FLIGHT SAFETY FOUNDATION

Accident Prevention

Vol. 58 No. 4 *For Everyone Concerned With the Safety of Flight* April 2001

Flight Crew Incapacitation Follows Learjet 35 Cabin Depressurization

The airplane remained airborne about three hours, 46 minutes after the last known radio transmission by the crew and struck terrain far from the intended destination. The investigation did not determine what had caused the airplane's cabin to depressurize or why the pilots had not used, or had not received, supplemental oxygen after the cabin depressurized.

FSF Editorial Staff

About 1313 Eastern Daylight Time on Oct. 25, 1999, a Gates Learjet 35 struck terrain near Aberdeen, South Dakota, U.S. All six occupants were killed. The last known radio transmission had been made by the crew near Gainesville, Florida, about 0927, soon after the crew reported that the airplane was climbing through Flight Level (FL) 230 (23,000 feet).

The U.S. National Transportation Safety Board (NTSB), in its final report, said that the probable cause of the accident was "incapacitation of the flight crewmembers as a result of their failure to receive supplemental oxygen following a loss of cabin pressurization for undetermined reasons."

The accident airplane was manufactured in 1976 and had been operated and maintained since January 1999 by Sunjet Aviation of Sanford, Florida. The airplane had accumulated 10,500 flight hours and 8,043 landings.

Sunjet Aviation, founded in 1992, was a fixed-base operator that provided fuel service, aircraft charter service (Learjet and Cessna Citation) and maintenance service. The company had 70 employees and six airplanes. (The company returned its U.S. Federal Aviation Regulations [FARs] Part 135 operating certificate to the U.S. Federal Aviation Administration [FAA] on July 17, 2000.)

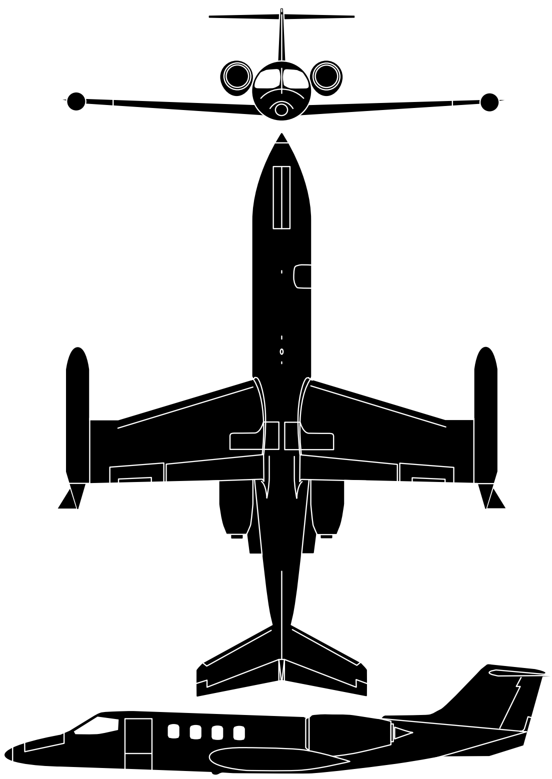
Maintenance records showed that, during a flight on Feb. 9, 1998, the accident airplane did not maintain cabin pressurization at low altitudes.

"The maintenance-clearing action noted in the airplane's logbook indicated that the airplane had been operationally checked on the ground and that the problem could not be duplicated," the report said.

During a flight on July 22, 1999, the pressurization system failed to maintain maximum pressurization differential — 8.7 pounds per square inch (psi) [0.06 kilopascal (kPa)]. During the flight, cabin altitude began to climb at more than 2,000 feet per minute. A work order dated July 23, 1999, said that the pressurization system was checked and that maintenance personnel cleaned the cabin-pressure outflow valve.

"No mechanic's signatures or initials (indicating completion of corrective actions) or inspector's signatures or initials (indicating inspection of the completed corrective actions) were found on [the work order]," the report said.

On July 28, 1999, a pilot told the company's maintenance supervisor that cabin altitude had increased when thrust was reduced during descent. A subsequent work order said that maintenance personnel cleaned the outflow valve, tested the pressurization system and found the system "O.K. for flight."



