA Synthesizer Purged at AFIP (Percent of Total Liquid Removed)

Substance	CAP A5	CAP B6	OX 2	AUX 3
Total liquid	69 µl	51.8 µl	20.81 µl	71.4 µl
Acetonitrile	85.8% (59 µl)	91.9% (47.6 µl)	81.2% (17 µl)	93.6% (67 µl)
THF	1.4% (1.2 µl)	0.4% (0.2 µl)	1.4% (0.3 µl)	0.3% (0.2 µl)
Water	12.8% (8.8 µl)	7.7% (4.0 µl)	17.3% (3.6 µl)	6.2% (4.4 µl)

67 For a detailed description of this demonstration, see appendix J.

Table 2. Quantitative GC/MS Analysis of Bottles from the DNA Synthesizer on the Accident Flight

(Percent of Total Liquid Removed)

Substance	CAP A5	CAP B6	OX 2	AUX 3
Total liquid	28.8 µl	27.4 µl	56.1µl	Approx. 4-5 mL
Acetonitrile	55.9% (16 µl)	38.7% (10.6 µl)	68.6% (39 µl)	4.3% (172-215 µl)
THF	13.9% (4 µl)	12.0% (3.3 µl)	8.7% (4.9 µl)	0.01% (0.4-0.5 µl)
Water	27.1% (7.8 µl)	40.1% (10.9 µl)	22.3% (12.5 µl)	95.6% (3.8-4.8 mL)
DEGMBE	3.1% (0.9 µl)	1.5% (0.4 µl)	0.4% (0.2 µl)	0.05% (2-2.5 µl)
Pyridine	----	0.4% (0.1 µl)	----	----
N-Methyl imidazole	----	7.3% (2.0 µl)	----	----

Safety Board investigators met with the Associate Administrator for Hazardous Materials Safety, Research and Special Programs Administration (RSPA), regarding the applicability of the DOT hazardous materials regulations to small quantities of hazardous materials. The Associate Administrator is the senior DOT official responsible for the development, implementation, and interpretation of the hazardous materials regulations for all modes.

According to the Associate Administrator, the DOT hazardous materials regulations are generally consistent with internationally developed standards. They are based on a system that first requires the identification and classification of hazardous materials and then compliance with applicable regulatory standards for packaging, marking, labeling, and shipping documentation. If a material is listed in the hazardous materials regulations or classified (i.e., it meets defining criteria) as a DOT-regulated hazardous material, the transportation of that material in any quantity is subject to the hazardous materials regulations. Once a material has been identified and classified as a hazardous material, the quantity and form of that hazardous material will then determine how it is regulated in transportation.

The Associate Administrator further stated that the transportation of any type of equipment that contains a hazardous material, even in minute quantities, is also subject to the hazardous materials regulations in the same manner as the transportation of that material in more typical containers such as drums, cylinders, jars, and tanks. He also noted that although there are special regulatory exceptions for small quantity, limited quantity, and consumer commodity shipments, very few exceptions apply to the transportation of hazardous materials aboard aircraft.

The Associate Administrator explained that RSPA has on infrequent occasions issued *de minimus* rulings exempting a specific form and quantity of specific hazardous materials from the DOT hazardous materials regulations when it does not pose a risk to life and property when transported in commerce (e.g., the lithium batteries in wrist watches). In such cases, the person requesting such a ruling must demonstrate to RSPA that the quantity and form of a hazardous material does not pose a risk in transportation. The Associate Administrator emphasized that RSPA alone has the discretionary authority to issue a *de minimus* ruling, and that permitting thousands of shippers nationwide to exercise their own discretion in such cases would erode the consistent application and interpretation of the hazardous materials regulations.

As provided by law, RSPA is authorized to issue exemptions that recognize alternative means for compliance with the hazardous materials regulations, usually based on selection of alternative safety control measures that will provide an equivalent level of safety. According to the Associate Administrator, the exemptions do not signify that the materials are not subject to the hazardous materials regulations.

1.17 FedEx Organizational and Management Information

FedEx began operations on April 17, 1973. In fiscal year 1996, FedEx reported revenues of $10.3 billion. Approximately 2.5 million packages were handled daily by 122,000 employees, of which approximately 3,200 were flightcrew members. The airline served 325 airports worldwide in 211 countries with its fleet of 559 airplanes. Of the 2.5 million packages, only about 6,000 (less than 0.25 percent) are declared shipments of hazardous materials.

FedEx received its first DC-10 in March 1980. At the time of the accident, FedEx had 13 DC-10-10 and 22 DC-10-30 airplanes.

1.18 Additional Information

1.18.1 Postaccident Actions by FedEx

After the accident, FedEx revised its “Fire & Smoke” checklist by renaming it “Fire, Smoke & Fumes” and adding a step titled, “Land at Nearest Suitable Airport (if required),” and noting under that step that a new “Quick Evacuation” checklist is to be used for emergencies that require immediate evacuation. This step also instructs the crew to consider stopping on the runway to allow emergency equipment access to the aircraft.

FedEx also revised its “Cabin Cargo Smoke Light Illuminated” checklist to include an introductory paragraph indicating that the procedures are intended to depressurize the aircraft, ventilate the cockpit, and deprive the cargo section of oxygen for fire suppression, and emphasizing the importance of depressurizing. It also has a reminder to ensure that the “Fire & Smoke” checklist is completed before beginning the checklist. Step No. 6, to “PULL” the “Cabin Air Shutoff Handle,” has been moved to step No. 2, with the direction to “PULL DOWN AND FORWARD.” Step No. 4 (formerly step No. 3), “Courier Masks and Goggles,” now has information about the oxygen mask settings. Under step No. 5, “Cab/Press Man/Auto Handle,” (formerly step No. 4, “Airplane Altitude”) the directions have been expanded to include specific instructions on how to manually raise the cabin altitude and maintain the 0.5 pressure differential, and to incorporate former steps No. 5 and No. 7. Step No. 7 (formerly step No. 9), "If It Is Necessary To Leave The Cockpit To Fight A Fire [DON/ACTIVATE Protective Breathing Equipment]," has been revised to include donning and activating a walk-around oxygen bottle and donning leather gloves. Two new steps have been added to the end of the checklist. After step No. 8 (formerly step No. 10), "Land at the Nearest Suitable Airport," are step No. 9, "Manual CAB ALT Control Wheel……….OUTFLOW VALVE/FULL OPEN," which directs crews to "Accomplish immediately after landing to ensure clearview windows and/or doors will open," and step No. 10, "Accomplish the EMER EVAC [emergency evacuation] Checklist, Chapter 2-13, as required." Both the revised "Emergency Evacuation (Land)" and "Fire, Smoke & Fumes" checklists direct crews to "Evacuate with a copy of DG [dangerous goods] Form Part A and all Part Bs, if possible."

FedEx also added to its "Emergency Evacuation (Land)" checklist a step to manually open the cabin outflow valve once the airplane has landed and stopped. It has also created a new one-page "Quick Evacuation" checklist, which is designed to be used in emergencies that require immediate evacuation of the aircraft and when time and conditions do not permit the use of the longer checklist.

1.18.2 Marijuana Shipments on the Accident Airplane

According to a November 1996 NYSP Investigation Report, a total of 91.55 pounds of green material, later positively identified as marijuana, were removed from the wreckage. This total amount comprised four separate items that were given to the police during the inspection of the cargo debris.

According to the police report, the first item was turned over to the police on September 16, 1996, after it was found by a "FedEx Inspector" in the debris from cargo container 4L. It consisted of a box containing 38.35 pounds of marijuana. According to the police report, the box "was partially burned along with its attached packing/routing slip leaving no positive leads or suspects relative to ownership." The second item, found on September 19, 1996, by another FedEx employee identified as a "security supervisor" consisted of "a clear plastic bag (extensive fire damage) containing approx. 13.90 lbs. of green veg. matter," later identified as marijuana. The police report provided no information about the location of this package other than that it was found "in a large pile of debris." The report also noted that no airbill or identification was found with this item. The third item, turned over on September 21, 1996, by the same FedEx security supervisor who turned over the second item, consisted of "two plastic bags containing approx. 11.30 lbs. of green veg. matter (marijuana)." The police report indicated that this item was found "in the general area of" cargo container 7L, but noted that it could not be determined "if the item was in fact from that container due to the extensive amount of debris from numerous containers present as [the item] was secured." The fourth item, turned over by another FedEx security employee to police on September 23, 1996, consisted of "a clear plastic bag containing green veg. matter (marijuana)," weighing approximately 28 pounds.

The NYSP investigator who prepared the report testified during the Safety Board's deposition proceeding that each of the four packages was damaged by fire and water. He also stated that the packages were all wrapped differently and appeared to him to have been prepared by different shippers.

The police report stated that "no leads were developed…due to the fact that no airbill slip was recovered with [any of the items,] along with the fact that the original exact weights of the items could not be established." On September 25 and 26, 1996, a K-9 dog search of the remaining debris was conducted. According to the report, "no additional contraband was detected." The police report further stated that on November 7, 1996, the marijuana was destroyed.

During the deposition proceeding, the police investigator stated that the specially trained dogs used by police to search for such contraband are highly sensitive to the smell of marijuana. He stated that the dog brought into the accident airplane would have detected the presence of additional marijuana, if any had been on board, even if it had been totally consumed in the fire. In response to questioning during his deposition, he stated that during his 20 years as a police investigator, he had never heard of a fire being caused by heat generation inside a package of marijuana, nor was he aware of any information or research regarding the spontaneous combustion of marijuana.

1.18.3 Programs to Deter Undeclared Hazardous Materials Shipments

The number of hidden and undeclared shipments of hazardous materials is unknown; however, statistics compiled by the Air Transport Association (ATA) and the DOT indicate an increase in the air transportation of cargo. According to the ATA, the volume of cargo transported by air increased from 8.26 billion freight/express ton-miles in 1987 to 17.96 billion freight/express ton-miles in 1997, an increase of 117 percent.[68] An official of the ATA estimated that industry-wide, declared shipments of hazardous materials represent less than ½ of 1 percent of the total cargo volume.

The number of hazardous material releases for aviation, as reported to the DOT Hazardous Materials Information System (HMIS), increased from 163 incidents in 1987 to 1,015 incidents in 1997, an increase of 523 percent. Following changes in the HMIS incident reporting format in 1990, the number of incidents caused by declared versus undeclared shipments could also be distinguished. Of the 297 total aviation incidents reported for 1990, 234 incidents (79 percent) were attributed to declared shipments and 63 incidents (21 percent) to undeclared shipments. In comparison, of the 1,015 incidents reported in 1997 (an increase of 242 percent from 1990), 666 incidents (65 percent for 1997) were attributed to declared shipments and 349 incidents (35 percent for 1997) to undeclared shipments. Thus, between 1990 and 1997, the number of hazardous material releases attributed to declared shipments increased by 185 percent, and the number of hazardous material releases attributed to undeclared shipments increased by 454 percent. Further, in the 2-year period from 1996 through 1997, the number of incidents

[68] Air Transport Association. 1998 Annual Report. Washington, DC. 1998. A freight/express ton-mile is 1 ton of cargo other than U.S. mail transported 1 mile.

resulting from undeclared shipments rose 82 percent, from 192 incidents in 1996 to 349 incidents in 1997.

The manager of the dangerous goods program for FedEx testified during the deposition proceeding that hidden and undeclared shipments of hazardous materials are typically discovered when the package leaks, emits odors, or results in a release after the package is in the FedEx system. He also stated that FedEx employees receive hazardous materials awareness training and are trained to report any instance that indicates a package may contain an undeclared hazardous material. FedEx does not ask customers to identify the contents of a package when it is presented for shipment. The FedEx manager stated that although it would be beneficial to have customers identify the contents of their packages, such a practice would be so burdensome as to drive express carriers out of business. The manager also stated that FedEx has a revised airbill that asks the customer to indicate whether the package being presented for shipment contains dangerous goods or hazardous materials. However, older versions of the airbill (which do not include this question) are still in use and can be used until their supply is depleted. He stated that other measures employed by FedEx to screen and detect hidden shipments include the use of posters at receiving stations about the shipment of hazardous materials and enhancement of its education and outreach programs for FedEx customers.

During the deposition proceeding, the manager of the FAA's Dangerous Goods and Cargo Security Division described FAA initiatives within the past 12 months to reduce the incidence of hidden shipments of hazardous materials. He stated that subsequent to the crash of ValuJet 592 in May 1996, the FAA hired 118 new agents dedicated to the dangerous goods and cargo security enforcement program. (Before the ValuJet crash, the FAA had 14 dedicated agents for its hazardous materials enforcement program. Agents from other specialties were also used periodically.) All of the newly hired agents had experience in hazardous materials safety. In conjunction with hiring the new agents, the FAA lengthened its hazardous materials training course and developed and implemented a new training course for cargo security. The FAA dangerous goods manager estimated that after the new programs are established, these agents will spend 60 percent of their time on the hazardous materials enforcement program and 40 percent on the cargo security program.[69]

The FAA has also initiated an inspection program known as "Haz Strikes." Under this program, agents from the FAA and other Federal and State agencies, such as RSPA, U.S. Customs, the U.S. Postal Service, Federal Highway Administration, and State police, conduct intensive inspections to check the movement of hazardous materials on all carriers serving a particular airport. The inspections have not only included carrier freight operations, but also the operations of shippers and freight forwarders (companies that consolidate shipments from multiple shippers into containers) who are typically located off the airport property. The

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[69] The hazardous materials enforcement program includes assessment of carriers' hazardous materials program (training, manuals, policies and procedures), package inspections, ramp inspections, and inspections of shippers. The cargo security program addresses carrier and shipper programs to detect and prevent the introduction of a bomb or some type of weapon onto an aircraft.

inspections are conducted over several days at all hours of the day. Haz Strike inspections to date have been conducted in major cities including Chicago, Miami, Los Angeles, and at New York's Kennedy airport where large volumes of freight are handled.

The FAA is also publicizing dangerous goods enforcement actions in which civil penalty fines of $50,000 or more have been levied. According to the FAA dangerous goods manager, this negative publicity serves as an incentive for shippers and carriers to strengthen their compliance efforts. The FAA manager estimated that of the 36 press releases announcing fines of $50,000 or more, nearly all were for undeclared shipments of hazardous materials.

The FAA is also promoting an outreach program with all major associations involved with air transportation, including the Air Transport Association, Airline Pilots Association, International Federation of Airlines, Council on Safe Transportation of Hazardous Articles, Chemical Manufacturers Association, Repair Station Association, and paint manufacturers. Through presentations, speeches, and attendance at meetings and conferences of these associations, the FAA has emphasized the need for training to ensure that company employees are knowledgeable about the shipment and transportation of dangerous goods. The FAA manager stated that the vast majority of undeclared shipments by air occur because of a lack of understanding of the regulations. To address this, the FAA has developed and distributed brochures, posters, videos, and compact discs to increase understanding of requirements that apply to the shipment of dangerous goods by air and to heighten the awareness of the types of materials that are regulated for air transportation. The FAA is also meeting monthly with the U.S. Postal Service and providing guidance on general awareness training for postal employees.

According to the FAA manager, the FAA has also established a database that will be used to conduct trend analyses of the sources and causes of dangerous goods releases in air transportation. The FAA will utilize the hazardous materials incident system maintained by RSPA and supplemental data obtained through reports made directly to the FAA. Based on its analysis of this data, the FAA will adjust its outreach program to address identified trends.

The FAA dangerous goods manager also stated that the FAA is continuing its evaluation and oversight of carrier programs for accepting dangerous goods shipments and screening for hidden shipments in response to urgent Safety Recommendations A-96-25 and -26, issued following the crash of ValuJet 592 in May 1996.[70] The FAA conducted an initial survey

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[70] Safety Recommendation A-96-25 asked the FAA to "immediately evaluate the practices of and training provided by all air carriers for accepting passenger baggage and freight shipments (including company materials) and for identifying undeclared or unauthorized hazardous materials that are offered for transport. This evaluation should apply to any person, including ramp personnel, who accepts baggage or cargo for transport on passenger and cargo aircraft." In a June 3, 1998, letter, the FAA Administrator stated that the FAA had "concluded that additional sampling to evaluate…all air carriers is not necessary," and that "[r]andom sampling of air carriers…taken in nine different regions, provided the FAA with adequate data reflecting the status of the regulated community as a whole." She indicated that she considered the FAA's action to be completed on this safety recommendation.

Safety Recommendation A-96-26 asked the FAA to "require all air carriers, based on the evaluation performed under Safety Recommendation A-96-25, to revise as necessary their practices and training for of more than 300 carriers and is now concentrating on those carriers that do not accept dangerous goods. The FAA manager estimated that 1,200 inspections of air carriers would be conducted this year. (A given air carrier may be inspected in different cities and thereby have multiple inspections.) Because the FAA manager considered these inspections to be continuous and ongoing, he did not specify a completion date for conducting these evaluations and requiring changes as may be needed.

The FedEx and FAA managers both questioned the practicality of requiring customers to identify the contents of their shipments, developing and using enhanced technology such as x-raying packages, or seeking the authority to open suspicious packages. Both of them also indicated that they knew of no efforts within the aviation or shipping community to consider or evaluate such measures. They expressed the opinion that public education, awareness, and carrier training were the most effective methods to reduce the number of hidden and undeclared shipments of hazardous materials.

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accepting passenger baggage and freight shipments and for identifying undeclared or unauthorized hazardous materials that are offered for transport." In the June 3, 1998, letter, the Administrator stated that the FAA was clarifying the regulatory requirements for, and developing standardized procedures and training guidelines for, hazardous materials recognition training for "persons under the operational control of the certificate holder."

2. ANALYSIS

2.1 General

The flightcrew was properly certificated and qualified in accordance with the applicable regulations and company requirements. Evidence from crew duty time, flight time, rest time, and off-duty activity patterns did not indicate that behavioral or psychological factors related to fatigue affected the flightcrew on the day of the accident.

The smoke detection system installed on the airplane functioned as intended and provided the crewmembers with sufficient advance warning of the in-flight fire to enable them to land the airplane safely.

The ATC personnel involved with the flight were all properly certificated and qualified. The Boston Center ARTCC and New York TRACON controllers responded appropriately once they were aware of the emergency and provided appropriate and needed information to assist the crew in the emergency descent and landing.