Gates Learjet 35

The Learjet 35 made its first flight in 1973; deliveries began in 1974. The airplane is similar to the Learjet 25 but has turbofan engines rather than turbojet engines, a longer fuselage and longer wings. Each of the Honeywell (formerly Garrett and AlliedSignal) TFE731-2-2B engines is rated at 3,500 pounds thrust (15.6 kilonewtons). Usable fuel capacity is 925 gallons (3,501 liters).

The airplane has accommodations for two pilots and up to eight passengers. (A longer-range version, the Learjet 36, accommodates up to six passengers and has a usable fuel capacity of 1,100 gallons [4,164 liters].) The pressurization system can maintain a cabin altitude of 6,500 feet at the airplane's maximum operating altitude, 45,000 feet.

Maximum takeoff weight is 17,000 pounds (7,711 kilograms). Maximum landing weight is 15,300 pounds (6,940 kilograms). Maximum rate of climb at sea level is 4,760 feet per minute (fpm). Maximum single-engine rate of climb at sea level is 1,470 fpm. Maximum operating Mach number is 0.81. Maximum cruising speed at 41,000 feet and mid-cruise weight is 460 knots. Economy cruise speed at 45,000 feet and mid-cruise weight is 418 knots. Maximum range with four passengers and a 45-minute fuel reserve is 2,196 nautical miles (4,067 kilometers).

Source: *Jane's All the World's Aircraft*

On the day of the accident, the airplane was scheduled for a repositioning flight from Orlando Sanford International Airport to Orlando International Airport, where three passengers would be boarded for a charter flight with stops in Dallas, Texas, and in Houston, Texas.

The captain, 42, had an airline transport pilot certificate and type ratings in the Boeing 707, B-720 and Learjet. He had served in the U.S. Air Force from 1981 to 1984 as a KC-135A standardization/evaluation copilot and as an emergency-procedures evaluator, and from 1984 to 1988 as an E-3A commander. From 1988 to 1993, he served in the U.S. Air National Guard as a KC-135E instructor pilot.

"During his [Air Force and Air National Guard] career, the captain accumulated 3,953 hours flying KC-135 and E-3A airplanes and achieved the rank of major," the report said. "For approximately the next six years, [he] worked in a nonflying capacity."

On Sept. 21, 1999, he earned a Learjet type rating, completed a FARs Part 135 pilot competency/instrument-proficiency check in the Learjet 35 and was hired by Sunjet Aviation.

"According to Sunjet Aviation employees, the captain was an excellent pilot who transitioned into the Learjet without difficulty," the report said. "They also indicated that he was knowledgeable about the airplane and that he was a confident pilot with good situational awareness."

At the time of the accident, the captain had accumulated 4,280 flight hours.

"He had flown a total of 60 hours with Sunjet Aviation, [including] 38 hours as a Learjet pilot-in-command and 22 hours as a Learjet second-in-command," the report said. "The captain had flown 35 [hours] and six hours in the last 30 [days] and seven days (respectively) and zero hours in the last 24 hours before the accident."

The first officer, 27, had a commercial pilot certificate, a flight instructor certificate and type ratings in the Cessna Citation 500 and Learjet. She was hired by Sunjet Aviation on Feb. 27, 1999.

On April 15, 1999, she earned a Learjet type rating and completed a FARs Part 135 second-in-command check ride and pilot competency/instrument-proficiency check in the Learjet 35.

"Pilots who had flown with the first officer before she was hired by Sunjet Aviation indicated that she was a knowledgeable pilot with good aircraft-handling skills; one pilot stated that she was a serious pilot who had a 'meticulous' style in the cockpit and was not someone who abbreviated procedures or neglected checklists," the report said. "Sunjet Aviation pilots indicated that she was a confident pilot with excellent radio-communication skills."

At the time of the accident, the first officer had accumulated 1,751 flight hours, including 99 flight hours as second-in-command in the Learjet. She had flown 35 hours in the previous 30 days, six hours in the previous seven days and had not flown in the 24 hours preceding the accident.

"A review of FAA records indicated that the flight crewmembers had no records of airplane accidents, incidents or enforcement actions," the report said. "In addition, both flight crewmembers held valid Florida driver's licenses with no history of accidents or violations during the three years before the accident."

On the day of the accident, the captain reported for duty at 0630. The first officer reported for duty at 0645. A Sunjet Aviation customer-service representative said that both pilots were in a good mood and appeared to be in good health.