The airplane was properly certificated, equipped, and maintained in accordance with applicable regulations. No evidence of systems, mechanical, or structural failures was found.

2.2 Flightcrew Performance

2.2.1 Crew Coordination

Although the airplane was landed successfully, several required items were not accomplished during the descent and landing. The flight engineer failed to perform step No. 6 of the "Cabin Cargo Smoke Light Illuminated" checklist (pulling the cabin air shutoff T-handle).[71] If he had done so, airflow would have been shut off to the main cargo deck area while being maintained to the cockpit. The Safety Board concludes that the flight engineer's failure to pull the cabin air shutoff T-handle, as required by the "Cabin Cargo Smoke Light Illuminated" checklist, allowed the normal circulation of air to continue to enter the main cargo area, thereby providing the fire with a continuing source of oxygen and contributing to its rapid growth. However, the Safety Board could not determine the degree to which it might have contributed to the severity of the fire.

The flight engineer also failed to complete step No. 7 of the "Cabin Cargo Smoke Light Illuminated" checklist (to maintain a 0.5 psi differential cabin pressure). As a result, the occupants were unable to immediately open and exit from the primary evacuation exits (the L1

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[71] Although the CVR recorded the flight engineer stating, "pull cabin air" at 0538:40, its position after the accident indicates that the cabin air shutoff T-handle had not been pulled.

and R1 doors) because the airplane was still pressurized. The flight engineer acknowledged that instead of manually maintaining the appropriate pressure differential, after he had placed the outflow valve control in the manual position, he only “cranked it open a couple of times [turns].” Because they were at 33,000 feet and operating on only one pressurization pack, the outflow valve would have been almost completely closed before the flight engineer cranked it. As demonstrated in the Safety Board’s test on a similar DC-10, manually cranking the outflow valve control two times will not perceptibly open the outflow valve from fully closed on a static airplane. The Safety Board concludes that the evacuation was delayed because the flightcrew failed to ensure that the airplane was properly depressurized.

The CVR transcript reveals that the flight engineer was overloaded and distracted from his attempts to accomplish the “Fire & Smoke” and “Cabin Cargo Smoke Light Illuminated” emergency checklists (in addition to his normal descent and before-landing checklist duties) by his repeatedly asking for the three-letter identifier for Stewart so that he could obtain runway data for that airport.

After the accident, the captain said that he had allowed the first officer to continue flying the airplane during the emergency so that he could coordinate with ATC and work with the flight engineer on completing the checklists. This should have resulted in an effective apportionment of the workload among the three crewmembers, in that the flying pilot would not have been overly distracted from flying the airplane, the flight engineer would have received needed assistance with his duties,[72] and the captain would have had the opportunity to oversee the actions of both. However, the Safety Board is concerned that, despite the captain’s stated intention to serve in a monitoring and coordinating role, he failed to provide sufficient oversight and assistance to ensure completion of all necessary tasks.

The captain did not call for any checklists to address the smoke emergency, which was contrary to FedEx procedures.[73] (The flight engineer initiated the "Fire & Smoke" and "Cabin Cargo Smoke Light Illuminated” checklists.) Nor did he explicitly assign specific duties to each of the crewmembers. The captain also did not recognize the flight engineer’s failure to accomplish required checklist items, provide the flight engineer with effective assistance, or intervene to adjust or prioritize his workload. In fact, the captain repeatedly interrupted the flight engineer during his attempts to complete the “Fire & Smoke” checklist,[74] thereby distracting him further from those duties.

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[72] At the time of the accident, the flight engineer had only 188 hours as a DC-10 flight engineer and had been working for FedEx for less than 6 months.

[73] The FedEx DC-10 Flight Manual indicates, under “Emergency and Abnormal Checklist Procedures,” that “Phase One [memory]” items are to be “performed when directed by the Captain.” Further, it states, “all checklists containing Phase One items should be requested by the Captain by name” and strongly recommends that the captain and flight engineer “work together on the review of the Phase One items and the accomplishment of the Phase Two items.”

[74] At 0538:38 and 0539:13, the captain interrupted him to ask whether he had run a test on the smoke detector system, which is not an item listed on the checklist.

Further, the captain did not initiate the "Emergency Evacuation" checklist, which was required to be initiated during the preparation for landing. The "Emergency Evacuation" checklist includes depressurizing the airplane before landing. If this checklist had been initiated, it would have provided another opportunity for the crew to accomplish the necessary depressurization that was missed on the "Fire & Smoke" checklist. In addition, the captain told investigators that he did not initiate the emergency descent checklist, but said that he thought he had accomplished the items on that checklist by memory. Although the emergency descent checklist (titled "Rapid Depressurization/Emergency Descent") was probably not applicable to this situation, the captain's statement is troubling because it suggests a belief that checklist items can be adequately accomplished from memory alone. Finally, the CVR transcript indicates that the captain did not call for an emergency evacuation. (After the captain said "we need to get…out of here," the flight engineer said "emergency ground egress.")

The Safety Board concludes that the captain did not adequately manage his crew resources when he failed to call for checklists or to monitor and facilitate the accomplishment of required checklist items. Therefore, the Safety Board believes that the FAA should require the principal operations inspector (POI) for FedEx to review the crew's actions on the accident flight and evaluate those actions in the context of FedEx emergency procedures and training (including procedures and training in crew resource management) to determine whether any changes are required in FedEx procedures and training.

2.2.2 Crew's Use of Emergency Equipment

Within 48 seconds after the first indication of a problem, the crew donned oxygen masks, as required by the "Fire & Smoke" checklist. The captain elected not to don his smoke goggles because they did not fit over his eyeglasses and they were dirty and scratched. The first officer elected not to wear his smoke goggles because he felt that they unduly restricted his peripheral vision. The flight engineer put his smoke goggles on but subsequently removed them because there was no smoke in the cockpit.

The Safety Board is concerned that cockpit smoke may affect crewmembers' vision, imperiling their ability to operate the airplane or properly address the emergency. Evidence in this accident indicates that smoke did not enter the cockpit in significant amounts until after the crew landed and stopped the airplane. However, the Safety Board is concerned that under different circumstances, the failure of crewmembers to don smoke goggles or to keep the goggles on during an emergency could adversely affect the outcome.

In connection with its investigation of the May 11, 1996, accident involving ValuJet flight 592,[75] the Safety Board concluded that there is inadequate guidance for air carrier pilots about the need to don oxygen masks and smoke goggles immediately in the event of a smoke emergency. In Safety Recommendation A-97-58, the Safety Board asked the FAA to

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[75] National Transportation Safety Board. 1997. *In-flight Fire and Impact with Terrain, ValuJet Airlines Flight 592, Everglades, Near Miami, Florida, May 11, 1996.* Aircraft Accident Report NTSB/AAR-97/06. Washington, DC.

issue guidance on this point to air carrier pilots. In a November 17, 1997, response, the FAA indicated it would issue a flight standards handbook bulletin in November 1997 containing guidance on procedures to don PBE for smoke and fume protection. The FAA did not issue the bulletin. Recently, it has been learned that the bulletin will not be issued until after the FAA reviews the results of a special emphasis inspection of smoke goggles during en route and ramp inspections. On March 20, 1998, the FAA called for this special survey of smoke goggles as part of its response to Safety Recommendation A-97-60 (also from the ValuJet report), which sought a requirement that smoke goggles currently approved for use by the flightcrews of transport-category aircraft be packaged in such a way that they can be easily opened by the flightcrew. The survey has been completed, and the FAA is reviewing the results. The Board has been assured that the FAA is still in agreement with the intent of the recommendations addressing flightcrew smoke goggles and that action on Safety Recommendations A-97-58, -59, and -60 will follow the results of the survey. The Board is very concerned that the issuance of the guidance bulletin regarding the need for flightcrews to don smoke goggles at the first indication of a possible in-flight smoke or fire emergency has been delayed until after the completion and review of the special survey. Based on this delay, the Board classifies Safety Recommendation A-97-58 “Open—Unacceptable Response.”

In the ValuJet report, the Safety Board also concluded that the smoke goggle equipment currently provided on most air carrier transport aircraft requires excessive time, effort, attention, and coordination by the flightcrew to don and, in Safety Recommendation A-97-59, asked the FAA to establish a performance standard for the rapid donning of smoke goggles and ensure that all air carriers meet this standard through improved smoke goggle equipment, improved flightcrew training, or both. In response, the FAA indicated that it believed the intent of this recommendation is addressed in 14 CFR 121.337, which establishes standards for PBE for smoke and fume protection and requires that the equipment be conveniently located on the flight deck and easily accessible for immediate use. However, there is no standard for the optimum equipment location that will facilitate quick donning of such equipment or for the time required to don the equipment. The FAA also stated that it would issue a flight standards handbook bulletin to provide additional guidance on the location and donning of this equipment and procedural guidance on flightcrew training requirements. However, it did not address the recommendation to establish a standard to ensure that, through equipment design, equipment installation, or flightcrew training, a specific performance standard is achieved for donning smoke goggles. The FAA has indicated that it will await the results of the special emphasis inspection before it takes further action. The Safety Board classifies Safety Recommendation A-97-59 “Open—Unacceptable Response.”

This accident again demonstrates that crews may not use the equipment currently available and that some characteristics of the current equipment may interfere with the flightcrew’s performance of its duties. Accordingly, the Safety Board reiterates Safety Recommendations A-97-58 and -59.

During the evacuation, the flight engineer stated that before he entered the foyer area to evacuate via the R1 door, he filled his lungs with oxygen from his oxygen mask. He did not use the PBE, which would have provided him with protection from the smoke while he attempted to open the foyer doors. In postaccident interviews, he stated that he was anxious to open the exit doors quickly, and he forgot that the PBE was available. The Safety Board concludes that crewmembers who do not use PBE during a smoke or fire emergency may place themselves at unnecessary risk in attempting to address or escape from the situation. Although most carriers' emergency evacuation checklists instruct crewmembers to don PBE when circumstances warrant, there is no reference to the PBE in the FedEx "Emergency Evacuation" checklist. Therefore, the Safety Board believes that the FAA should require FedEx to modify its evacuation checklist and training to emphasize the availability of PBE during evacuations in an environment containing smoke, fire, or toxic fumes.

The L-1 door was not available as an emergency exit because it only opened partially as a result of the flight engineer's attempt to open the door while the airplane was still pressurized. As discussed in section 1.6.4, when there is no electric power to the airplane the motor that operates the door is powered by a charged air bottle. If an attempt is made to open the door when the cabin pressure differential is above 0.5 psi, the bottle pressure will bleed off and the door will not open. Although the lack of the L-1 door as an escape route was not a significant factor in this accident, the Safety Board is concerned that under other circumstances the loss of a passenger exit door could have serious safety consequences. The Safety Board concludes that crewmembers may not be adequately aware that attempting to open a passenger exit door when the airplane is still pressurized may result in the door not opening. Therefore, the Safety Board believes that the FAA should require all Part 121 operators of airplanes that rely on air pressure to operate exit doors to make crewmembers aware of the circumstances of this accident and remind them of the need to ensure that the airplane is depressurized before attempting to open the passenger exit doors in an emergency.

2.3 Fire Initiation

2.3.1 Location from Which the Fire Might Have Initiated

Because the fire burned for about 4 hours after smoke was first detected in the cabin cargo compartment, under changing conditions, much of the potentially helpful evidence was destroyed by the fire.[76] The growth of the fire was likely affected by the failure to pull the cabin air shutoff T-handle and the opening of doors L1 and R1 about 0556, which (even though L1 did not open completely) would have provided additional ventilation (oxygen), and thus increased the rate of fire growth. An even greater addition of oxygen occurred about 0650 when the cargo door was opened. (Witnesses reported that flames first broke through the fuselage shortly after the cargo door was opened. The airport operations log recorded that flames breached the crown of the fuselage about 0655, which was 1 hour after the airplane landed and about 1 hour and 19 minutes after the illuminated smoke detector lights were first noted by the flightcrew.) Despite the length of time the fire burned and the resulting destruction of potentially

[76] It should nonetheless be noted that even after the prolonged fire, many containers (including those in rows 1, 2, 3, 14, 15, and 16) were not severely compromised, or still contained substantial quantities of highly combustible materials (such as magazines, technical manuals, dry cleaning bags, bubble wrap, and clothing) that remained unburned.

helpful evidence, the postfire condition of the airplane and its contents were nonetheless examined for clues as to the location from which the fire might have initiated.

One factor that investigators considered was the "V" burn pattern that originated at container 6R. It is a basic premise of fire science that such a “V” pattern often points to the origin of a fire. However, as explained in the National Fire Protection Association’s *Guide for Fire and Explosion Investigations,* NFPA 921, “each time another fuel package is ignited or the ventilation to the fire changes, the rate of energy production and heat distribution will change. Any burning item can produce a plume and, thus a ‘V’ pattern. Determining which pattern was produced at the point of origin by the first material ignited becomes more and more difficult as the size and duration of the fire increases.” [Par. 3-7][77]

Several areas in the main cabin cargo compartment exhibited extensive fire damage; however, the deepest and most severe heat and fire damage was found in and around container 6R.[78] More of 6R's structure was consumed than of any other container, and it was the only container that exhibited severe floor damage, which was likely caused by burning/melting Lexan wall material that fell inward onto the unprotected container floor. (Container 6R was one of the more sparsely loaded containers, enabling fire to reach the floor level without having to consume much cargo in the process.) Further, 6R was the only container to exhibit heat damage on its bottom surface, and the area below container 6R showed the most extensive evidence of scorching of the composite flooring material. In addition, the overall burn damage pattern to the cargo containers in the main cargo cabin showed that the deepest burned-out area centered over container 6R and that the cargo containers surrounding 6R and the contents in these containers were all burned to a greater depth along the sides common to container 6R.

There was heat damage to the cabin floor just aft of container 9L, but there was no cargo container in this area on the accident flight. This damage to the floor was consistent with burning material falling from the burning fuselage crown or contents from cargo container 9L falling into this empty space. Two aerosol cans found in this area showed evidence that they had been heated by fire on the outside of the cans, and that they had overpressurized and ruptured.

If the fire had not burned so long, the "V" burn damage pattern and the extensiveness of the fire damage to 6R would have been stronger evidence of a fire originating inside 6R. Further, the deep burn and severe damage found in container 6R could also be accounted for by the fact that it was relatively empty and therefore largely unprotected by cargo. Thus, the Lexan side walls and nylon curtain could have fallen directly onto the floor of 6R and burned there, resulting in the severe damage to the floor of 6R and the exterior surfaces of the synthesizer. When Lexan is heated, it typically burns, melts, and puddles, producing heat that would be sufficient to cause the damage to container 6R and its contents. Thus, a fire that

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[77] See also Par. 3-7.2, which states, “[a]reas of great damage are indicators of a high heat release rate, ventilation effects, or long exposure. Such areas, however, are not always the point of fire origin.”

[78] In every other cargo container there was a layer of unburned cargo covering the container floor.

originated outside of 6R but eventually spread to that area could have resulted in a similar damage pattern.

Comments on the CVR suggest that the smoke detector activation sequence might have begun with detector number 9 and initially moved forward; this suggests that the fire might have started aft of row 6. Further, some of the first flames to have breached the crown were observed approximately above the area occupied by cargo container rows 8 and 9.[79] Although the smoke detector activation sequence and location of the early breakthrough of flames cannot be considered reliable indicators of a fire's initial location,[80] a possible connection between these factors and the location of the fire's origin could not be discounted. Therefore, the Safety Board also considered the possibility that the fire originated aft of container row 6.

Although there was some significant burn damage to the containers in rows 8 and 9, their contents, and the surrounding area of the aircraft, this damage appeared to have been less than the damage in the area of container 6R. For example, container 8L's aluminum roof and two of its three Lexan walls were consumed by fire, as was the upper two-thirds of the third Lexan wall; its inboard forward and aft cornerposts measured 5 feet 10 inches and 5 feet 2 inches, respectively, and its outboard forward and aft cornerposts measured 1 foot 4.5 inches and 3 feet 6.5 inches, respectively. Container 9R's aluminum roof and two of its three Lexan walls were consumed by fire, as was the upper portion of the third Lexan wall; its inboard cornerposts were intact, but its outboard forward and aft cornerposts measured 1 foot 3.5 inches and 1 foot 5 inches, respectively. However, 9L contained a significant quantity of undamaged materials[81] with a low melting point (polyurethane, polystyrene, and polyethylene), and the cornerposts of

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[79] It should be noted that a FedEx mechanic who was standing near the cargo door indicated that at about the same time that flames were first seen venting from the aft section of the airplane in the 8/9 area, or possibly earlier, flames were also starting to break through the side of the fuselage in the area of 6L. His observations were not contradicted by the other eyewitnesses. Rather, they suggest that flames might have been breaking through the fuselage at more than one place at the same time. The video footage showing flames breaking through farther aft was taken from the right of the airplane and would not have captured a breakthrough of flames on the left side.

[80] The breakthrough principle is illustrated by several previous main cabin aircraft fires. For example, a cabin fire occurred in Atlanta in 1995 on a ValuJet DC-9 after an engine failure started in the aft end of the cabin from a failed engine compressor disk that punctured a fuel line and penetrated the cabin. (See, National Transportation Safety Board. 1996. *Uncontained Engine Failure/Fire, ValuJet Airlines Flight 597, DC-9-32, N908VJ, Atlanta, Georgia, June 8, 1995.* NTSB/AAR-96/03. Washington, DC.) In a report submitted to the Safety Board, an FAA fire specialist noted that in that accident, in spite of rapid fire department response, the fire gutted the cabin and penetrated the fuselage skin just behind the cockpit—at the opposite end of the cabin from where the fire started. Another example is an in-flight fire that originated in the left rear lavatory of an Air Canada DC-9 that forced the flightcrew to make an emergency landing on June 2, 1983, at the Greater Cincinnati Airport. In that fire, the first evidence of fuselage breakthrough occurred at the front of the aircraft, significantly forward of the initiation point. In addition, in a fire that originated below the floor immediately aft of the right galley on a Delta 737 while it was on the ground at Salt Lake City, Utah, on October 14, 1989, the first fuselage breach was in the first-class cabin, well forward of the fire's origin.

[81] Although 6R also contained a small amount of unburned combustible material (for example, newspaper wrapped around the industrial valves loaded in the outboard aft corner of the container), unlike the contents of containers in rows 8 and 9, the vast majority of easily burned unprotected material in 6R was consumed by the fire.

that container sustained fire damage only to the forward outboard post. Similarly, containers 9R and 8R contained significant amounts of unburned combustibles (such as paper items) after the fire.

In analyzing the significance of the unburned materials in rows 8 and 9, the Safety Board recognized that when material towards the top of the containers in those rows burned, it could have formed an insulating layer of charred debris that would have slowed the downward progress of the fire.[82] Postaccident examination revealed a significant amount of burned material (as well as unburned material) in that area. However, the high-pressure water streams from the firefighting efforts would have disrupted the arrangement of the burned and unburned materials, thus erasing any obvious signs of an insulating layer.

Finally, investigators also noted that there was a "V" soot pattern on the interior of the fuselage originating at the floor level of the junction between 8L and 9L, but this is consistent with the exposure of that area when the fuselage separated and the fire vented at that point and is probably not related to the location of the fire's origin.

Thus, in comparing the fire damage in 6R with that in rows 8 and 9, it is possible that the fire in those rows was as significant as that in the area of 6R, but it might have started at or near the top of a container and was unable to progress very far into the volume of cargo loaded into those containers.

In sum, there was insufficient reliable evidence to reach a conclusion as to where the fire originated.

2.3.2 Ignition Source of the Fire

Because of an initial recognition among the fire investigators participating in the investigation that "V" burn patterns are generally highly significant, investigators examined the contents of 6R to try to identify a possible source of the fire. All items found in, or known to have been shipped in, container 6R were examined in detail (see section 1.14.2.1.1). In particular, the Safety Board examined the DNA synthesizer as a potential source of ignition because of the chemical smell noticed inside the unit and because the other items in that container were ruled not likely to have provided a source of ignition. The nature and degree of the fire damage to the synthesizer, particularly the heavy damage to the internal circuitry of the synthesizer's controller panel (which is made of a low-flammability material), was thought to be suggestive of a source of fuel inside the synthesizer. (However, given the presence of volatile chemicals, and possibly vapors, inside the synthesizer, it is possible that a fire ignited external to the synthesizer could have produced a damage pattern similar to that resulting from an internal ignition source.)

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[82] According to the National Fire Protection Association's *Guide for Fire and Explosion Investigations,* NFPA 921, "[a] protected area results from an object preventing the products of combustion from depositing on the material that the object protects, or prevents the protected material from burning." [Par. 4-15.2]

Tests of the liquids from the accident synthesizer showed that flammable chemicals (THF and acetonitrile) were still present in the bottles on the machine after the fire. The quantity of chemicals remaining in the synthesizer's bottles after the fire was insufficient to have caused the extensive internal fire damage to the synthesizer and the cargo container. However, it is likely that significant amounts of the chemicals were consumed in the prolonged and intense fire and thus the synthesizer probably contained much larger quantities of these flammable chemicals before the fire. (The presence of firefighting agent inside most of the bottles and the damage to many of the tubes that entered the bottles indicates that the bottles had been open to the atmosphere during at least part of the fire sequence.)

These volatile chemicals—particularly the THF—could ignite a fire. THF, which is highly flammable under any circumstances, can also form unstable peroxides that can explode on contact with certain other materials or autoignite (spontaneously explode) in sufficient concentrations. Although the investigation examined this as a possible ignition scenario, it could not be determined whether the chemicals in the synthesizer played any role in igniting the fire. The investigation could not develop a viable and convincing scenario to explain how the synthesizer could have started a fire.

Further, although the cargo debris from all of the cargo containers that had been carrying general cargo was also examined for possible ignition sources, it was not initially examined in as much detail as the items known to have been loaded into 6R because of the volume and condition of the debris. When a more detailed examination of that cargo debris was conducted later in the investigation, no ignition sources were identified in that cargo debris. However, because of the deteriorated condition of the cargo debris and the possibility that some cargo had been completely destroyed in the fire, the Safety Board could not rule out that on the accident flight, an ignition source was present in one of those cargo containers.

In light of the discovery of several shipments of marijuana on board the accident flight and the suggestion of one of the parties that marijuana is subject to spontaneous combustion, investigators considered this as a possible ignition source. The Safety Board recognizes that some organic matter, such as hay, can generate a biological/organic reaction producing heat and combustion if it is both wet and sufficiently compressed yet still exposed to oxygen. However, all of the marijuana shipments on board the airplane had been vacuum packed. (The police investigator who documented the marijuana seizures testified that the specially trained dog would have detected the presence of additional packages of marijuana, if any had been on board, even if the packages were completely consumed in the fire.) The police investigator who documented the marijuana seizures explained that shippers of contraband such as marijuana attempt to reduce the size of the package by "using a vacuum to vacuum out all the air and get it as compact as possible." Thus, although the marijuana would have been compressed, there would have been little or no oxygen available to permit or support the biological reaction needed to lead to spontaneous combustion. Further, neither the police investigator nor any of the fire experts or consultants questioned during the course of the Safety Board's investigation were aware of a fire being initiated by spontaneous combustion of a marijuana shipment. Therefore, spontaneous combustion of a marijuana shipment was ruled out as a possible ignition source.

Finally, all of the airplane systems were examined for possible ignition sources; the electrical system showed no evidence of arcing, and none of the other aircraft systems showed any evidence of malfunction. Further, neither the crew interviews nor the FDR or CVR data indicated any failures or malfunctions in the airplane's systems that might have played a part in initiating the fire. Therefore, aircraft systems were ruled out as a possible ignition source for the fire.

In sum, the Safety Board could not conclusively identify an ignition source for the fire.

2.4 Undeclared Hazardous Materials on Airplanes

2.4.1 The Synthesizer

As noted above, the DNA synthesizer in container 6R was found to contain flammable liquids after the fire. The largest liquid sample in the accident synthesizer (approximately 5 mL in the AUX 3 reagent bottle) had a concentration of 4.3 percent of acetonitrile and .01 percent of THF. This is equivalent to about 200 µl of acetonitrile and 0.5 µl of THF. In comparison, the AUX 3 bottle from the synthesizer that was purged at AFIP, according to the procedures in Perseptive's manual, contained only 66 µl of acetonitrile and 0.2 µl of THF. Thus, after the accident, the AUX 3 bottle from the accident synthesizer contained about two and a half times the amount of acetonitrile and THF as did the AUX 3 bottle from the synthesizer purged at AFIP using the prescribed PerSeptive procedures. Further, the OX 2 bottle from the accident synthesizer contained about 5 µl of THF, which is about five times as much as the most THF that was left in any of the bottles from the synthesizer purged at AFIP. (The most THF in the synthesizer purged at AFIP was found in the CAP A5 bottle, which contained approximately 0.966 µl of THF. The CAP A5 bottle from the accident synthesizer contained approximately 4 µl of THF.)

To determine why acetonitrile and THF were present in the accident synthesizer in quantities greater than those of a properly purged unit, investigators reviewed the operating and maintenance history of the synthesizer and the procedures used to prepare the instrument for shipment. The instrument had sat idle for more than 6 months without being flushed or cleaned before the PerSeptive field engineer prepared it for shipment on August 28, 1996. Although the field engineer stated that he noted no malfunctions or problems, and that the synthesizer functioned properly during the purging procedure, the output log that recorded his actions during the purging procedure showed 44 "manual function invoked" entries that could not be accounted for by the steps prescribed in PerSeptive's Service Note 89-006. When questioned about these entries, the field engineer explained that they represented multiple "prime individual" functions that he had invoked for each of the individual reagent positions on both column positions. (The priming function pumps a small, fixed amount of liquid from each individual reagent position through the flowpath.)

Although the field engineer asserted that there were no problems with the purging of the machine, he also indicated that he performed the additional individual priming functions as an additional measure to ensure that liquid was flowing through the machine. This suggests that he wanted to ensure that liquid was flowing properly. These additional manual priming functions could be consistent with his having made repeated attempts to isolate or correct a perceived problem. Further, the existence of a breach in the system might also explain how chemicals found their way to enclosed areas of the machine that later exhibited severe fire damage.

Although the Safety Board could not positively determine the specific deficiency in the purging process, the purging and drying procedures performed at PerSeptive's corporate offices and at AFIP demonstrated that if the procedures in Service Note 89-006 were properly carried out, it would result in the synthesizer bottles containing trace amounts of chemicals less than those found in the accident synthesizer.[83] Thus, based on the results of the Safety Board's tests at NASA, it is clear that this process was not followed correctly and that chemicals in amounts greater than should have existed were left in at least some of the bottles.

The most reasonable explanation for the presence of excessive quantities of chemicals in the synthesizer is that one or more of the bottles containing chemical reagents used in the DNA synthesis process (at least one of which contained THF) was not sufficiently emptied before the purging process began.

This error alone (failure to sufficiently empty one or more of the bottles before the flushing cycle) might not have resulted in chemical residues being left in the synthesizer if the bottles had been replaced with new, dry, empty bottles before the drying cycle. However, it is unclear from Perseptive's procedures whether this was expected. In any event, the quantities of chemicals found in some bottles (for example, AUX 3, OX 2, CAP A5, and CP B6) indicate that the field engineer probably failed to sufficiently empty one or more of the internal reagent bottles after the flushing process and before the drying cycle, and that some of the chemicals left in those bottles remained in the synthesizer even after the drying cycle was complete. Therefore, the Safety Board concludes that the DNA synthesizer was not completely purged of volatile chemicals (including acetonitrile and THF) before it was transported on board flight 1406.

The RSPA Associate Administrator for Hazardous Material Safety indicated that the shipment of any amount of material classified by the DOT hazardous materials regulations as hazardous materials (as are acetonitrile and THF) is subject to DOT requirements for packaging, labeling, and shipping documentation to accurately identify the hazardous nature of a shipment. He also indicated that the transportation of any type of equipment that contains hazardous materials, even in minute quantities, is also subject to the hazardous materials regulations just as it would be if it were shipped in more typical containers. Because the synthesizer was not intended to be shipped with any hazardous materials, it was shipped as general freight and was not packaged or labeled in accordance with DOT requirements and was not accompanied by the required paperwork.

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[83] If the instructions in Service Note 89-006 to replace the bottles with "dry empty" bottles before the drying step is interpreted as a requirement that new bottles be installed, then even smaller quantities of trace chemicals (or none at all) would be found inside them. During the purging demonstrations, the bottles were simply emptied and shaken between the flushing and drying, rather than replaced with new, clean bottles.

Because the presence of flammable chemicals in the DNA synthesizer was wholly unintended and unknown to the preparer of the package (PerSeptive) and the shipper (Chiron), it is unlikely that the shipment of those chemicals on board flight 1406 would have been prevented by better hazardous materials education or improved screening of packages offered for transportation. However, it does demonstrate the safety threat posed by undeclared and improperly packaged hazardous materials.

2.4.2 Other Prohibited Items

Several other items discovered on board the accident airplane might also have constituted shipments of undeclared hazardous materials. As discussed in section 1.14.2.1.1, seven aerosol cans and several plastic bottles containing acidic or alkaline liquids that could be corrosive, and two samples containing potentially flammable or combustible liquids were found in the cargo debris.[84] Although the original contents of the aerosol cans recovered from the accident aircraft could not be determined, aerosol cans, as pressurized containers with compressed gases, are regulated hazardous materials. The acidic and alkaline liquids in the plastic bottles were also likely subject to the DOT hazardous materials regulations as corrosive materials. Although the DOT hazardous materials regulations allow exceptions to packaging, marking, labeling, or shipping paper requirements, depending on the quantity and form of the material being shipped, these exceptions generally are not applicable when the item is being transported by air. Consequently, the aerosol cans and the containers of acidic liquid likely constituted undeclared shipments of hazardous materials. Although these items were ruled out as possible ignition sources, they again raise concerns about the prevalence of unknown hazardous materials being carried on board airplanes.

The ease with which prohibited materials can find their way onto commercial airplane flights was further highlighted by the discovery of several illegal shipments of marijuana on board the accident flight. Marijuana is not classified as a hazardous material for purposes of air transportation, and the marijuana found on board flight 1406 was not a factor in the accident. Further, the Safety Board notes that most undeclared shipments of hazardous materials are unintentional, although the shipment of marijuana is clearly a deliberate attempt to ship contraband material. Nonetheless, the Safety Board concludes that the presence of the aerosol cans, the containers of acidic liquid, as well as several packages of marijuana on board the accident flight illustrates that common carriers can be unaware of the true content of many of the packages they carry.

2.4.3 Federal and Industry Oversight

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[84] The hazardous materials regulations define a corrosive material as “a liquid or solid that causes full thickness destruction of human skin at the site of contact within a specified period of time; [or a] liquid that has a severe corrosion rate on steel or aluminum.” (49 CFR 173.136.) They also prescribe packaging standards based on the length of exposure of the corrosive material to human skin and the time after exposure for destruction of the skin to occur. (49 CFR 173.137.)

The shipment of undeclared and improperly packaged hazardous materials on board airplanes and the oversight by the FAA and air carriers to detect and identify such shipments was most recently addressed by the Safety Board in its report of the May 11, 1996, accident involving ValuJet Airlines. The Safety Board determined that the in-flight fire was initiated by the actuation of one or more chemical oxygen generators being improperly carried as cargo. These generators had not been identified as hazardous materials and were not properly packaged for transportation.

The Safety Board stated in the ValuJet report that the practices, procedures, and training of the personnel involved in the identification and handling of undeclared hazardous materials have remained inadequate. The Safety Board further noted that the ValuJet accident and incidents that occurred after that accident clearly demonstrate that the shipment of undeclared hazardous materials in air transportation is a serious problem that has not been adequately addressed. In the ValuJet report, the Safety Board further stated the following:

> [T]he FAA has initiated the evaluation requested by the Safety Board in Safety Recommendations A-96-25 and -26 of the practices and training provided by all air carriers for accepting passenger baggage and freight shipment (including COMAT [company materials]) and for identifying undeclared or unauthorized hazardous materials that are offered for transport and, based on this evaluation, to require air carriers to revise as necessary their practices and training in this area.
>
> Further, the FAA is developing a hazardous materials education and enforcement program that will focus on air freight forwarders. Also, shortly after August 1996, the FAA issued, under 14 CFR Part 109 (Indirect Air Carrier Security), shipper endorsement requirements that require all shippers, and freight forwarders to certify that all packages being shipped do not contain unauthorized explosives, destructive devices, or hazardous materials. Signing the endorsement also gives permission to search the shipment. Because the transport of oxygen generators has continued since the accident, despite the regulations, the Safety Board will closely monitor the FAA’s progress in fulfilling these proposed improvements.

The FAA initiatives that have been undertaken since the ValuJet accident (e.g., hiring new agents, comprehensive inspections of carriers’ and shippers’ facilities, increased penalties for violations, a renewed outreach program, and the establishment of a database for trend analysis) are positive measures to reduce the number of hidden or undeclared shipments of hazardous materials. However, although the Safety Board supports these efforts, this accident illustrates that there is continued cause for concern. The Safety Board is especially concerned that, except in the case of properly packaged and declared shipments of hazardous materials, carriers generally do not inquire about the content of packages being shipped domestically, nor are they required to do so. The Safety Board also notes that the dangerous goods managers for FedEx and the FAA questioned the practicality and usefulness of carriers questioning a shipper about the contents of packages offered for shipment. Although air carriers and the FAA apparently agree on the seriousness of the problem, consideration is not being given to innovative measures, such as identifying package contents on the airbills or using technologies like x-ray machines to detect undeclared hazardous materials.

The Safety Board concludes that transportation of undeclared hazardous materials on airplanes remains a significant problem and more aggressive measures to address it are needed. Thus, the Safety Board believes that, in addition to the efforts already underway by the FAA, the DOT should require, within 2 years, that a person offering any shipment for air transportation provide written responses, on shipping papers, to inquiries about hazardous characteristics of the shipment, and develop other procedures and technologies to improve the detection of undeclared hazardous materials offered for transportation. The inquiries may include answering individual and specific questions about whether a package contains a substance that might be classified hazardous, (e.g., "does this package contain a substance that might be corrosive [or flammable, a poison, an oxidizer, etc.]")

2.5 Dissemination of Hazardous Materials Information

After the occupants had successfully evacuated the airplane, the most immediate problem for the firefighters and other emergency responders was to prevent the fire from spreading and involving the fuel that remained on the airplane. In this case, the unavailability to the incident commander of specific information about the declared hazardous materials on board did not affect the firefighting strategy of the NY ANG. (For more information see Section 1.15.2, Emergency Response.) Nevertheless, in accidents that involve hazardous materials, it is critical that firefighters and other emergency responders receive timely information regarding the identity, quantity, number of packages, and location of declared hazardous materials. Such information can influence the type and level of response and may be necessary to adequately protect emergency response personnel, the environment, and the surrounding communities.

Neither the assistant fire chief who served as the initial incident commander nor the ANG fire chief received specific information during the firefighting phase of the emergency (before 0925) about the identity of the hazardous materials, their quantities, or the number of packages on the airplane. By 0700, about 1 hour after the airplane had landed, the only information about the hazardous materials on board the airplane that had been provided to the initial incident commander came from the Part A form and a handwritten list provided by the FedEx station at the airport. This information indicated only the hazard classes of the hazardous materials on board the airplane and their location in the airplane by cargo container position. Emergency guidance about specific chemicals was available through the Orange County HMRT and its communications link to CHEMTREC; however, this information was of little use until the specific identity and quantities of the declared hazardous materials on board the airplane were known. About 0915, approximately 10 minutes before the fire was extinguished, the fire chief received from the Orange County HMRT coordinator a copy of the weight and load plan and a handwritten list identifying some of the chemicals on board.

The NY ANG and other participating emergency response agencies, including airport operations at Stewart, repeatedly requested specific information about the hazardous materials on board the airplane. Throughout the morning (beginning at 0635) and into the early afternoon, FedEx, primarily through its GOCC in Memphis, faxed as many as 12 transmissions of various hazardous materials shipping documents to the EOC at the airport operations building and the NYSP barracks at Stewart, although many of the faxes were illegible. However, none of these reached the incident commander. (The lack of coordination among the involved agencies is addressed in section 2.6.)