The captain told a line-service technician to remove the airplane from the hangar, attach a ground-power unit to the airplane and increase the fuel supply to 5,300 pounds (2,404 kilograms). The first officer was aboard the airplane during the refueling operation. The captain conducted the preflight inspection of the airplane.

The Learjet 35/36 airplane flight manual (AFM) states the following:

> Normal preflight procedures (all checklist line items) must be accomplished prior to takeoff at the original point of a flight. At each intermediate stop of flight where both engines are shut down, the Through-Flight Checklist may be used for preflight provided certain criteria are met during a stop.

Among the tasks required by the preflight checklist is to ensure that the oxygen-bottle pressure-regulator/shutoff valve is selected ON. This task is not required by the through-flight checklist.

The oxygen bottle is in the nose section; the oxygen-bottle pressure-regulator/shutoff valve is accessed through an exterior hatch. The oxygen-bottle pressure-regulator/shutoff valve is not accessible from the cockpit.

"According to the FAA principal operations inspector (POI) assigned to the Sunjet Aviation [FARs Part 135 operating] certificate, the labeling on the oxygen bottle [pressure-regulator/shutoff valve] is misleading; the word OFF is visible when the valve is open," the report said. "In addition, according to the Sunjet Aviation chief pilot, during the exterior preflight procedure, it would be possible to confuse the ON/OFF status of the oxygen system because of misleading markings.

"[The chief pilot] stated that he reviewed that issue with the accident captain during training. He further stated that Sunjet Aviation pilots never turn the oxygen system off."

Among the tasks required by the through-flight checklist is to check the oxygen-pressure gauge, which is on the instrument panel in front of the right pilot seat. A Sunjet Aviation official said that, before the airplane departed from Orlando Sanford, the captain told him that the oxygen-pressure gauge showed oxygen pressure in the green band (1,550 psi to 1,850 psi [10.7 kPa to 12.8 kPa]).

The through-flight checklist also requires that the CABIN AIR switch be set to NORM, to pressurize the cabin.

The airplane departed from Orlando Sanford about 0754 and was landed at Orlando International (about 15 nautical miles [28 kilometers] southeast of Sanford) about 0810. Four passengers boarded the airplane about 30 minutes later.

"An additional passenger, who was not on the original charter-flight request, boarded the accident airplane at [Orlando International]," the report said. "Several bags were placed on board the airplane, including what [was] described as a big golf bag weighing about 30 pounds [14 kilograms]." [Among the passengers was Payne Stewart, a professional golfer.]

A cooler containing wet ice and soft drinks also was aboard the airplane; the report said that the cooler did not contain dry ice.

The captain had filed an instrument flight rules flight plan with a requested route from Orlando to Cross City, Florida [about 108 nautical miles (200 kilometers) northwest of Orlando], then to Dallas Love Field. The flight plan showed four hours, 45 minutes of fuel aboard the airplane. Requested cruising altitude was FL 390.

The airplane departed from Orlando International at 0919. At 0921, the first officer told Jacksonville (Florida) Air Route Traffic Control Center that the airplane was climbing through 9,500 feet. The controller told the crew to climb to FL 260 and to maintain FL 260.

At 0923, the controller told the crew to fly directly to Cross City and then directly to Dallas Love Field. At 0926, the controller told the crew to contact Jacksonville Center on another radio frequency.

The crew selected the new radio frequency; and, at 0927, the first officer reported that the airplane was climbing through FL 230.

The controller told the crew to climb to FL 390 and to maintain FL 390.

The first officer acknowledged the instructions by repeating the flight level and saying the last two digits in the aircraft's call sign (N47BA): "Three nine zero, bravo alpha."

Postaccident analysis of the ATC recording of the first officer's radio transmissions showed that she was not wearing an oxygen mask.

"Her speech was normal, [and] her phraseology was accurate and appropriate," the report said.

The recording did not include the sound of the airplane's cabin-altitude aural warning, which activates when cabin altitude increases above 10,000 feet.

Recorded ATC radar data showed that, at 0930, the airplane turned a few degrees right while climbing through 30,200 feet.

"Because the airplane's ground track (and, presumably, its heading) was maintained for nearly the remainder of the flight, it is likely that this right turn was initiated by human input to the autopilot heading-select knob," the report said.

At 0933, the controller told the crew to contact Jacksonville Center on another radio frequency. The airplane was climbing through about 36,400 feet at the time.

"The controller received no response from N47BA," the report said. "The controller called the flight five more times over the next 4 1/2 minutes but received no response."