Another problem was that FedEx did not have the capability to generate, in a timely manner, a single list indicating the shipping name, identification number, hazard class, quantity, number of packages, and the location of each declared shipment of hazardous materials on the airplane. To prepare such a list, FedEx would have had to compile information from copies of all of the individual Part Bs for each individual shipment of hazardous materials on the airplane. Because FedEx did not have the capability to quickly consolidate that information, it relied on faxing copies of the individual Part Bs for the approximately 85 hazardous materials packages on board, which proved to be burdensome, time consuming and, in this case, ineffective. Also, because of the poor quality and legibility of many of the handwritten Part Bs, much of the information was unusable.

In contrast, railroads operating freight trains can generate a computerized list of all of the freight cars in the train that identifies which freight cars are transporting hazardous materials and provides the shipping name, hazard class, identification number, and type of packaging, quantity, and emergency response guidance for each hazardous material transported. Such a printed, comprehensive list can be generated quickly and thus the information can be provided in a timely fashion to the appropriate emergency responders and in a more useful format than numerous faxed copies of partially legible Part B forms.

In both this accident and the crash of the FedEx MD-11 at Newark, the on-board Part B hazardous materials shipping papers were not available to emergency responders,[85] and FedEx was unable to provide complete information to emergency responders in a timely manner. Further, in two subsequent accidents near Clarksville, Tennessee, and Bismarck, North Dakota, the effectiveness of FedEx's hazardous materials recordkeeping system was again called into question. In the Clarksville accident, the shipping papers on board the airplane and on file at FedEx's Memphis Operations Center were found to be inaccurate. And in the Bismarck accident, FedEx was unable to confirm whether there were hazardous materials on board the airplane until 2 hours and 49 minutes after receiving the request for this information.

Safety Board investigators surveyed the capability of other carriers to provide this information in similar circumstances and found that only one carrier had an on-line capability to provide detailed information about the hazardous materials on board its airplane. The remaining

[85] The DOT hazardous materials regulations [49 CFR Part 173] require that the proper shipping name, hazard class, identification number, packaging group, and total quantity of the material appear on the shipping papers for any shipment of hazardous materials. Further, the regulations stipulate [49 CFR Part 175] that an operator must provide this information in writing to the pilot-in-command and that a copy of the shipping papers must accompany the shipment on board the airplane.

carriers, like FedEx, rely on paper copies of the hazardous material shipping documentation retained at the departing station if the on-board documentation is destroyed. The Safety Board is pleased that FedEx has committed to developing and implementing an electronic system for tracking and retrieving information about hazardous materials being carried on board FedEx flights. As discussed in section 1.15.2.1.2, FedEx plans to implement intermediate and long-term plans that would make computerized information about hazardous materials information available from all FedEx facilities. However, the Safety Board does not agree with FedEx's position that the proper shipping name is not relevant to emergency responders. Although this information may not always be required, in many cases it may be vital that emergency responders know exactly what substances are on board an aircraft so that appropriate measures can be taken to address potential risks.

Compared to the other modes of transportation, it is less likely that shipping papers on board an accident aircraft will survive or be accessible because of the greater likelihood of fire and destruction of the airplane. Because of the danger of fire, a flightcrew is also less likely to have time to retrieve the shipping papers after a crash. The Safety Board concludes that the DOT hazardous materials regulations do not adequately address the need for hazardous materials information on file at a carrier to be quickly retrievable in a format useful to emergency responders. Therefore, the Safety Board believes that the FAA and the RSPA should require, within 2 years, that air carriers transporting hazardous materials have the means, 24 hours per day, to quickly retrieve and provide consolidated, specific information about the identity (including proper shipping name), hazard class, quantity, number of packages, and location of all hazardous materials on an airplane in a timely manner to emergency responders.

Another obstacle in this case to emergency responders receiving hazardous materials information was FedEx's inappropriate statement to the ANG command post (at about 1300) that copies of the hazardous materials shipping documentation could not be provided to them because the Safety Board had taken over the investigation. This created the false impression that such information could not be released without the Safety Board's approval. FedEx later stated that this was consistent with company policy that once the Safety Board has taken control of an aircraft accident investigation, all information pertaining to that investigation should be forwarded to the Safety Board. Although the Safety Board appreciates FedEx's efforts to recognize the Board's primacy in aircraft accident investigations, the Safety Board has not promoted, nor does it support, a policy that would interfere with a carrier's ability to assist emergency responders in transportation emergencies, especially when hazardous materials are involved. The Safety Board concludes that FedEx's policy of providing information only to the Safety Board after the Safety Board initiates an investigation is inconsistent with the need to quickly provide emergency responders with essential information to assess the threat to themselves and the local community. Therefore, the Safety Board believes that the FAA should require the POI for FedEx to ensure that all FedEx employees who may communicate with emergency responders about a transportation accident involving hazardous materials understand that they should provide those emergency responders with any available information about hazardous materials that may be involved.

2.6 Emergency Response

Postaccident evaluations by airport personnel and representatives of the participating agencies indicated that many believed that communication and coordination among the agencies were lacking during the emergency response. Although all participating agencies recognized the ANG fire chief as the incident commander,[86] representatives from these agencies had differing opinions about who was to be present at the EOC, who was in charge at the EOC, the role of other agencies (including the Safety Board), and which emergency plan had been implemented in this accident. Although each of the participating agencies has conducted drills and exercises under their respective emergency plans for transportation and nontransportation hazardous materials incidents, joint exercises had not been conducted at Stewart for a simulated hazardous materials incident. The failure of the incident commander to receive the hazardous materials information that was being provided to other emergency responders indicates that communication and coordination among the participating agencies were not effective. Further, inadequate emergency preplanning and coordination among the responding emergency response agencies resulted in confusion about the responsibilities of the participating agencies and contributed to the failure of information about the hazardous materials on the airplane to reach the incident commander.

The Safety Board concludes that more effective preparation for emergencies involving hazardous materials and a system for coordination among the ANG, Stewart International Airport management, and all local and State emergency response agencies are needed. The Safety Board recognizes that after this accident Stewart revised its emergency plan, and that airport operations personnel at Stewart have acknowledged the need to address those deficiencies in the airport's emergency plan. However, the Safety Board is concerned that FAA requirements[87] do not specifically address the need to prepare for hazardous materials emergencies, and that other airports may be similarly unprepared for hazardous materials emergencies. The Safety Board concludes that airport emergency plans should specifically address hazardous materials emergencies. Therefore, the Safety Board believes that the FAA should require all certificated airports to coordinate with appropriate fire departments, and all State and local agencies that might become involved in responding to an aviation accident involving hazardous materials, to develop and implement a hazardous materials response plan for the airport that specifies the responsibility of each participating local, regional, and State agency, and addresses the dissemination of information about the hazardous materials involved. Such plans should take into consideration the types of hazardous materials incidents that could occur at the airport based on the potential types and sources of hazardous materials passing through the airport. The Safety Board also believes that the FAA should require airports to coordinate the scheduling of joint exercises to test these hazardous materials emergency plans.

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[86] The assistant fire chief on duty served as incident commander until 0700, when the fire chief arrived on scene.

[87] 14 CFR 139.325 specifies what must be included in airport emergency plans of airports certificated under Part 139.

Firefighters were positioned on scene before the airplane landed and began firefighting efforts immediately. Although the firefighters initially attempted to conduct an interior attack on the fire from the foyer area, the location of the cargo containers prevented them from approaching the seat of the fire. After the cargo door was opened, firefighters observed orange flames and heavy smoke in the airplane, and the incident commander evacuated them from the airplane. The initial incident commander's decision to evacuate the firefighters from the interior of the airplane was appropriate given the danger posed by the smoke and fire-filled airplane. However, the initial incident commander acknowledged that use of the SPAAT tool to penetrate the fuselage was delayed while he attempted to accommodate the flight engineer's request that damage to the airplane be minimized.[88] Although it is not clear whether an earlier entry would have improved the effectiveness of the firefighting efforts in this case, the Safety Board is concerned that more aggressive measures to enter the airplane, such as use of a fuselage penetrating tool, were not taken sooner. The Safety Board notes that the ANG fire chief testified that based on "lessons learned" from this accident, if a similar situation were to occur, he would immediately "get right in there with a hand line and deploy some type of penetrating tool on the outer skin of the aircraft."

The Safety Board has long been concerned about the lack of success of airport fire departments in extinguishing interior fires.[89] On June 4, 1996, the FAA published "Airport Rescue and Firefighting Mission Response Study," in the *Federal Register* and invited comments from interested parties. According to the *Federal Register* notice, the study was undertaken to compare the mission and requirements for civil airport fire services to those of the Department of Defense. On August 1, 1996, the Safety Board commented:

> [T]he current mission set forth in 14 CFR Part 139 to "provide an escape path from a burning airplane" no longer suffices. The Safety Board supports a full study of the mission statement by the FAA with a view towards providing adequate [ARFF] resources to rapidly extinguish aircraft interior fires and to extricate aircraft occupants from such interior fires. All aspects of this issue, including staffing, extinguishing agents, firefighter training, and response times, should be evaluated and compared with DOD standards to develop a broader mission statement that includes interior cabin fire suppression and extrication of aircraft occupants.

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[88] The assistant fire chief who served as the initial incident commander testified that at the flight engineer's suggestion a telephone call was placed to the airplane manufacturer (Douglas) in an unsuccessful attempt to determine whether there were alternate means for entering the airplane.

[89] Air Canada DC-9-32 in Covington, Kentucky, June 2, 1983 (23 persons killed by smoke/and or fire); USAir 737 collision with a Skywest Fairchild Metro 227 in Los Angeles, California, on February 1, 1991 (22 persons killed by smoke/and or fire); Northwest Airlines DC-9 collision with a Northwest 727 in Detroit, Michigan, on December 3, 1990 (eight persons killed by smoke and/or fire); Air Transport International DC-8-62 in Jamaica, New York, on March 12, 1991 (freight only); Ryan International Airlines B-727 in Hartford, Connecticut, on May 3, 1991 (freight only); and TWA Lockheed L1011 in Jamaica, New York, on July 30, 1992.

Accident history suggests that the environment inside a burning airplane's interior may be beyond the current technological capabilities of fire departments to extinguish within adequate time frames to successfully evacuate occupants or protect cargo. The Safety Board is aware that the FAA has researched fire extinguishing systems for airplane interiors, including testing of a water spray system that would discharge water into a particular area of the airplane when triggered by sensors in that area. Because the system would discharge water only to a focused area of potential fire, it would minimize the total amount of water that would need to be carried on board, thereby reducing the weight penalty of such a system. FAA tests showed that when this system was used to fight a fire, it delayed the onset of flashover, reduced cabin air temperatures, improved visibility, and increased potential survival time.

The Safety Board is concerned about the number of losses that have occurred and concludes that currently, inadequate means exist for extinguishing on-board aircraft fires. Therefore, the Safety Board believes that the FAA should reexamine the feasibility of on-board airplane cabin interior fire extinguishing systems for airplanes operating under 14 CFR Part 121 and, if found feasible, require the use of such systems.

The Safety Board realizes that requiring on-board extinguishing systems may not entirely resolve these safety concerns because they may become disabled by crash impacts. Further, the Safety Board realizes that the full implementation of such technology will require a number of years. Therefore, the Safety Board concludes that in addition to the safety benefits provided by on-board extinguishing systems, ARFF capabilities must also be improved so that firefighters are able to extinguish aircraft interior fires in a more timely and effective manner. Therefore, the Safety Board believes that the FAA should review the aircraft cabin interior firefighting policies, tactics, and procedures currently in use, and take action to develop and implement improvements in firefighter training and equipment to enable firefighters to extinguish aircraft interior fires more rapidly.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew was properly certificated and qualified in accordance with the applicable regulations and company requirements. Evidence from crew duty time, flight time, rest time, and off-duty activity patterns did not indicate that behavioral or psychological factors related to fatigue affected the flightcrew on the day of the accident.

2. The smoke detection system installed on the airplane functioned as intended and provided the crewmembers with sufficient advance warning of the in-flight fire to enable them to land the airplane safely.

3. The Boston Center air route traffic control center and New York terminal radar approach control controllers responded appropriately once they were aware of the emergency and provided appropriate and needed information to assist the crew in the emergency descent and landing.

4. The airplane was properly certificated, equipped, and maintained in accordance with applicable regulations. No evidence of systems, mechanical, or structural failures was found.

5. The flight engineer's failure to pull the cabin air shutoff T-handle, as required by the "Cabin Cargo Smoke Light Illuminated" checklist, allowed the normal circulation of air to continue to enter the main cargo area, thereby providing the fire with a continuing source of oxygen and contributing to its rapid growth. However, the Safety Board could not determine the degree to which it might have contributed to the severity of the fire.

6. The evacuation was delayed because the flightcrew failed to ensure that the airplane was properly depressurized.

7. The captain did not adequately manage his crew resources when he failed to call for checklists or to monitor and facilitate the accomplishment of required checklist items.

8. Crewmembers who do not use protective breathing equipment during a smoke or fire emergency may place themselves at unnecessary risk in attempting to address or escape from the situation.

9. Crewmembers may not be adequately aware that attempting to open a passenger exit door when the airplane is still pressurized may result in the door not opening.

10. The DNA synthesizer was not completely purged of volatile chemicals (including acetonitrile and tetrahydrofuran) before it was transported on board flight 1406.

11. The presence of the aerosol cans, the containers of acidic liquid, as well as several packages of marijuana on board the accident flight illustrates that common carriers can be unaware of the true content of many of the packages they carry.

12. The transportation of undeclared hazardous materials on airplanes remains a significant problem and more aggressive measures to address it are needed.

13. The Department of Transportation hazardous materials regulations do not adequately address the need for hazardous materials information on file at a carrier to be quickly retrievable in a format useful to emergency responders.

14. FedEx's policy of providing information only to the Safety Board after the Safety Board initiates an investigation is inconsistent with the need to quickly provide emergency responders with essential information to assess the threat to themselves and the local community.

15. More effective preparation for emergencies involving hazardous materials and a system for coordination among the Air National Guard, Stewart International Airport management, and all local and State emergency response agencies are needed.

16. Airport emergency plans should specifically address hazardous materials emergencies.

17. Currently, inadequate means exist for extinguishing on-board aircraft fires.

18. In addition to the safety benefits provided by on-board extinguishing systems, aircraft rescue and firefighting capabilities must also be improved so that firefighters are able to extinguish aircraft interior fires in a more timely and effective manner.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was an in-flight cargo fire of undetermined origin.

4. RECOMMENDATIONS

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

To the Department of Transportation:

> Require, within 2 years, that a person offering any shipment for air transportation provide written responses, on shipping papers, to inquiries about hazardous characteristics of the shipment, and develop other procedures and technologies to improve the detection of undeclared hazardous materials offered for transportation. (A-98-71)

To the Federal Aviation Administration:

> Require the principal operations inspector for Federal Express (FedEx) to review the crew's actions on the accident flight and evaluate those actions in the context of FedEx emergency procedures and training (including procedures and training in crew resource management) to determine whether any changes are required in FedEx procedures and training. (A-98-72)

> Require Federal Express to modify its evacuation checklist and training to emphasize the availability of protective breathing equipment during evacuations in an environment containing smoke, fire, or toxic fumes. (A-98-73)

> Require all Part 121 operators of airplanes that rely on air pressure to open exit doors to make crewmembers aware of the circumstances of this accident and remind them of the need to ensure that the airplane is depressurized before attempting to open the passenger exit doors in an emergency. (A-98-74)

> Require, within 2 years, that air carriers transporting hazardous materials have the means, 24 hours per day, to quickly retrieve and provide consolidated, specific information about the identity (including proper shipping name), hazard class, quantity, number of packages, and location of all hazardous materials on an airplane in a timely manner to emergency responders. (A-98-75)

> Require the principal operations inspector for Federal Express (FedEx) to ensure that all FedEx employees who may communicate with emergency responders about a transportation accident involving hazardous materials understand that they should provide those emergency responders with any

available information about hazardous materials that may be involved. (A-98-76)

Require all certificated airports to coordinate with appropriate fire departments, and all State and local agencies that might become involved in responding to an aviation accident involving hazardous materials, to develop and implement a hazardous materials response plan for the airport that specifies the responsibility of each participating local, regional, and State agency, and addresses the dissemination of information about the hazardous materials involved. Such plans should take into consideration the types of hazardous materials incidents that could occur at the airport based on the potential types and sources of hazardous materials passing through the airport. Airports should also be required to coordinate the scheduling of joint exercises to test these hazardous materials emergency plans. (A-98-77)

Reexamine the feasibility of on-board airplane cabin interior fire extinguishing systems for airplanes operating under 14 Code of Federal Regulations Part 121 and, if found feasible, require the use of such systems. (A-98-78)

Review the aircraft cabin interior firefighting policies, tactics, and procedures currently in use, and take action to develop and implement improvements in firefighter training and equipment to enable firefighters to extinguish aircraft interior fires more rapidly. (A-98-79)

To the Research and Special Programs Administration:

Require, within 2 years, that air carriers transporting hazardous materials have the means, 24 hours per day, to quickly retrieve and provide consolidated specific information about the identity (including proper shipping name), hazard class, quantity, number of packages, and location of all hazardous materials on an airplane in a timely manner to emergency responders. (A-98-80)

Additionally, the Safety Board reiterates the following recommendations to the FAA:

Issue guidance to air carrier pilots about the need to don oxygen mask and smoke goggles at the first indication of a possible in-flight smoke or fire emergency. (A-97-58)

Establish a performance standard for the rapid donning of smoke goggles; then ensure that all air carriers meet this standard through improved smoke goggle equipment, improved training, or both. (A-97-59)

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July 22, 1998

5. APPENDIXES

APPENDIX A—INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was initially notified of this accident about 0700 on September 5, 1996, by the FAA communications center. Two investigators from the Safety Board's Northeast Regional Office were immediately dispatched to the scene and arrived about 1200. A partial go-team, comprising the investigator-in-charge and five specialists, arrived about 1500. Washington-based specialists provided assistance in the areas of airworthiness, fire, hazardous materials, operations, and air traffic control/weather.

Parties to the investigation were the Federal Aviation Administration; Federal Express; Boeing, Douglas Products Division; PerSeptive Biosystems, Inc.; and Chiron Corporation.

2. Public Hearing

No public hearing was held in connection with this accident investigation. Depositions were conducted from May 18 through 20, 1998, in Memphis, Tennessee, and on May 29, in Washington, D.C. A total of 27 witnesses were questioned during those deposition proceedings.

APPENDIX B-CVR TRANSCRIPT

RDO	Radio transmission from accident aircraft
CAM	Cockpit Area Microphone sound or source
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Second Officer
-4	Voice identified as male ground personnel
-?	Voice unidentified
TWR	Miami Local Controller (tower)
GND	Miami Ground Controller
CLR	Miami Clearance Controller
HOU	Houston HF radio
UNK	Unknown source
*	Unintelligible word
@	Nonpertinent word
#	Expletive deleted
	Break in continuity
()	QuestionAle text
(())	Editorial insertion
	Pause

Notes : All times are expressed in eastern daylight savings time. only radio transmissions involving the accident aircraft were transcribed.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0536:00 CAM	[start of transcript]		
0536:00 CAM-1	oh you were back there when we discussed all this, I forgot.		
0536:04 CAM-1	this thing's on a .. this thing is on a check status.		
0536:07 CAM-2	is it?		
0536:07 CAM-1	it's just the fact that they got the paperwork all screwed up.		
0536:10 CAM-2	we'll couple it up?		
0536:12 CAM-1	you just want to go ahead and couple it yourself and just go ahead and make the landing?		
0536:15 CAM-2	yeah, do they want an autoland though?		
0536:17 CAM-1	yeah.		
0536:18 CAM-2	they do want an autoland?		
0536:18 CAM-1	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0536:19 CAM-2	* * *.		
0536:20 CAM-1	just follow through on it? .. it's visual, I don't give a #.		
0536:23 CAM-1	what the hell's that?		
0536:25 CAM-2,3	cabin cargo smoke.		
0536:27 CAM-1	you see that .. we got cabin cargo smoke ... cabin cargo smoke.		
0536:31 CAM-3	cabin cargo smoke, oxygen masks on.		
0536:36 CAM-3	slash courier communication established.		
0536:38 CAM-1	alright we got it.		
0536:40 CAM-3	okay it's number nine smoke detector.		
		0536:40 BCNTR	fedex fourteen zero six turn twenty degrees left vectors behind company for boston.
0536:44 CAM-3	let the courier know.		

INTRA-COCKPIT COMMUNICATION

TIME and SOURCE	CONTENT
0537:03 CAM-2	why don't you have those guys come up here.
0537:08 INT-1	there you go .. everybody checked in.
0537:09 INT-2	okay why don't you have those -
0537:11 INT-3	okay second officer up.
0537:18 INT-2	why don't you have those guys come up here.
0537:22 INT-1	okay we're getting two of them now.
0537:26 INT-1	let's get on it .. on the red tabs there and ah -

AIR-GROUND COMMUNICATION

TIME and SOURCE	CONTENT
0536:46 RDO-1	understand twenty left for fourteen zero six?
0536:49 BCNTR	that's correct .. I have company traffic about twenty-five north of ya at thirty-three also going into boston .. he's an airbus.
0536:56 RDO-1	roger.
0536:59 BCNTR	I didn't figure I'd have to vector this early in the morning.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0537:29 INT-2	why don't you have those guys come up here?		
0537:31 INT-1	let's open the door and see what it looks like.		
0537:42 CAM-3	why don't you guys come up.		
0537:48 INT-1	let's find out what we've got going here.		
0537:56 INT-1	okay it's moving forward whatever it is .. it's up to seven.		
0538:06 INT-3	okay fire and smoke .. oxygen mask and smoke goggles as required on one hundred percent .. crew and courier communication established .. that completes the phase ones.		
0538:14 INT-1	roger.		
0538:17 INT-3	cockpit door and smoke screen closed.		
0538:27 INT-3	it's closed ... if descent is required proceed to step six ... if descent not required proceed to step fourteen.		
0538:38 INT-1	have you run a a-		

INTRA-COCKPIT COMMUNICATION | **AIR-GROUND COMMUNICATION**

TIME and SOURCE	CONTENT	TIME and SOURCE	CONTENT
0538:40 INT-3	pull cabin air.		
0538:42 INT-3	type of smoke or fire on step fourteen .. descent not required.		
0538:48 INT-3	cabin cargo smoke.		
0538:55 INT-3	can best be recognized by checking smoke detectors second officer's panel by observing smoke or fire in the main deck cargo area .. that completes ah fire and smoke going to cabin cargo smoke.		
0539:07 INT-1	what we've got is cabin cargo, correct?		
0539:11 INT-3	that's affirmative.		
0539:13 INT-1	alright ... have you run the test on it yet?		
0539:18 INT-3	doing that now.		
0539:28 INT-1	that's seven and eight.		
0539:31 INT-3	those others may be failing in the blinking mode.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0539:37 INT-1	the blinking mode is a normal test is it not?		
0539:41 INT-3	pardon me?		
0539:43 INT-1	they should come on blinking on the test, isn't that correct?		
0539:45 INT-3	no they should come on steady on the test.		
0539:47 INT-1	okay.		
0539:47 INT-3	everything should come on steady.		
0539:49 INT-1	okay.		
0539:50 INT-3	okay ready to run the cabin cargo smoke light -		
0539:52 INT-1	I got ten now.		
0539:55 INT-3	ready to run the cabin cargo smoke light illuminated.		
0539:57 INT-1	go ahead.		
0540:01 INT-3	okay it says pack function selectors two off .. two are off.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0540:07 INT-1	we've definitely got smoke guys .. we need to get down right now let's go.		
		0540:18 RDO-1	okay what's the closest field I wonder .. here let me talk to them here.
		0540:22 RDO-1	center fedex fourteen zero six.
		0540:24 BCNTR	- saying something about the closest field I'll get back to that in a second but one hundred heading seven thousand expect straight in runway six.
		0540:30 RDO-1	let's run it, let's get this thing depressurized .. let's get it down.
		0540:34 RDO-1	center fedex fourteen zero six.
		0540:38 RDO-1	center fedex fourteen zero six.
		0540:40 BCNTR	fedex fourteen zero six go ahead .. you have a problem?
		0540:43 RDO-1	yes sir we do .. we have smoke in the cabin at this time .. we're at three three zero .. we'd like to proceed direct and we need to descend at this time.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0540:53 BCNTR	fedex fourteen zero six roger descend and maintain one one thousand .. stewart altimeter three zero one five and if you want to go to albany it's in your eleven o'clock and about fifty miles .. stewart is probably the closest airport it'll be at ah hundred and eighty degree turn and about twenty-five miles.
		0541:11 RDO-1	okay stewart field ah and a right turn to ah a hundred and eighty degrees now?
		0541:17 BCNTR	you'd make a left hand turn to a heading of two four zero and it is uhm let's see now twenty-five miles .. left turn heading two four zero.
		0541:27 RDO-1	left turn two four zero .. say the weather at stewart.
0541:32 CAM-1	(go ahead turn).		
0541:35 INT-3	okay ready to run when you are.		
0541:38 INT-1	okay run the checklist.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0541:41 INT-3	okay courier mask and goggles verify on one hundred percent .. cockpit air outlets open ... they are open ... it says ah land as soon as possible ... and we are descending now ... if unable to extinguish fire and smoke manually raise cabin altitude to twenty-five thousand .. while you're in a descent to eleven?		
0542:03 INT-1	roger, go ahead and start raising it.		
0542:07 INT-3	okay continue the descent.		
0542:21 INT-3	and we now have just detectors eight, nine and ten .. we've lost detector seven .. it's gone out.		
0542:28 INT-1	roger.		
0542:30 INT-3	okay what's that ah .. stand by.		
		0542:36 BCNTR	fedex fourteen zero six I've got albany if you want to go up to stewart you can do that .. I've got albany in your eleven o'clock and about forty-five miles or stewart in your southwesterly position and ah forty miles .. your choice.
		0542:49 RDO-1	okay we need to get it on the ground .. we need to get to stewart .. give us vectors.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0542:53 BCNTR	okay fedex fourteen zero six roger turn left heading two four zero .. you can remain in a left hand turn and stewart's wide open for ya.
		0543:00 RDO-1	roger.
0543:02 INT-3	and I'm manually raising the cabin altitude .. there is smoke in the ah cabin area.		
0543:03 CAM	[sound of overspeed warning alert]		
0543:06 INT-1	roger.		
0543:12 INT-2	okay .. okay you have an approach plate for us?		
0543:25 CAM-?	*.		
0543:22 INT-3	what's the three letter identifier for stewart.		
		0543:30 RDO-1	give me a plate for -
		0543:38 BCNTR	fedex calling boston say again please.
		0543:43 RDO-1	center .. stewart field .. what's that listed under?

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0543:47 BCNTR	sierra whiskey foxtrot newburgh new york.
0543:49 CAM-?	newburgh new york.		
		0543:51 RDO-1	okay.
		0544:04 BCNTR	fedex fourteen zero six if you could when you get a chance the uhm fuel on board and souls please.
0544:12 INT-3	thirty-three thousand pounds.		
		0544:14 RDO-1	thirty-three thousand pounds .. five souls on board.
		0544:18 BCNTR	could you say that one more time please?
		0544:19 RDO-1	thirty-three thousand pounds .. five souls on board.
0544:19 CAM	[sound of overspeed warning alert]		
		0544:22 BCNTR	thirty-three thousand five souls .. thank you.
0544:25 INT-3	and ah current altimeter.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0544:27 RDO-1	current altimeter setting please?
		0544:28 BCNTR	stewart altimeter three zero one five, sir.
		0544:32 RDO-1	three zero one five.
0544:34 INT-3	three zero one five set in the back.		
		0544:44 BCNTR	fourteen zero six descend and maintain four thousand .. you can proceed direct to kingston VOR .. that's india golf november .. that's for the VOR runway two seven at stewart.
		0544:55 RDO-1	okay what's that frequency?
		0544:57 BCNTR	stand by one second ..... frequency's one one seven point six, sir.
0545:15 INT-3	and it looks like we just have smoke detector ten lit now.		
		0545:19 RDO-1	okay, sir, we don't have the VOR approach to two seven on file here on the airplane.
		0545:34 BCNTR	fedex fourteen zero six roger .. would you like a visual to the airport?

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0545:36 RDO-1	roger, get us down to the airport and we'll take the visual ... the only thing we have on board is for the ILS to nine.
		0545:44 BCNTR	alright ILS to nine is the only thing you can handle okay .. it's a two one zero heading now for the airport and it's twenty-eight point two miles from your present position and you can expect a visual.
		0545:55 RDO-1	roger two one zero.
0545:57 INT-3	okay what is the three letter identifier for -		
		0545:58 BCNTR	and fedex fourteen zero six maintain four thousand.
		0546:08 RDO-1	it's cleared to four thousand now for fedex fourteen zero six?
		0546:10 BCNTR	fedex fourteen zero six affirmative maintain four thousand.
0546:14 INT-3	three letter identifier again for that airport?		
		0546:19 RDO-1	ah stewart?
0546:21 INT-3	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0546:21 RDO-1	S-T-W.
		0546:26 BCNTR	sierra whiskey foxtrot is stewart.
0546:31 INT-3	okay we are depressurized.		
0546:34 INT-1	alright.		
		0546:41 RDO-1	and center, I don't know if I did it before but fourteen zero six is declaring an emergency and we do need equipment standing by.
		0546:44 BCNTR	fourteen zero six, that's already been taken care of .. the equipment will be standing by.
		0546:51 RDO-1	roger.
0546:52 INT-3	okay, it says fire .. check extinguished .. the lights are off .. it's still smoky out there.		
		0546:56 BCNTR	fourteen zero six fly your present heading ... expect a visual approach to the stewart airport from new york approach control .. contact new york approach one three two point seven five.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0547:05 RDO-1	three two seven five, roger.
0547:08 INT-3	caution .. no crewmember should leave the cockpit to fight a fire ... we're not gonna do that.		
		0547:14 RDO-1	approach, fedex fourteen zero six.
		0547:17 NYAPP	fedex fourteen zero six new york approach .. stewart altimeter is three zero one eight .. descend and maintain four thousand ... did you figure out what approach you need yet?
		0547:24 RDO-1	three zero one eight down to four thousand.
		0547:27 RDO-1	keep the speed up man, don't slow to two fifty .. we're in an emergency situation here.
		0547:31 NYAPP	american fourteen zero six speed's your discretion .. speed's not a problem .. I just need to know what approach you want?
		0547:36 RDO-1	roger we do not have a two seven approach plate .. all we have is runway nine .. if we can get it we'd like to get in there visually if you can line us up.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0547:43 NYAPP	roger fourteen zero six .. do you want me to run line up for runway niner or runway two seven?
		0547:47 RDO-1	two seven.
		0547:49 NYAPP	american fourteen zero six roger .. fly heading two one zero .. correction fly heading one niner zero.
		0547:54 RDO-1	one nine zero.
0548:07 INT-3	I need the three letter identifier for that airport so I can call it up.		
		0548:11 RDO-?	S-W-F.
		0548:13 NYAPP	american fourteen zero six be advised stewart weather as of zero nine four five zulu winds are calm .. three miles visibility .. fog and a broken layer at seven thousand feet .. stewart altimeter's three zero one eight.
		0548:26 RDO-1	three zero one eight, roger.
0548:27 CAM-2	slats extend.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0548:29 INT-3	okay, land at nearest suitable airport .. cabin cargo smoke light illuminated checklist complete.		
		0548:36 RDO-1	okay, they're out, aren't they?
0548:38 CAM	[sound of overspeed warning alert]		
		0548:38 RDO-1	get rid of it .. but we still need to get this thing on the ground.
0548:41 CAM-2	what's the field elevation?		
		0548:41 NYAPP	american fourteen zero six roger .. the VOR runway two seven approach course goes off the kingston two four four radial if you want to tune that in.
0548:50 CAM	[sound of altitude alert and overspeed warnings]		
		0548:54 RDO-1	roger, two forty-four degree radial.
		0548:59 NYAPP	american fourteen zero six descend and maintain three thousand.
		0549:02 RDO-1	three thousand, fourteen zero six.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0549:08 RDO-1	boy this sucks doesn't it.
0549:09 CAM	[interrupt in CVR audio from tape splice]		
0549:09 INT-3	is there a three letter identifier -		
0549:10 CAM-2	is there a VOR or something on the field?		
		0549:13 RDO-1	yeah, two forty-four here .. intercept that ... that's off the kingston VOR .. going into the runway.
		0549:17 NYAPP	fedex fourteen zero six that's affirmative .. on your present .. turn ten degrees right to intercept the kingston two four four radial.
		0549:23 RDO-1	intercept the two four four radial .. ten degrees right.
0549:25 CAM	[sound of altitude alert warning]		
0549:28 INT-3	I can't give you any take-off or landing data.		
0549:32 INT-1	you can't?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0549:33 INT-3	I can't find the airport in my directory.		
		0549:37 RDO-1	just get a weight and use your table tops.
		0549:43 RDO-1	get rid of the boards.
		0549:48 RDO-1	three hundred and thirty thousand pounds.
		0549:53 RDO-1	V ref is one thirty-one for flaps fifty ... one thirty-six for thirty-five.
		0550:03 NYAPP	fedex fourteen zero six turn right heading two two zero to intercept the kingston two four four radial .. descend and maintain two thousand five hundred.
		0550:11 RDO-1	two thousand five hundred and two two zero on the heading.
0550:13 CAM	[sound of altitude alert warning]		
0550:20 INT-3	in range .. airspeed bugs.		
		0550:22 RDO-1	okay we're working on it ... two seventeen's your top bug.