The report said that the flight crew apparently became incapacitated between 0926 and 0933. The airplane's ground track continued to deviate from the crew's assigned route, and did not stop climbing at the assigned altitude (FL 390).

"There was no evidence that the flight crew attempted to intervene … as the airplane continued to fly off course," the report said.

Jacksonville Center requested that the Air Force intercept the Learjet. At 1054, the pilot of an F-16 intercepted the Learjet at 46,400 feet.

"The [F-16 pilot] made two radio calls to N47BA but did not receive a response," the report said. "[The pilot] began a visual inspection of N47BA. There was no visible damage to the airplane, and he did not see ice accumulation on the exterior of the airplane. Both engines were running, and the rotating beacon was on. He stated that he could not see inside the passenger section of the airplane because the windows seemed to be dark.

"Further, he stated that the entire right-cockpit windshield was opaque, as if condensation or ice covered the inside. He also indicated that the left-cockpit windshield was opaque, although several sections of the center of the windshield seemed to be only thinly covered by condensation or ice; a small rectangular section of the windshield was clear, with only a small section of the glareshield visible through this area. He did not see any flight-control movement."

The F-16 pilot completed the visual inspection and flew away from the Learjet at about 1112. At 1213, the pilots of two F-16s intercepted the airplane. One of the pilots said, "We're not seeing anything inside. Could be just a dark cockpit, though. … He is not reacting, moving or anything like that. He should be able to have seen us by now." The F-16 pilots flew away from the Learjet at 1239 and conducted aerial refueling.

At about 1250, the F-16 pilots again intercepted the Learjet. The pilots of two other F-16s also had intercepted the airplane. One pilot said, "It's looking like the cockpit window is iced over and there's no displacement in any of the control surfaces as far as the ailerons or trims."

The Learjet's cockpit voice recorder (CVR) recorded cockpit sounds during the last 30 minutes of the flight. The sounds included continuous activation of the cabin-altitude aural warning.

"The continuous sounding of the cabin-altitude aural warning during the final 30 minutes of cruise flight (the only portion recorded by the CVR) indicates that the airplane and its occupants experienced a loss of cabin pressurization some time earlier in the flight," the report said.

The CVR at 1310 recorded the sound of thrust decreasing from one engine and sounds similar to stick-shaker [stall-warning system] activation and autopilot disconnection. Recorded ATC radar data showed that, at 1312, the airplane began a right turn and a descent.

"Information on the [CVR] indicated that the airplane's final descent was initiated by an engine ceasing to operate," the report said. "Considering the length of time that the airplane had been flying, this was most likely caused by fuel exhaustion."

One F-16 pilot said, "The target is descending, and he is doing multiple aileron rolls. Looks like he's out of control … in a severe descent."

Another F-16 pilot said, "It's soon to impact the ground. He is in a descending spiral."

The airplane struck a field, creating a crater 42.3 feet (12.9 meters) long, 21.5 feet (6.6 meters) wide and 8.5 feet (2.6 meters) deep.

Toxicological tests of tissue specimens from the first officer produced negative results for major drugs of abuse (i.e., marijuana, cocaine, opiates, phencyclidine and amphetamines) and positive results for ethanol.

"The [toxicology] report noted that the 'ethanol found in this case may potentially be from postmortem ethanol formation and not from the ingestion of ethanol,'" the report said. "No toxicology testing was completed for the captain because of the difficulty of identifying and isolating tissue samples."

Tear-down inspections of the engines showed that the left engine was not operating on impact and that the right engine was operating on impact.

"Further inspection revealed that no preaccident condition on either engine would have interfered with normal operation," the report said.

In the Learjet 35, engine bleed air — that is, air extracted from engine compressor sections — is used to pressurize the cabin, heat the cabin, defog the windshield and prevent ice from forming on the windshield, wing leading edges, stabilizer leading edges and engine nacelles.

The flow of bleed air from the engines is controlled by two BLEED AIR switches — one switch for the left engine, one switch for the right engine — on the instrument panel in front of the right seat. When a BLEED AIR switch is in the OFF position, the bleed air shutoff/regulator valve — also called the modulation valve — for that engine is closed. When the BLEED AIR switch is in the ON position, the modulation valve is open and regulates the flow of bleed air to a manifold that supplies the various pneumatic systems. (The manifold receives bleed air from both engines.)