INTRA-COCKPIT COMMUNICATION		**AIR-GROUND COMMUNICATION**	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0550:30 RDO-1	one eighty-seven's the next one .. one fifty-five .. the next one -
		0550:41 NYAPP	fedex fourteen zero six when you get a second the fire department needs to know if there's any hazardous material on the plane.
0550:48 INT-1	(Larry)?		
0550:49 INT-3	yes.		
		0550:50 RDO-1	yes there is, sir.
0550:53 INT-1	okay, it's coming alive.		
		0550:59 RDO-1	go to twenty-five hundred feet.
0551:04 INT-3	and I've got additional smoke detectors on now.		
		0551:06 NYAPP	fedex fourteen zero six the lights are all the way up .. you can expect to stay on this frequency .. you will not have another frequency change .. you'll be cleared to land from this ah on this frequency .. the airport is at twelve o'clock and ten miles .. report in sight.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0551:16 RDO-1	fourteen zero six wilco.
		0551:21 RDO-1	okay, what's your double bug?
		0551:23 NYAPP	fedex fourteen zero six descend and maintain two thousand three hundred.
		0551:26 RDO-1	twenty-three hundred, roger.
0551:27 CAM-2	flaps fifteen.		
		0551:28 RDO-1	twenty-three hundred.
		0551:30 RDO-1	what's the double bug in there on the table top .. for ah three hundred thirty thousand?
0551:32 CAM	[sound of altitude alert warning]		
0551:36 INT-3	ah three thirty .. stand by.		
		0551:41 NYAPP	fedex fourteen zero six .. this is not a standard approach .. this is an angled approach to the runway.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0551:42 INT-3	two fifty-eight is optimum.		
		0549:32 RDO-1	roger.
0551:50 INT-1	what'd you get for a double bug?		
0551:52 CAM-2	hey bruce, I don't have the plate .. you're gonna have to talk me in to this.		
		0551:56 RDO-1	I am talkin' you into it .. we don't have the plate for this either .. we're doing a visual.
0551:59 INT-3	okay for thirty-five ah .... thirty-five extend that's all I've got.		
0552:06 CAM-2	flaps twenty-two.		
		0552:08 NYAPP	fedex fourteen zero six descend and maintain two thousand.
		0552:10 RDO-1	two thousand fedex fourteen zero six.
0552:12 INT-3	V ref thirty-five extend is one thirty-six.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0552:13 CAM	[sound of altitude warning alert]		
		0552:15 NYAPP	fedex fourteen zero six field is twelve o'clock and seven and a half miles.
		0552:17 RDO-1	roger.
0552:21 INT-3	one thirty-six for V ref flap .. thirty-five extend.		
0552:26 CAM-2	gear down .... before landing checklist.		
		0552:32 RDO-1	I think I'm starting to see the runway out there at twelve o'clock.
		0552:38 RDO-1	it comes in at an angle.
		0552:42 NYAPP	fedex fourteen zero six field is now twelve o'clock and five miles .. do you need lower?
		0552:48 RDO-1	yeah affirmative .. have they got the lights all the way up .. we don't see the runway.
		0552:52 NYAPP	fedex fourteen zero six that's affirmative .. the lights are all the way up.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0552:57 INT-3	landing gear?		
0552:59 INT-1	down and three green.		
		0553:00 NYAPP	fedex fourteen zero six descend and maintain one thousand two hundred.
0553:01 INT-3	twelve o'clock.		
		0553:02 RDO-1	that's not it.
0553:06 INT-3	thrust computer.		
		0553:08 RDO-1	fourteen zero six ... fourteen zero six doesn't have the field here, sir ... we've ah we're visual conditions sir .. we do not see the runway.
		0553:15 NYAPP	fedex fourteen zero six say again.
		0553:17 RDO-1	yes sir, we do not see the runway ah at stewart ... now we have it in sight.
0553:21 INT-3	over here at the left.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		0553:23 NYAPP	fedex fourteen zero six you said you have the field?
		0553:26 RDO-1	yes sir, I do believe we have the field at this time.
		0553:28 NYAPP	fedex fourteen zero six you're cleared to land runway two seven.
0553:31 CAM-2	flaps thirty-five .. go right to fifty.		
		0553:33 RDO-1	that's not the right runway I don't think, is it? .. yeah it is.
0553:37 INT-3	thrust computer.		
		0553:38 RDO-1	okay that's the runway right there.
0553:42 CAM	[GPWS one thousand foot call]		
0553:42 INT-3	thrust computer .. antiskid .. spoiler.		
		0553:45 RDO-1	test and armed.
		0553:49 RDO-1	want some flaps fifty.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0553:55 INT-1	want the autothrottles?		
0554:01 INT-3	flaps and slats?		
		0554:02 RDO-1	okay I've got fifty land.
0554:05 INT-3	before landing checklist complete.		
0554:06 CAM	[GPWS five hundred foot call]		
0554:08 CAM	[two GPWS sink rate warnings]		
		0554:11 RDO-1	pull it on up.
		0554:16 RDO-1	everything's done.
0554:20 CAM	[GPWS one hundred foot call]		
0554:21 CAM	[GPWS sink rate warning]		
0554:23 CAM	[GPWS fifty, forty, thirty, twenty and ten foot calls]		
0554:28 CAM	[sound similar to that of touchdown]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0554:29 CAM	[sound similar to that of auto-spoiler deployment]		
0554:37 CAM	[sound similar to that of reverse thrust]		
0554:44 CAM	[sound similar to that of engine spooling down]		
0554:46 INT-1	okay, I've got it ... nice job.		
		0554:56 NYAPP	fedex fourteen zero six when able you can go over to tower frequency twenty-one eight.
		0555:01 RDO-2	twenty-one what?
		0555:02 NYAPP	one two one point eight.
0555:03 INT-3	okay on the lights we've got a .. (forward fire .. I'm deploying aft).		
		0555:07 RDO-1	we need to get the hell out of here.
0555:10 CAM	[sound of engine fire warning alarm starts]		
0555:12 INT-3	agent arm cylinder one switch.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
0555:19 INT-3	emergency ground egress.		
0555:23 CAM	[sound of engine fire warning alarm stops]		
		0555:24 RDO-1	blow blow the door.
0555:27 CAM	[end of tape]		

APPENDIX C – DC-10 CHECKLIST "EMERGENCY EVACUATION (LAND)"

DC-10 FLIGHT MANUAL

DC-10 EMERGENCY EVACUATION (LAND)

INFLIGHT PREPARATION (IF REQUIRED)

1. **Crew & Couriers (Flight Attendants and Passengers, if on board)** .... NOTIFY

   A. On passenger flights, time permitting:
      (1) Summon the Senior Flight Attendant to brief:
         (a) Nature of emergency.
         (b) Time remaining to prepare.
         (c) Cockpit commands "Brace For Landing."
         (d) Cockpit commands "Evacuate."
         (e) Special instructions.
      (2) Brief passengers:
         (a) Nature of emergency.
         (b) Plan of action.
         (c) Follow Flight Attendant directions.
   B. On cargo aircraft the S/O briefs the jumpseaters.

2. **ATC & Company** .... NOTIFY

3. **Cockpit Doorlock CB (LM E-2)** .... TRIP

4. **Fuel** .... DUMP, AS REQUIRED

5. **Pressurization** .... DEPRESSURIZE BEFORE LANDING

   A. Cabin Pressure Auto/Man selector .... MAN

   B. Manual Cabin Altitude control .... OPEN

6. **Cockpit Loose Items** .... SECURED

THIRTY SECONDS PRIOR TO TOUCHDOWN

7. **Announce** .... "BRACE FOR LANDING"

GROUND EVACUATION AFTER STOPPED

8. **Parking Brake** .... SET

9. **Tower/Ground** .... NOTIFIED

10. **Emergency Power Switch** .... ON

11. **Start Levers** .... OFF

(CONTINUED)

DC-10 FLIGHT MANUAL

DC-10 EMERGENCY EVACUATION (LAND)

(CONTINUED)

AS SOON AS POSSIBLE

12. **Thunderstorm Light** .... ON

13. **Evacuation** .... INITIATE
    A. Command "Evacuate" with Passenger Address system.

    B. Direct cabin crew to specific exits considering:
       (1) High wind effects on escape slides.
       (2) Irregular ground conditions.
       (3) Structural damage or fire.

14. **Engine Fire Handles** .... DOWN

15. **Engine Fire Bottles** .... DISCHARGE, IF REQUIRED

16. **Cockpit Voice Recorder C/B (AV B-5)** .... TRIP

17. **Emergency Power Switch** .... OFF

18. **Battery Switch** .... OFF

19. **Crew Evacuation Duties** .... ACCOMPLISH

NOTE
Check visually for fire or obstructions before opening an exit.

Captain:
- Direct & assist to ensure all occupants have evacuated.
- On passenger aircraft, exit (or designate a representative) through door L4.

First Officer:
- Obtain first aid kit, exit aircraft & assist from outside.
- On passenger aircraft ensure Zones A and B are evacuated then exit through door R1.

Second Officer:
- Assist the Captain as necessary to ensure all occupants have evacuated.
- On passenger aircraft ensure the airplane is evacuated then exit through door R4.

(End of Procedure)

APPENDIX D—CARGO CONTAINER EXAMINATION CHART

Each description includes the position that the container had occupied on flight 1406, the type of cargo container construction,[90] and the fire damage.

Container Position	Fuselage Station Number	Description of Container Damage
1R	543-631	The AYY cargo container's aluminum roof, outboard wall, and forward Lexan doors were consumed by fire. The upper inboard aluminum wall of the cargo container exhibited heat damage, but the 8-inch lower side wall and cargo container were intact and undamaged by fire. The outboard forward and aft cornerposts measured 1 foot 9 inches and 1 foot 6 inches, respectively. Both inboard cornerposts were intact.
2L	631.5-757	The AMJ cargo container's aluminum roof and outboard side were intact. The top quarter of the aft and forward Lexan walls were melted and distorted from heat. The upper portion of the inboard and outboard cargo container wall showed no fire or heat damage, but its contents were sooted.
2R	631-757	The AMJ cargo container's aluminum roof and upper Lexan walls were consumed by fire, and the lower walls were heat damaged. The upper two-thirds of the nylon fabric roll-up door was consumed by the fire. The lower aluminum side walls and cargo containers were intact. The outboard forward and aft cornerposts measured 2 feet and 4 feet 1.5 inches, respectively. Both inboard cornerposts were intact.

[90] The International Air Transport Association identifies types of cargo containers using a three-letter designator. The first letter describes the general type of unit. (An "A" designation indicates that the compartment is a certified aircraft container and "P" indicates a certified aircraft pallet.) The second letter indicates base dimensions. ("G" and "M" are 96 by 125 inches, and "Y" indicates miscellaneous sizes with the largest dimension being no bigger that 96 inches.) The third position relates to the container's contour and compatibility and indicates in what part of the aircraft the container will fit.

3L	757-883	Approximately two-thirds of the aft portion of the AMJ cargo container's aluminum roof was consumed by fire. The remainder of the forward section of roof exhibited heat, soot, and smoke damage. The outboard Lexan wall was intact. The upper portion of the aft Lexan wall was mostly consumed by the fire, and the lower portion was heat damaged. The forward Lexan wall exhibited heat damage and the lower wall and 8-inch aluminum side wall were intact. The upper portion of the nylon fabric roll-up door was consumed, but the lower portion was intact. The outboard forward and aft cornerposts measured 3 feet 8 inches and 2 feet 3 inches, respectively. The inboard cornerposts were both intact.
4L	883-1009	The AMJ cargo container's aluminum roof and forward Lexan upper wall were completely consumed by fire; the lower Lexan wall and 8-inch aluminum side walls were intact. The aft and forward Lexan wall and nylon roll-up door were consumed by the fire. The outboard forward and aft cornerposts measured 7 feet 7.5 inches and 2 feet 9 inches, respectively. The inboard forward and aft cornerposts measured 6 feet 2 inches and 5 feet 6 inches, respectively.
4R	883-1009	The AMJ cargo container's aluminum roof and Lexan aft and outboard walls were consumed by fire. The inboard lower half of the forward wall exhibited heat damage, and the upper wall was consumed by the fire. The aluminum floor and 8-inch aluminum side walls were intact. The outboard forward and aft cornerposts measured 3 feet 11.5 and 1 foot 6 inches, respectively. The inboard forward cornerpost was intact, and the aft cornerpost measured 5 feet 2 inches.
5L	1009-1135	The AMJ cargo container's aluminum roof and the aft, forward, and outboard Lexan walls were consumed by fire, but the aluminum floor and 8-inch aluminum side walls were intact. The outboard forward and aft cornerposts measured 3 feet 2.5 inches and 3 feet 5 inches, respectively. The inboard forward and aft cornerposts measured 5 feet 9.5 inches and 5 feet 6 inches, respectively.
5R	1009-1135	This position was occupied by a PAG pallet that was loaded with footwear in cardboard boxes piled in stacks that were 3 feet in height. The shoes and boxes were burned along the aft side of the pallet, but the aluminum floor was intact.

6L	1135-1261	The AMJ cargo container's aluminum roof, the nylon fabric roll-up door, and all Lexan walls were consumed by fire, but the aluminum floor and 8-inch aluminum side walls were intact. Two-thirds of the upper door assembly spring cover was consumed by fire along the aft portion. The outboard forward and aft cornerposts measured 2 feet 7 inches and 3 feet, respectively. The inboard forward and aft cornerposts measured 2 feet 9.5 inches and 2 feet 10.5 inches, respectively.
6R	1135-1261	The AMJ cargo container's aluminum roof and the Lexan walls were consumed by fire except for a small portion of the center aft lower wall. The nylon fabric roll-up door spring assembly, including the spring cover, was melted to the floor near the inboard forward cornerpost. Melted aluminum was puddled on the floor along the inboard side of the door. There were three areas where the 8-inch aluminum side wall had melted along the edge of the cargo container: 5 feet along the outboard side, 12 inches along the inboard forward edge, and 17 inches along the center of the forward edge. The outboard forward cornerpost was completely consumed by the fire, and the outboard aft cornerpost measured 3 feet 9 inches. The inboard forward cornerpost measured 1 foot 2 inches, and the inboard aft cornerpost measured 3 feet 6 inches.
7L	1261-1387	The AMJ cargo container's aluminum roof and Lexan outboard, forward, and aft walls were consumed by fire. The outboard forward cornerpost measured 3 feet 1 inch, and the outboard aft cornerpost measured 1 foot 4.5 inches. The inboard forward wall cornerpost measured 4 feet, 3 inches; the inboard aft cornerpost measured 6 feet 1.5 inches. The aluminum floor and 8-inch aluminum side wall were intact.

7R	1261-1387	The AMJ cargo container's aluminum roof and the lower outboard forward and aft walls were consumed by fire except for a small area at the lower center position of the forward wall. There was also a horizontal burn through the contents positioned along the forward outboard edge of the cargo container next to the aft contents in 6R. The nylon fabric roll-up door was consumed by fire. However, the door assembly was intact. The outboard forward and aft cornerposts measured 2 feet 1 inch and 5 feet 7.5 inches, respectively. The inboard forward cornerpost measured 4 feet 6 inches, and the aft cornerpost measured 7 feet 1.5 inches.
8L	1387-1513	The AMJ cargo container's aluminum roof and the Lexan outboard and forward walls were consumed by fire. The lower third of the center area of the aft Lexan wall was distorted from heat, and the upper two-thirds was consumed by fire. The inboard forward and aft cornerposts measured 5 feet 10 inches and 5 feet 2 inches, respectively. The outboard forward and aft cornerposts measured 1 foot 4.5 inches and 3 feet 6.5 inches, respectively.
8R	1387-1513	The AMJ cargo container's aluminum roof was consumed by fire. The bottom half of the forward Lexan wall was distorted from heat and the upper two-thirds was consumed by fire. The upper three-quarters of the outboard Lexan wall was consumed by fire, and the bottom quarter was distorted by heat. The nylon fabric roll-up door (inboard wall) was also consumed by fire. The inboard forward cornerpost measured 5 feet 10 inches, and the inboard aft cornerpost measured 6 feet 2 inches. The outboard forward cornerpost measured 5 feet 5.5 inches, and the outboard aft cornerpost measured 1 foot 6 inches.

9L	1513-1639	This AMJ cargo container's aluminum roof and outboard Lexan wall were consumed by fire. The lower mid-section of the forward Lexan wall was intact, but the upper wall was consumed by fire. The Lexan aft wall was consumed. The nylon fabric roll-up door was partially consumed by fire. However, some fabric was visible at the bottom of the door. The vertical roof support remained attached to the cornerposts. The 8-inch aluminum lip that extends up from the cargo container floor was melted down to a height of approximately 3 inches along an 18 inch length in the center of the outboard edge. The underside of the container was undamaged. The outboard forward cornerpost measured 3 feet. All other cornerposts were intact.
9R	1513-1639	The AMJ cargo container's aluminum roof was completely consumed by fire. The lower section of the forward Lexan wall was intact, but the upper wall was consumed by fire, as was the aft wall and the outboard wall. The nylon fabric roll-up door was consumed by fire, but the aluminum door assembly frame was intact. The vertical roof support remained attached to the cornerposts. No damage was done to the floor side wall of the container. The underside of the container was undamaged. The outboard forward and aft cornerposts measured 1 foot 3.5 inches and 1 foot 5 inches, respectively. The inboard cornerposts were intact.
	1639-1728	Note: The space, normally occupied by two AYY cargo containers, between cargo containers 9 and 14, was vacant for the accident flight.
14L	1728-1817	The AYY (Demi) cargo container's aluminum roof and one-third of the outboard wall were consumed by fire. Two-thirds of the lower outboard wall was intact. The forward aluminum wall was heat damaged and distorted from excessive heat along the upper third of the wall. The upper third of the aft Lexan door was consumed by fire. The inboard and outboard cargo container walls were distorted from heat, and the lower two-thirds of the wall was intact.
14R	1728 -1817	The AYY (Demi) cargo container's aluminum roof, the outboard, inboard, forward, and aft walls were completely consumed by fire. The outboard forward and aft cornerposts measured 3 feet 7 inches and 2 feet 10.5 inches, respectively. The inboard cornerposts were intact.

15L	1817-1906	The AYY (Demi) cargo container's aluminum roof and one-third of the outboard wall was consumed by fire. The remaining two-thirds of the lower outboard wall was intact. The forward aluminum wall was heat damaged and distorted from excessive heat along the upper third of the wall. The upper third of the aft Lexan door was also consumed by fire. The inboard and outboard cargo container walls were distorted from heat, and the lower two-thirds of the wall were intact.
15R	1817-1906	The AYY (Demi) cargo container's aluminum roof and the forward and aft Lexan doors were completely consumed by fire. The outboard aluminum wall was distorted from heat, and the aft section of the aluminum inboard wall was consumed by fire. The upper two-thirds of the remaining inboard wall was distorted from heat but intact.
16L	1906-1995	The AYY (Demi) cargo container's aluminum roof and one-third of the outboard wall were consumed by fire. Two-thirds of the lower outboard wall was intact. The forward aluminum wall was heat damaged and distorted from excessive heat along the upper third of the wall. The inboard and outboard cargo container walls were distorted from heat.
16R	1906-1995	The AYY (Demi) cargo container's aluminum roof and Lexan outboard wall were completely consumed by fire. The forward Lexan door was consumed by fire, and the aft lower portion of the aluminum door was intact. The upper half of the inboard Lexan wall was consumed by fire, and the lower half remained intact.

APPENDIX E—CONTENTS OF NINE CARDBOARD BOXES LABELED "9R"

Box 66—a package of medical vials (containing unidentified liquid) in what appeared to be a cold pack. The package was heat damaged, but the vials were intact. The box also contained paychecks and four additional airbills.

Box 67—computer cables in reasonably good condition. A laptop computer was located. The internal components were not fire damaged, and the outer case was slightly melted. There was also one vial identical to those located in 9L.

Box 68—a small-size crimp top empty amber vial, cold pack (silicone), and plastic capped-centrifuge vials (melted).

Box 69—seven intact plastic bottles containing liquid. This box also contained miscellaneous paper products (manuals, photos, etc.), two more plastic bottles containing fluid, disks, software, and plastics. Some of the items exhibited minor fire damage, others did not.

Box 70—two large boxes wrapped in bubble-type wrap. The wrap material and the box were unburned. There was also a severely burned electronic unit that appeared to be a monitor.

Box 71—two 1-quart plastic bottles as well as an electronic component that appeared to be a portable printer and exhibited minor heat damage.

Box 72—miscellaneous debris, paper, computer materials, silicone-filled bags, metal strips, and software. Some of the items exhibited minor fire damage, others did not.

Box 73—what appeared to be a laptop computer that was extensively fire damaged. The cells of the battery pack were exposed. This box also contained other miscellaneous, unidentified electronic equipment and numerous rings, which appeared to be costume jewelry.

Box 74—a considerable amount of burned, printed material. One printed computer board was found with little fire damage. One small plastic bottle was found that contained a solid material, resembling pills. A badly burned computer board and a metal cosmetic box with some contents were also found.

APPENDIX F - DETAILED EXAMINATION OF FIRE DAMAGE TO DNA SYNTHESIZER

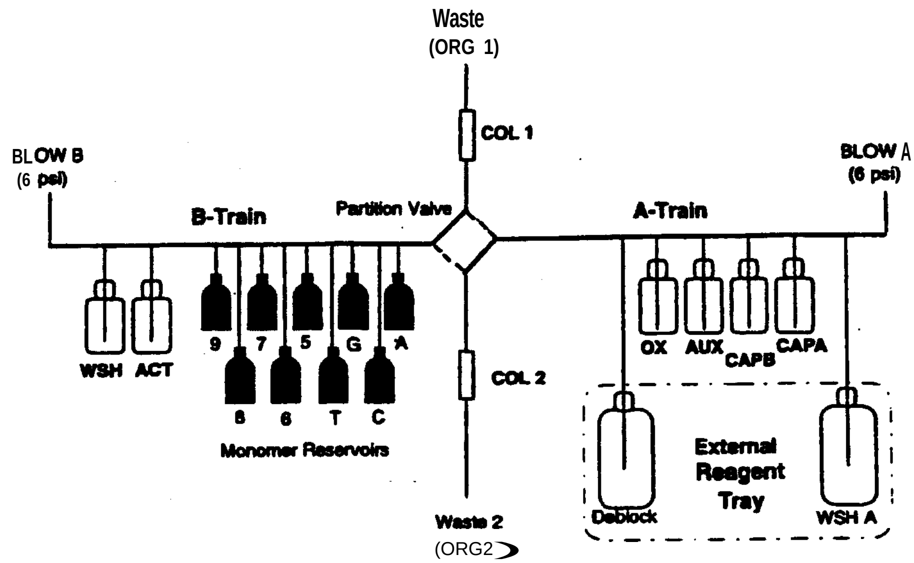
The following describes the results of an examination of the accident synthesizer conducted by the Fire Group at PerSeptive Biosystems' manufacturing facility in Framingham, Massachusetts from February 18 through 20, 1997.

A 3-inch piece of white, unburned crumpled paper and a 3-inch piece of unburned cardboard were observed on the top rear of the synthesizer between the RS 422 port and the printer port. (See figure A.) The floppy drive port was severely damaged and empty. Melted aluminum was observed on the outside surface of the right side of the synthesizer. The left side of the synthesizer was blackened except for two 4- by 4-inch areas at the bottom corners consistent with the location of the Styrofoam packaging blocks and four areas consistent with the location of the packing tape used for packaging the synthesizer. The bottom two unburned areas had yellow packaging tape attached. Glass normally installed in the front door window was missing, and the column door window was intact. The outside face of the keypad assembly was severely damaged and unrecognizable. The RS 422 and option ports were not visible. The printer port and the Event Out ports were fire and heat damaged.

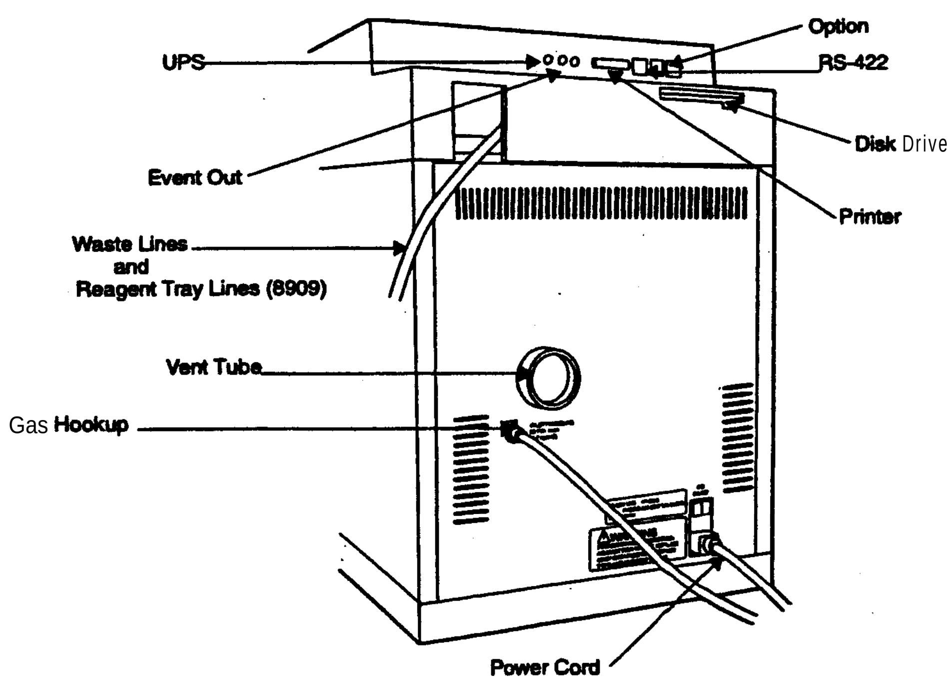
The back panel of the damaged synthesizer was removed. (The exterior and interior of the back panel exhibited fire, soot, and corrosion damage.) Debris, ashes, and other unidentified materials adhered to the interior side of the panel. The on/off switch for the power inlet module and the receptacle plug-in were destroyed by fire.

A paper diagram of the bottle locations and system schematic taped inside the front door of the synthesizer exhibited slight soot damage. The paint on the inside of the door below the window frame was undamaged but exhibited some sooting. The inside of the door exhibited heavier heat damage above the lower window frame than was observed below the window frame. The stainless steel bottle bracket was heavily sooted behind bottles 4, 5, and 6. The plastic dip tubes were cut off during the on-site accident phase. The upper third of the right side of the stainless steel bottle bracket exhibited some sooting and discoloration. The left side was sooted from the base to the top of the synthesizer. The polyethylene drip tray was melted along the right rear side and was heavily sooted along the left and forward walls. An 8½- by 9½-inch rectangular soot-free area was observed approximately 1 inch from the left side of the drip tray. Pieces of broken glass and a large amount of debris were found in the bottom of the drip tray. The floor of the synthesizer was heavily sooted and also contained pieces of debris. There was some blue discoloration along the right side of the stainless steel bracket where it intersected the mounting for bottles 1, 2, and 3.

Removal of the synthesizer controller top revealed that the controller top's interior exhibited extensive fire damage, and all of the electrical wire insulation was destroyed. The wire conductors were intact and brittle. The inside of the top was heavily sooted. Most of the paint was charred and missing under the controller PC board and around the floppy drive at the rear of the controller top. The resin binder for the controller PC board was destroyed by fire. The



Fluidics diagram.



Electrical hookup and gas lines.

Figure A.—Expedite Model 8909 DNA synthesizer instrument diagram.

component side of the controller PC board was discolored and charred. The surface normally covered by the battery had a thin layer of shiny black material that flaked off readily. The printed circuits in positions U6 and U7 with the sockets were found separated from the controller PC board. Various other smaller electrical components were found separated from the controller PC board. The controller PC board was removed and its underside was observed to be severely burned.

The three-cell battery pack was detached from the PC controller board. The ribbon cable and header normally located next to the battery on the controller PC board was fused to the battery pack with the other end of the ribbon cable still connected. One of the battery lead sockets had separated from the circuit board and was attached to the battery lead. When investigators later examined the batteries in more detail, no indication of internal damage was observed.

The drive port for the 3½-inch floppy disk was removed and examined. No evidence of the 3½-inch floppy disk was found. The drive was severely fire damaged, and the ribbon cable insulation was destroyed with the wires intact and embrittled.

The display driver was burned and delaminated along the top edge, but the bottom of the circuit board remained structurally intact. The ribbon wire insulation was destroyed, and the wire conductors were embrittled but remained intact. The bottom right side of the board remained intact with the word "Millipore"[91] inscribed on the board. The keypad driver was severely heat damaged except for the lower right corner. The front side of the driver board's crystal display was a bluish color with a darkened heat-damaged area on the right side, approximately 1 inch from the edge.

The exterior metal case of the trityl monitor was heat damaged on its top and sides. The monitor's external wire insulation was burned, and the plastic spill tray was deformed. A legible inspection test sticker with a test date of August 26, 1994, was found on the bottom of the monitor. A partially legible SN label was observed on the side of the unit. A third label was seen on the top of the monitor and it was melted, shrunken, and unreadable. Disassembly of the monitor showed that all the internal components and wire insulation were intact. The circuit board inside the trityl monitor had little or no fire damage. The rear ribbon cable insulation inside the monitor had some heat damage.

The fluid access panel, which separated the fluidics module from the upper housing of the synthesizer, was removed. The upper surface of the fluidics access panel was sooted and showed extensive fire and heat damage. The right rear lower surface of the panel was more sooted and heat damaged than on the remaining panel surface. The plastic insulators on the wiring boards of the instrument also exhibited greater melting on the right side than on the left side. The fluidic solenoids and wire insulation were heavily sooted, and the wire insulation was not damaged.

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[91] PerSeptive Biosystems acquired the synthesis products business from Millipore BioScience Division in 1994.

The sides and top of the fluidics module were heavily sooted; however, the pneumatics umbilical area was clean except for a lightly sooted area above the pneumatic umbilical fittings. The four vertical umbilical gas fittings along the far right side of the module were melted. The polyethylene gas lines (located directly above the monomer bottles) for pressurizing the monomer bottles were uniformly melted. The polyethylene pressurizing tubing was melted, and holes or openings in some bottle cap assemblies (the block for screwing the bottles to the instrument) were found in positions 6, 7, and WSH 1. These openings provided direct access to the interior of the bottles that had been screwed to the damaged DNA synthesizer. The inert gas polyethylene tubing for pressurization of bottle positions 1 through 6 was melted and thermally distorted. The fluid lines were sooted and were not melted.

The spiral wrap that bundled the caddy tube line was intact to the point where the line exited the machine and was melted at its termination point. The spiral-wrapped bundle was intact, the gas lines within the spiral wrap were melted, and the fluid lines were intact. A portion of the caddy line external to the machine was not recovered, and the waste tubing bundle was also missing about 2 inches from the point where it would have exited the machine. The internal portion of the waste bundle was intact and sooted.

The pneumatic module was extensively sooted and contained debris throughout the module's chassis. The lower portion of the module that contained the regulator and pneumatic components was heat and soot damaged, and the lower portion of the regulator contained a name plate with a "Wilkerson" manufacturing label. Melted debris was also affixed to the bottom of the regulator and the power wires. Insulation within the compartment was intact, and heat and soot damage was observed throughout the wiring. The connector for the power wiring transitioning out of the compartment was intact with heat and soot damage and some melting. The wire insulation from the right isolation valve was intact, and the grommet transitioning out of the compartment was melted. The wires and insulation from the left isolation valve were intact and had some heat and soot damage. The grommet through the chassis on the left side was displaced and brittle. The plastic tubing attached to the fittings on the isolation valves dripped downwards vertically towards the base of the synthesizer towards the pneumatic drip tray, and melted residue was next to the melted tubing.

The two barostats had fire and heat damage, and the gas inlet fitting ring was found adhered to the power supply. An 11- by 6-inch mass of debris was removed from the aft left side of the unit between the inside chassis wall and pneumatic module frame. This is the same side on which the unit was found resting in the airplane. The debris was similar to the burned and water-soaked cargo residue that was among the wreckage. Another mass of debris, which measured 5½ by 5 inches, was removed from the inside left pneumatic frame. The adjustment knob for the pressure regulator had fire and heat damage with wires to two isolation valves entrapped in the melted portion. The aluminum frame surfaces were intact and were heavily sooted. The plastic solenoid mufflers were melted. The pressure gauge glass window was intact, and it was covered with debris and soot.

All four ribbon cables remained attached to the valve/solenoid driver printed circuit board (PCB), and the insulation on the ribbon cables and their connectors were destroyed by heat and fire. All the insulation on the electrical wiring and the connectors above the regulator adjustment knob were destroyed by heat and fire. All the electrical wires in the same area were intact and brittle. The gas inlet quick disconnect fitting was missing, and the fitting's spring was found fused in plastic to the power supply case.

Examination of the upper portion of the pneumatic module found that the power wire pair connector had some melting and soot damage, the fiberglass circuit board's resin was consumed, and the board was delaminated. The bottom side of the valve/solenoid driver PCB was charred and the pneumatic solenoid distribution PCB beneath the driver PCB was similarly damaged by extensive heat and fire. The electronic components that were mounted on the board were unrecognizable from the extensive fire damage. The wiring to the PCB had its insulation burned off and the wires were brittle. The etched copper on the circuit board remained intact.

The aluminum gas distribution block that housed the gas solenoid valves had soot damage and was not melted. The exhaust fan was dislodged from its mount, was sagging downward, and was found resting against the bottom of the fan housing. Three of the seven fan blades were partially melted and fused to the fan housing.

APPENDIX G—RINSE PROCEDURE AND QUANTITIES RINSED FOR 1996 NASA CHEMICAL ANALYSIS

Position 8

The Pos 8 bottle contained about 10 µl of fluid and a filter. 100 µl of methanol was rinsed through the filter into a clear glass sample vial. Another 100 µl of methanol was added. The 100 µl flushed through the filter was added and swished about to mix the remaining residue on the sides of the bottle with the methanol. The solution was then transferred to a clear sample vial and analyzed. The final solution had a yellowish tint.

OX 2

Three droplets adhered to the side of the bottle, which contained a filter. 100 µl of methanol was rinsed through the filter and placed into a separate clear, glass sample vial. Another 400 µl of methanol was added to the bottle to rinse it. The rinse from the OX 2 was then transferred to the clear sample vial that contained the 100 µl of methanol from the filter rinse and sealed. The solution appeared to have a slight yellow tint.

WSH 1

This bottle appeared to be empty. Therefore, 1 mL of methanol was added to the WSH 1 bottle. The bottle was rinsed, and then the rinse liquid was transferred to a clear sample vial that was sealed and labeled. The solution was clear.

Position A

This bottle appeared to be dry, so 500 µl of methanol was added to the bottle. The bottle was rinsed, and then the liquid was transferred to a clear sample vial that was sealed and labeled. The solution was clear.

Position G

500 µl of methanol was added to the empty bottle, rinsed around, and then transferred to a clear sample vial that was sealed and labeled. The solution was clear.

Position 9

500 µl of methanol was added to the empty bottle, rinsed around, and then transferred to a clear sample vial that was sealed and labeled. The solution was clear.

Position T/U

500 µl of methanol was added to the empty bottle, rinsed around, and then transferred to a clear sample vial that was sealed and labeled. The solution appeared to have a slight yellow tint.

Position 5 (Spacer Reagent)

500 µl of methanol was added to the empty bottle, rinsed around, and then transferred to a clear sample vial that was sealed and labeled. The solution was clear.

CAP B6

1 mL of methanol was added to the empty bottle, rinsed around, and then transferred to a clear sample vial that was sealed and labeled. The solution contained some small black particulate in clear liquid.

<u>CAP A5</u>

1 mL of methanol was added to the empty bottle, rinsed around, and then transferred to a clear sample vial that was sealed and labeled. The solution was clear.

<u>Position C</u>

500 μl of methanol was added to the empty bottle, rinsed around, and then transferred to a clear sample vial that was sealed and labeled. The solution was amber colored.

<u>Position 6</u>

The volume of liquid in the bottle was estimated by visual inspection to be 250 μl.*[92] Therefore, the sample for injection was pulled directly from the bottle, instead of being transferred to a sample vial. The solution was clear.

<u>Position 7</u>

The volume of liquid in the bottle was estimated by visual inspection to be 50 to 100 μl.* Therefore, the sample for injection was pulled directly from the bottle, instead of being transferred to a sample vial. The solution was clear.

<u>AUX 3</u>

This bottle contained between 4 and 5 mL.* The liquid was transferred to sterile vial for a visual examination. The liquid had a slight yellowish tint.

<u>ACT 4</u>

This bottle contained a quantity of fluid estimated at 1 mL.* The liquid was transferred to a sterile vial and a slight yellowish tint was observed.

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[92] The volumes marked with an asterisk (*) were estimated by viewing a side-by-side comparison of the liquids with a hand-graduated sterile vial.

APPENDIX H—SUMMARY CALIBRATION AND GC/MS DATA FOR 1996 NASA TESTING

CHEMICAL	PURITY %	SOURCE	IDENTIFICATION	EXPIRATION
Tetrahydrofuran	98.5	Chem. Service	O-574	7/90
Acetic Anhydride	95	Chem. Service	O122	2/89
Acetonitrile	99	Chem. Service	O-834	5/89
Pyridine	99.2	Chem. Service	O-706	3/90
Dichloroacetic acid	96	Chem. Service	O-45	9/89
Trichloroacetic acid	99	Chem. Service	O-46	11/89
Trichloroacetic acid		PerSeptive		
t-BPA		PerSeptive		
1-Methylimidazole		PerSeptive		
DEGMBE	95	Chem. Service	O-172	3/90

The GC/MS data could not be obtained for iodine because it does not elute from the GC column. The injection port on the GC was set at 250°C, and an injection of 0.1 µl of the standard solutions and unknown fluids from the reagent bottles from the accident synthesizer were extracted with a 0.5 µl syringe. The syringe was flushed 10 to 20 times with methanol after each injection and was followed by a vacuum pull on the syringe at an elevated temperature. This was done to make sure the syringe was not contaminated.

APPENDIX I – SERVICE NOTE 89-006

SERVICE NOTE 89-006

Date:	October 29, 1993
Subject:	Expedite™ 8900 Field Start-Up Procedure
Product:	Expedite™ 8909 Instruments (Part Number GEN105910) and Expedite™ 8905 Instruments (Part Number GEN105900)
Urgency:	At installation or demonstration
Originator:	Brent Morrison/John Pomer
Technical Product Manager:	Brent Morrison

Situation:

Expedite 8909 instruments installed during the initial shipment phase experienced low product yields and poor trityl colors. These low yields can be directly attributed to the method and procedure used to prepare the instrument for initial synthesis.

This Service Note describes the recommended procedure for installation of the instrument and chemical conditioning of an Expedite System during installation start-ups and for field demonstrations before syntheses are attempted.

Follow these procedures to ensure a successful synthesis of actual oligonucleotides at the customer site.