Bleed air is required to close the modulation valves, which are spring-loaded to the open position. The modulation valves in the accident airplane were almost closed.

"The nearly closed position of both valves at impact is consistent with a normal and adequate supply of engine bleed air from one or both engines," the report said. "Further, these nearly closed valve positions indicate that there was a low demand for bleed air by the airplane's air-conditioning and anti-icing systems and that both BLEED AIR switches, which were not recovered, would have had to have been selected to the ON position."

The flow of bleed air from the manifold to the various pneumatic systems is regulated by a flow-control valve, which is spring-loaded to the closed position.

"Although … bleed air was available to open the flow-control valve, the condition of the flow-control valve indicated that it was in its fully closed position at impact," the report said. "The valve requires several seconds to move from its fully open [position to its] fully closed position in normal operation, indicating that the valve was in its closed position before impact. This closed valve would have prevented bleed air from entering the cabin, thereby preventing normal pressurization."

The report said that the flow-control valve might have closed because of a mechanical malfunction of the venturi throat pressure sense line, actuator diaphragm, actuator opening chamber inlet orifice or shutoff-solenoid bleed-port orifice.

"The condition of the wreckage did not allow investigators to determine whether any of these failures occurred on the accident airplane," the report said.

The flow-control valve might have been closed because the flight crew neglected to select the CABIN AIR switch to NORM (normal) before takeoff.

"However, without the cabin air-conditioning [pressurization] system [functioning], the occupants of the airplane likely would have perceived a high cabin[-altitude] climb rate after takeoff, possibly causing discomfort," the report said. "At about 10,000 feet cabin altitude, the cabin altitude aural warning should have begun to sound, further alerting the flight crew to the lack of pressurization. Although the pilots could have manually silenced the warning, they would have had to repeat this action every 60 seconds.

"At about 14,000 feet cabin altitude, deployment of the passengers' oxygen masks would have provided an additional cue that the cabin was not properly pressurized. It is unlikely that the flight crew would have continued to climb despite this clear information that the airplane was unpressurized."

The absence of detectable symptoms of hypoxia in the first officer's radio transmissions and the absence of the sound of the cabin altitude warning in the recorded radio transmissions further indicate that the crew did not neglect to select the CABIN AIR switch to NORM before takeoff, the report said.

The flight crew might have repositioned the CABIN AIR switch from NORM to OFF in flight, while conducting the checklist for loss of pressurization at altitude. The Learjet 35 does not have an automatic emergency pressurization system; emergency pressurization, which is provided through the windshield anti-ice/defogging system, must be activated manually.

"Step 4 of the Learjet Model 35/36 [AFM] checklist for a pressurization loss at altitude instructs pilots to select the WSHLD (windshield) HEAT AUTO/MAN switch to AUTO, thus initiating the emergency bleed air supply to the cabin," the report said. "Step 5 … instructs pilots to select the CABIN AIR switch to OFF, thereby closing the flow-control valve."

The report said that the flight crew might have experienced, or might have thought that they had experienced, a pressurization problem and, while conducting the checklist for a pressurization loss at altitude, omitted step 4.

"In summary, … an uncommanded closure of the flow-control valve would have been sufficient to depressurize the airplane," the report said. "However, there was insufficient evidence to determine whether the depressurization was initiated by a loss of bleed air inflow (caused by a malfunction of the flow-control valve or by inappropriate [flight crew action] or incomplete flight crew action) or by some other event."

FAA, on Nov. 4, 1999, began a special certification review (SCR) of the Learjet 35/36 oxygen system and pressurization system to determine whether the systems were certificated properly and whether the systems had any unsafe design features.

"The SCR team did not identify issues associated with the oxygen and pressurization systems that would lead to an unsafe condition," the report said.