Items Required:

GEN105910 Expedite™ 8909 Instrument or
GEN105900 Expedite™ 8905 Instrument
GEN105901 Start-up Kit, Expedite
GEN103258 Gas Regulator, Tank, 2 Stage for Helium (User may supply this item)
GEN002006 Dry Acetonitrile, 2.5 L (less than 0.005% H_2O or better)
Expedite Synthesis Chemicals (Amidites and Ancillary Solutions)

Tools Required:

9/64 Ball-end Hex Driver
#2 Phillips Screw Driver
12 inch Adjustable Wrench

Repackaging Materials:

Original Shipping Container
Nylon Rachet Straps or equivalent 1 inch wide x 10 feet

Options:

GEN105880 Trityl Monitor Option
GEN104823 Printer Kit, with cable and paper stand, (115VAC)
GEN104058 Printer Kit, with cable and paper stand, (230VAC)
GEN210222 Uninterruptible Power Supply Kit, 115VAC
GEN210282 Uninterruptible Power Supply Kit, 230VAC

MILLIPORE
BioScience Division

Installation Procedure:

To install the Expedite System:

1. Uncrate the instrument and place the unit on the lab bench. Retain the packaging materials. (Refer to section 3.3 of the Expedite Preliminary Service Manual.)
2. Inspect the unit for visible damage.
3. For 8909 instruments, remove the caddy housing with the attached bottle frame from the separate carton and place the caddy on the bench beside the instrument.
4. Open the startup kit and remove the contents: (See attached list of contents).
5. Attach the 2-L reservoir to the cap labeled WA and attach a 1-L reservoir to the cap labeled DB. Place the reservoirs in the retaining bracket of the caddy.

CAUTION:

For the operator's safety, use only the plastic coated bottles supplied with the instrument.

NOTE: Initial Expedite units were shipped with caddy assemblies that can only accommodate two 1-L bottles. The 2-L reservoir for Acetonitrile (800 cycles) should be placed in the waste tray. Future units will be provided with a caddy that will accommodate 1-1L and 1-2L plastic coated bottles.

6. Attach the waste cap to the 4-L plastic coated waste reservoir.
7. Install any ordered options. (Refer to Sections 4.6 - 4.9 and 4.24 of the Expedite Preliminary Service Manual.)
8. Connect the waste tubing and ventilation. (Refer to Section 4.7 "Assembling the Standard Waste Cap," Expedite Preliminary Service Manual. If a trityl monitor is installed, refer to Section 4.8 for waste tubing connection to the trityl waste reservoir.)
9. Connect the external gas supply line to the tank regulator. (Refer to Expedite Preliminary Service Manual, Section 3.3.6.)

NOTE: Do not turn on the gas supply at this time.

10. Install the vent hose and route the hose to a fume hood. (Refer to Expedite Preliminary Service Manual, Section 3.3.7.)
11. Check the fuses (Refer to Expedite Preliminary Service Manual, Section 4.1, "Checking the Fuses"). Connect the power cord to the power entry module on the rear of the instrument.

Start-Up Procedure:

To start the instrument:

1. Insert the boot diskette (from the Start-up Kit) into the disk drive in the rear of the top cover.
2. Power-up the system (Refer to Section 2.2, Expedite User's Guide).

NOTE: If you hear a continuous "BEEP" upon power-up, check the power supply voltage. (Refer to Section 4.19 "Checking and Adjusting the Power Supply" of the Expedite Preliminary Service Manual.)

3. Remove the rear panel.

4. Adjust the tank pressure regulator to 20 psi, adjust the internal gas pressure regulator to 6 psi and then proceed as follows to perform the Gas Pressure Leak Diagnostic Tests (Refer to Section 3.4.2 "Gas Pressure Tests" of the Expedite Preliminary Service Manual).

   From the Main instrument menu, select **Tools:Diag:Leak** followed by **Start**. (Refer to Section 3.6.1 "Diagnostic Routines" in the Expedite User's Guide). When the Leak Diagnostic test is started, the system is pressurized for a period of 20 seconds.

   The High Pressure Gas Leak Diagnostic test should give a "passed" message after 5 seconds. If a "failure" message appears, a problem may exist within the external tank regulator and/or gas inlet line connections. The tank regulator should be set at 20 psi.

   The Low Pressure Leak Diagnostic senses pressure in the reservoir blanketing system (6 psi). This test should give a *"passed"* message after 3 minutes of elapsed time. A *"marginal"* message will appear if the pressure drops below 4 psi between 30 second and 3 minutes. A *"failed"* message will appear if the pressure drops below the set point in less than 30 seconds.

5. If all these diagnostic tests give "passed" messages, proceed with the next step to chemically condition the instrument.

Chemical Conditioning:

The following steps must be performed each time an instrument is started-up during a new installation or field demonstration. This process flushes dry acetonitrile through the Expedite fluidic system to condition the flow passages and remove any residual contaminants:

1. Fill each reagent bottle with clean, dry acetonitrile (> 0.005% H_2O).
   a. Add 250 mL of dry ACN to the WashA (WA) and Deblock (DB) reservoirs in the External Caddy.
   b. Add 100 mL of dry ACN to Reservoirs 1-6 in the main reagent compartment.
   c. Add 20 mL of dry ACN to each monomer reservoir (A, C, G, T, 5, 6, 7, 8, 9 on an 8909; A, C, G, T, 5 on an 8905).
2. Place a female to female union in each column position.

CAUTION:

Do not perform the priming functions with a column in place.

3. Select **Prime** from the Main menu.
4. Select **2 (Prime all)** from the Prime menu.

Prime Column Position #1

5. Select **1** for Column# 1, the priming process will begin immediately.
6. Press **Cycle** when it appears on the display (about 2 minutes) to repeat the prime all function on Column #1.
7. Repeat Step 6 once more for a total of three **Prime all** functions on column position #1.

Prime Column Position #2

8. Press **Cancel** to return to the Prime menu.
9. Select **2 (Prime all)** from the Prime menu.
10. Select **2** for Column#2, the priming process will begin immediately.
11. Press **Cycle** when it appears on the display (about 2 minutes) to repeat t prime all function on Column #2.
12. Repeat Step 11 once more for a total of three **Prime all** functions on col position #2.

Change B-train Acn

13. Remove each B-train reservoir, one at a time, and discard the remaining acetonitrile into an appropriate waste container.

    B-Train Reservoirs:

    Position#1 WSH (Wash B)
    Position#4 ACT (Activator Solution)
    Monomer Reservoirs- A, C, G, T, 5, 6, 7, 8, 9 (for 8909)
    A, C, G, T, 5 (for 8905)

14. Refill each B-Train Reservoir with dry acetonitrile.
15. Repeat Steps 3 to 12 three more times to **Prime all** on column #1 and
16. Press **cancel** to return to the Prime menu followed by **Exit** to return to the Main menu.

The Test Synthesis:

To perform the test synthesis:

1. Enter the test 9-mer Sequence **5'-AAC-CGG-TTT-3'**. (Refer to Section 2. "Entering the Sequence" in the Expedite User's Guide)
2. Prepare and load the reagents for synthesis. Discard any remaining dry acetonitrile in the reservoir before loading the synthesis reagents. (Refer to Section 2.4 "Preparing and Loading the Reagents," in the Expedite User' Guide).
3. Place a female to female union in each column position.

CAUTION:
Do not perform the priming functions with a column in place.

4. Select **Prime** from the Main menu.
5. Select **2 (Prime all)** from the Prime menu.

Prime Column Position #1

6. Select **1** for Column#1, the priming process will begin immediately.
7. Press **Cycle** when it appears on the display (about 2 minutes) to repeat t prime all function on Column #1.
8. Repeat Step 7 once more for a total of three **Prime all** functions on col position #1.

Prime Column Position #2

9. Press **Cancel** to return to the Prime menu.
10. Select **2** (**Prime all**) from the Prime menu.
11. Select **2** for Column#2, the priming process will begin immediately.
12. Press **Cycle** when it appears on the display (about 2 minutes) to repeat the prime all function on Column #2.
13. Repeat Step12 once more for a total of three **Prime all** funcions on column position #2.
14. Place a 0.2 µmole "T" column in Column Position #1 and #2.
15. Start a 0.2 µmole scale synthesis on both columns. Modify the Synthesis Parameters to remove the 5' (final) DMT. (Refer to Section 2.5 "Starting the Synthesis" in the Expedite User's Guide.)
16. Watch each column for the sign of Trityl (Deblock) color during the deblocking step at the beginning of each cycle. If a Trityl Monitor is installed view the trityl display for each column to verify each column is functioning.

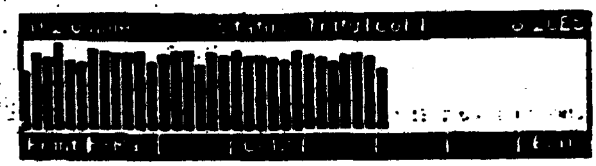

Figure 1: Successful Synthesis DNA -31 mer

The Installation Synthesis: If the trityls appear satisfactory in Step 15 (see Figure 1) perform the installation sequence on each column:

1. Enter the installation sequence (Refer to Section 2.3 "Entering the Sequence" in the Expedite User's Guide)
   5'-GAT-TGC-CTA-CCA-TCC-GTT-AGC-AAC-TGG-TGA-T-3'
2. Place a 0.2 µmole "T" column in Column Position #1 and #2.
3. Start a 0.2 µmole scale synthesis on both columns. Modify the Synthesis Parameters to remove the 5' (final) DMT. (Refer to Section 2.5 "Starting the Synthesis" in the Expedite User's Guide.)
4. Return the columns to the local Technical Support or Application laboratory for Ion Exchange HPLC analysis.

System Flush-out: Before repackaging the Expedite System for return or transport to another location for demonstration. You must:

- Remove the reagents from the instrument
- Wash the instrument out with dry acetonitrile
- Dry out the instrument

Perform the following procedure to ensure a clean system which is dry for storage or transport.

Remove Synthesis Reagents And Flush System With Acetonitrile

1. Use **Tools:Diag:Valve** to turn off the low pressure gas supply to the reservoir bottles.

NOTE: *Do not exit the Tools-Diag:Valve display screen until you have completed Step #3 to keep the blanket pressure turned off.*

2. Remove the reagent reservoirs containing any remaining synthesis reagent and cap the reagent bottles.
3. Add clean, acetonitrile to clean, dry bottles and place the bottles in all reservoir positions on the system.
   a. Add 200 ml of ACN to the WashA (WA) and Deblock (DB) reservoirs the External Caddy.
   b. Add 50 ml of dry ACN to Reservoirs 1-6 in the main reagent compartment (Reservoir #1, #2, #3, #4, #5 and #6).
   c. Add 10 ml of dry ACN to each monomer reservoir (A, C, G, T, 5, 6, 7, 8, 9 on an 8909: A, C, G, T, 5 on an 8905).
4. Place a female to female union in each column position.
5. Select **Prime** from the Main menu.
6. Select **2 (Prime all)** from the Prime menu.

Flush Column Position #1 With Acetonitrile

7. Select 1 for Column#1, the priming process will begin immediately. Make sure the appropriate waste containers (Organic "ORG" and Trityl "TRT") are attached to the system.
8. Press **Cycle** when it appears on the display (about 2 minutes) to repeat the prime all function on Column #1.
9. Repeat Step 8 once more for a total of three **Prime all** functions with ACN on column position #1.

Flush Column Position #2 With Acetonitrile

10. Press **Cancel** to return to the Prime menu.
11. Select **2 (Prime all)** from the Prime menu.
12. Select 2 for Column#2, the priming process will begin immediately.
13. Press **Cycle** when it appears on the display (about 2 minutes) to repeat the prime all function on Column #2.
14. Repeat Step 13 once more for a total of three **Prime all** functions with ACN on column position #2.

The Expedite system has been washed with acetonitrile to remove any residual reagent and is now ready for purging with blanketing gas (Refer to the procedure "Preparing an Expedite system for Storage or Transport").

Preparing An Expedite System For Storage Or Transport:

The Expedite system must not contain any reagents or solvents during transportation from site to site. Shipping a system containing solvents is in direct violation of federal and international shipping regulations.

Dry System With Blanketing Gas

1. Use **Tools-Diag:Valve** to turn off the low pressure gas supply to the bottles.

NOTE: Do not exit the Tools-Diag:Valve display screen until you have completed Step #3 to keep the blanket pressure turned off.

2. Remove any synthesis reagents remaining on the system and replace them with dry empty bottles. Press **Exit** 3 times to return to the Main menu.
3. Select **Prime** from the Main menu.
4. Select **2 (Prime all)** from the Prime menu.

Dry Column Position #1 With Blanket Gas

5. Select 1 for Column#1, the gas purge process will begin immediately.
6. Press **Cycle** when it appears on the display (about 2 minutes) to repeat the prime all function on Column #1.
7. Repeat Step 6 once more for a total of three **Prime all** functions with blanket gas on column position #1.

Dry Column Position #2 With Blanket Gas

8. Press **Cancel** to return to the Prime menu.
9. Select **2 (Prime all)** from the Prime menu.
10. Select **2** for Column#2, the gas purge process will begin immediately.
11. Press **Cycle** when it appears on the display (about 2 minutes) to repeat the prime all function on Column #2.
12. Repeat Step 11 once more for a total of three **Prime all** functions with blanket gas on column position #2.
13. If the system is on 8909, remove the Wash A (WA) and Deblock (DB) reservoir bottles for the caddy tubing and cap assemblies (WA and DB).
14. Make sure all reservoir bottles inside the reagent cabinet are tight and place a piece of tape across the bottles in each row to prevent them from shaking loose during shipment and causing damage to the unit.

Repackaging The Unit:

Return the unit to it's original shipping container. Position the unit on the skid and place the foam inserts in the appropriate locations on the top of the unit. Install the outer sleeve by dropping it over the unit.

Adjustable nylon straps (rachet type) should be used to secure the sleeve to the skid for transport by freight carriers.

Start-up Kit List for Expedite Models 8909 and 8905

MFG. PART No.	DESCRIPTION	QTY
105902	Start-up Kit List	1 ea
097194	Power cord, 8 ft., US	1 ea
097410	Power cord, 230 V European	1 ea
105405	Expedite User's Manual	1 ea
010123	Fuse, 2A, 5x20mm	2 ea
401290	Waste Bottle, 4 L, Plastic Coated	1 ea
105898	Waste Cap Kit, 4 hole w/plug	1 ea
064229	Waste Vent Tubing Teflon, $^1/_8$"	1 ea
046-12	Fitting, PEEK, $^1/_8$" for waste vent tube	1 ea
210112	Ferrule, PEEK, lock ring, $^1/_8$"	1 ea
330370	O-Ring, EPR, for monomer reservoirs	10 ea
330390	O-Ring, EPR, for Reservoir 1-6	6 ea
313720	O-Ring, EPR, for Caddy reservoirs	2 ea
317080	O-Ring, EPR, for 4 L waste reservoir	1 ea
105784	Filter, dip tube, all reservoirs	20 ea
210217	Waste bottle tray, poly	1 ea
322310	Union, female luer (for priming)	4 ea
331290	Ventilation Duct, flexible 15 ft.	1 ea
331280	Cuff for Ventilation duct	1 ea
210005	Clamp, Hose, for ventilation cuff	1 ea
330220	Bottle, 1 Liter Plastic Coated (DEBLOCK)	2 ea
102461	Bottle, 2 Liter, Plastic Coated (WASH A)	1 ea
210241	Cable, phone type, RJ45, interconnection	1 ea
335830	Gas inlet line assembly	1 ea
210310	Software, Expedite, 8900, V1.1	2 ea

APPENDIX J - DEMONSTRATION OF SYNTHESIZER PURGING AND DECONTAMINATION PROCEDURES

On February 18, 1997, Safety Board investigators and representatives from the parties to the investigation conducted, at PerSeptive's manufacturing facility, a demonstration of the purging and drying processes that the PerSeptive field engineer who prepared the accident unit for shipping reported he had followed. (The field engineer was invited to attend this demonstration but indicated he was unable to because of a schedule conflict.) The demonstration was intended to repeat, to the extent possible, the same sequence of steps taken by the field engineer who purged the accident instrument and prepared it for shipment.[93] The DNA synthesizer used in the demonstration was the same type as that involved in the accident.

For the demonstration, the 15 internal reagent bottles were filled about 25 to 50 percent full with acetonitrile. The two external reagent bottles were likewise filled about 15 to 25 percent full. A 4-liter brown glass bottle for the nonchlorinated wastes was about 65 percent full of waste. The clear glass bottle for the chlorinated wastes was empty. There were three external connections: the vent tube, power connection, and the inert gas (helium) hookup. A 3½-inch floppy disk[94] with the operating software had been inserted in the disk drive, which is located at the top rear of the synthesizer.

During the demonstration, the "prime all" cycle was then run three times on each of the two column positions (see figure A in appendix F). The "prime all" cycle was run a fourth time on the column 1 position to observe the flow of liquid to the waste bottles and to note the sequence of the priming function. Liquid was observed flowing into the waste bottles during the "prime all" cycle, and the menu (a screen on the front of the unit with computer-generated messages) indicated that every reagent position was primed.

The internal and external reagent bottles were then removed from the synthesizer and emptied by inverting them until no drops came out. Minute amounts of liquid were observed in the reagent bottles after the bottles were emptied and shaken. The amount of liquid remaining in one of the 25 mL reagent bottles was measured in a pipette and found to be approximately 0.005 mL.

The reagent bottles were reinstalled in the synthesizer without further attempts to remove the minute amounts of remaining residue. The system was then charged with helium to dry it. This was accomplished by running "prime all" three times on each column position. (The fluid injectors used for the flushing are pneumatically driven by the inert gas.) During the drying

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[93] During initial postaccident interviews, the field engineer initially stated that he followed PerSeptive's procedures, as outlined in Service Note 89-006 from memory, and thus those procedures were used as a guideline during the February 18, 1997, demonstration. However, as discussed above, he later acknowledged that he had performed 44 additional steps.

[94] The disk is required for the instrument to operate and records data regarding the keystrokes and operations performed on the synthesizer.

process liquid was observed dripping into the waste bottles. Upon completion of the “prime all” cycles, the helium gas (hookup) inlet line was disconnected, and all of the reagent bottles were loosened to depressurize the system.

After the drying process was complete, minute amounts of liquid were observed in the internal reagent bottles. Four of the 25 mL reagent bottles had about 0.001 mL of liquid, and a minute amount of liquid was also observed in at least one of the large reagent bottles. However, because the large bottles had been removed and sat uncapped for about 15 minutes to allow any remaining residue to flow to the bottom of each bottle, the residue had evaporated from the large bottles before measurements could be made.