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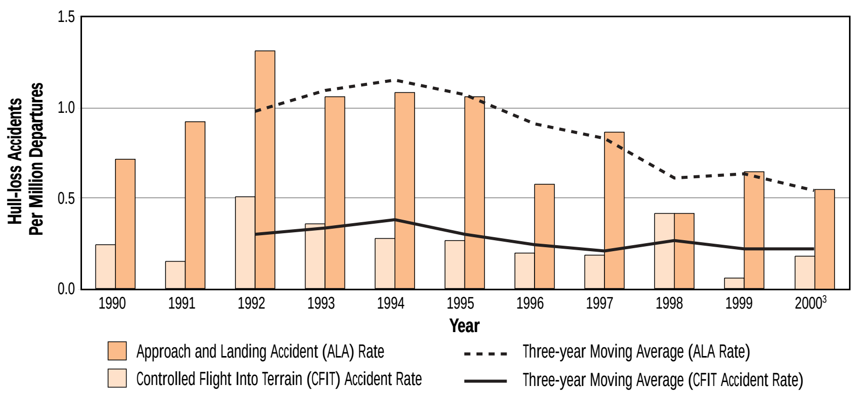
Controlled-flight-into-terrain and Approach-and-landing[1] Hull-loss Accidents

Worldwide Large Commercial Jet Airplanes[2]

1990–2000[3]



Notes:

1. Categorization of accidents for 2000 is preliminary.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.
3. Accidents through Oct. 15, 2000.

Source: Flight Safety Foundation *Flight Safety Digest*, August–November 2000

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The SCR team found, however, that the Learjet 35/36 AFM did not have an emergency procedure requiring that flight crews don oxygen masks immediately after the cabin-altitude aural warning is activated. [As a result of this finding, FAA issued Airworthiness Directive 2000-24-19, effective Jan. 4, 2001, which required revising the Learjet 35/36 "emergency descent" checklist to require that flight crews don oxygen masks and select 100 percent oxygen when the cabin-altitude aural warning activates or when cabin altitude exceeds 10,000 feet.]

The report said that, as a result of the review, the SCR team made the following recommendations:

- "Bombardier Aerospace [should] develop a kit to provide an annunciator light (or the equivalent) to advise the flight crew if the CABIN AIR switch is in the OFF position for Learjet airplanes without automatic emergency pressurization systems [Bombardier Aerospace is the parent company of Learjet; the report said that FAA "indicated that Learjet plans to issue service bulletins by September 2001 to address this recommendation"];

- "All [FAA] aircraft certification offices (ACO) [should] review the AFMs of all transport category pressurized airplanes certificated for flight above 25,000 feet and ensure [that] they contain information about emergency procedures upon activation of the cabin-altitude warning … and that the flight crew don the oxygen masks immediately after a cabin-altitude warning;

- "Manufacturers of transport [category], normal [category] and commuter category pressurized airplanes certificated for operation above 25,000 feet [should] determine if there is a means to annunciate to the flight crew that the pressurization system is selected off or develop a modification to provide an annunciation of the same; [and,]

- "FAA [should] distribute information to the pilot community, including FAA operations inspectors and examiners, that emphasizes the importance of pressurization [systems] and oxygen systems operations and procedures to avoid hypoxia."

The accident airplane's oxygen-bottle pressure-regulator/shutoff valve was in the ON position and both flight crew oxygen masks were connected to oxygen-supply lines when the airplane struck the ground. The report said that the crew's failure or inability to use supplemental oxygen after the cabin depressurized might have occurred because the oxygen bottle contained an inadequate supply of oxygen, the oxygen bottle was serviced improperly or the crew did not, or were not able to, don rapidly their oxygen masks.

Maintenance records showed that the oxygen bottle was serviced by Sunjet Aviation on Sept. 3, 1999. The airplane then was flown about 105 hours. From interviews with pilots and analysis of recorded ATC communications, investigators determined that the quantity of oxygen in the bottle might have been reduced by 14 percent to 25 percent before the accident flight.

"The oxygen bottle was found empty," the report said. "Witness marks on the cockpit oxygen-pressure gauge caused by the impact were consistent with an indication of no pressure in the oxygen bottle."

One flight crew oxygen mask had a Rogers regulator, which automatically would have begun supplying 100 percent oxygen when cabin altitude increased above 39,000 feet.

"This oxygen would have been released at 130 liters per minute at a pressure of approximately 0.5 psi [0.004 kPa] even if the mask was not being worn by a flight crewmember, depleting a fully charged bottle in about eight minutes," the report said. "Therefore, the postimpact reading on the oxygen-pressure gauge is not necessarily indicative of an inadequate predeparture oxygen supply on the accident flight.

"In summary, [the investigation did] not determine the quantity of oxygen that was on board the accident flight."

Tests of the source from which the oxygen bottle was serviced by Sunjet Aviation on Sept. 3, 1999, showed that it contained 99.8 percent pure oxygen.

"[NTSB] is aware of an accident involving pilot incapacitation from hypoxia as a result of improper servicing of an oxygen bottle with compressed air," the report said.

[The accident occurred on April 1, 1997, at Hickory, Pennsylvania. During an aerial-photography flight, the pilot of a Cessna 337D was cleared to climb to FL 250. Recorded ATC radar data showed that the airplane climbed to 27,700 feet. The pilot did not respond to ATC radio transmissions. The airplane entered an uncontrolled descent and came to rest in a tree. The accident report said that the pilot died from hypoxic hypoxia. The passenger received minor injuries. The passenger said that both occupants began using supplemental oxygen at 10,000 feet. She began feeling dizzy at about 20,000 feet and closed her eyes, which is the last thing she remembered until after the accident occurred. Tests of the cylinder from which the accident airplane's portable oxygen bottle was serviced showed that the bottle contained compressed breathing air with about 21 percent oxygen.[1]]

The report said, "Another possible explanation for the failure of the pilots to receive emergency oxygen is that their ability to think and act decisively was impaired because of hypoxia before they could don their oxygen masks."

The investigation did not determine whether the cabin depressurized explosively (in less than 1/2 second), rapidly (from 1/2 second to 10 seconds) or gradually (more than 10 seconds).

The report said that, following a rapid depressurization in which cabin altitude increases to 30,000 feet, a person's cognitive functioning and ability to complete complex tasks can be impaired in as little as eight seconds without supplemental oxygen.

"Investigation of [two] other accidents in which flight crews attempted to diagnose a pressurization problem or initiate emergency pressurization instead of immediately donning oxygen masks following a cabin altitude alert have revealed that, even with a relatively gradual rate of depressurization, pilots have rapidly lost cognitive or motor abilities to effectively troubleshoot the problem or don their masks shortly thereafter," the report said.

[On May 12, 1996, the cabin-altitude warning horn in a Boeing 727-290 activated at FL 330. The captain and flight engineer attempted, without using a checklist, to bring back on line the right air-conditioning pack. The flight engineer inadvertently opened the outflow valve, which resulted in a rapid loss of cabin pressure. The cabin oxygen masks deployed when cabin altitude increased to 14,000 feet. The captain, flight engineer and lead flight attendant lost consciousness because of hypoxia. The first officer, who had donned his oxygen mask when the cabin-altitude warning horn activated, began an emergency descent. The captain, flight engineer and lead flight attendant regained consciousness during the descent. An emergency landing was conducted in Indianapolis, Indiana. Of the 112 occupants, 11 received minor injuries, and 101 were not injured.[2]]

[On Aug. 13, 1998, the first officer (the pilot flying) of a Boeing 737-204 felt pressure in his ears when he reduced thrust to begin a descent from FL 350. He observed that the cabin-altitude rate-of-climb indication was at the top of its scale. He told the captain that they had a pressurization problem and selected the standby pressurization system, which did not solve the problem. He then donned his oxygen mask, declared a mayday and began an emergency descent. The cabin oxygen masks deployed, and all the passengers used them. When the captain was told about the pressurization problem, he asked a flight-deck visitor to return to her seat and then attempted to don his oxygen mask. The mask became entangled in his eyeglasses, and the eyeglasses fell to the floor. The captain lost consciousness while attempting to retrieve the eyeglasses. The first officer attempted unsuccessfully to assist the captain. The senior cabin crewmember lost consciousness while attempting to assist the captain. The first officer then was able to secure the captain's oxygen mask, and a cabin crewmember came to the flight deck with a portable oxygen system and revived the senior cabin crewmember. After the airplane was landed at London (England) Gatwick Airport, the depressurization was traced to a crack in the aft cargo door frame. Of the 123 occupants, five received minor injuries.[3]]

The Learjet accident report said, "In this accident, the flight crew's failure to obtain supplemental oxygen in time to avoid incapacitation could be explained by a delay in donning oxygen masks of only a few seconds in the case of an explosive [decompression] or rapid decompression, or a slightly longer delay in the case of a gradual decompression."

Based on these findings, NTSB on Dec. 20, 2000, sent a safety-recommendation letter to FAA. The letter said, "When cabin depressurization occurs at high altitudes, the immediate proper use of supplemental oxygen is critical; if supplemental oxygen is not used, unconsciousness and even death can quickly result."

The letter said that published information on time of useful consciousness (TUC) at altitude is inconsistent and misleading, and does not convey the urgency of donning oxygen masks immediately after cabin depressurization.

"For example, [Advisory Circular] AC 61-107 [*Operations of Aircraft at Altitudes Above 25,000 Feet MSL and/or Mach Numbers (Mmo) Greater Than .75*] indicates that the TUC at about 25,000 feet is three [minutes] to five minutes, whereas AC 25-20, *Pressurization, Ventilation and Oxygen Systems Assessment for Subsonic Flight, Including High Altitude Operation*, indicates that the TUC at about 25,000 feet is three [minutes] to 10 minutes," the letter said.

Furthermore, the TUC information in the ACs is based on studies typically using participants who were seated comfortably, expecting a simulated decompression, and who conducted simple tasks (such as counting backward from 1,000) after the decompression.

"These studies do not accurately replicate the complex and changing environment of an aircraft that is losing cabin pressure, and the tasks performed do not accurately simulate the types of tasks involved in accurately identifying and responding to an emergency situation," the letter said.

U.S. military services and some corporate flight departments require their pilots to complete periodic training in a hypobaric (altitude) chamber; the training includes a simulated rapid decompression. The FARs do not require civilian pilots to receive such training.

The letter said, however, that the usefulness of altitude-chamber training is questionable.

"The possibility exists that such training may contribute to pilot complacency (and thereby cause delayed response to decompression events in the aircraft) because the onset of symptoms at the altitudes experienced in chambers [typically 25,000 feet] does not accurately reflect the acute onset of symptoms experienced during decompression events at higher flight altitudes," the letter said.

The letter said that reports submitted to the U.S. National Aeronautics and Space Administration Aviation Safety

Reporting System (ASRS) show that some pilots do not conduct thorough preflight inspections of oxygen equipment.

"ASRS reports [have] documented instances in which flight crews donned oxygen masks, but system components were inoperative," the letter said. "In the event of a loss of cabin pressure, there may be insufficient time to troubleshoot an oxygen-mask problem in flight."

The checklists for some aircraft do not require the donning of oxygen masks as the first step in responding to a cabin decompression.

"According to FAA Order 8400.10, *Air Transportation Operations Inspectors Handbook*, paragraph 2177, a flight crew's donning of oxygen masks is considered to be an immediate-action item after the cabin altitude warning sounds because an imminent threat of incapacitation … exists," the letter said. "However, in paragraph 2207c, the order states that immediate-action items 'may be stated as policies rather than checklist items when appropriate.'

"The FAA offers the example of flight crews donning oxygen masks in the event of a loss of cabin pressure, adding, 'In this example, the loss-of-cabin-pressure checklist would contain subsequent items based on the assumption that the flight crew is on oxygen and has established interphone contact.'"

The letter said that NTSB does not agree with this guidance.

"Immediate-action items, including the flight crew's donning of oxygen masks, should be presented in the checklist to facilitate training and ensure that all appropriate actions have been completed during checklist review," the letter said.

NTSB made the following recommendations to FAA:

- "Revise existing guidance and information about high-altitude operations to accurately reflect the [TUC] and rate of performance degradation following decompression and to highlight the effect of hypoxia on an individual's ability to perform complex tasks in a changing environment, and incorporate this revised information into both the required general emergency training conducted under [FARs] Parts 121 and 135 and training and flight manuals provided to all pilots operating pressurized aircraft. (A-00-109);

- "Convene a multidisciplinary panel of aeromedical [specialists] and operational specialists to study and submit a report on whether mandatory hypoxia-awareness training, such as altitude chamber training, for civilian pilots would benefit safety. The report should consider alternatives to altitude chamber training, clearly identify which pilots and/or flight operations would benefit most from such training, and determine the scope and periodicity of this training. If warranted, establish training requirements based on the findings of this panel. (A-00-110);

- "Require that operators of all pressurized-cabin aircraft provide guidance to pilots on the importance of a thorough functional preflight of the oxygen system, including, but not limited to, verification of supply pressure, regulator operation, oxygen flow, mask fit, and communications using mask microphones. (A-00-111);

- "Remove the reference to the donning of oxygen masks in the event of loss of pressurization as an example of an immediate-action item that may be stated as a policy rather than as a checklist item as an acceptable use in [FAA] Order 8400.10 … , paragraph 2207c, and review the appropriateness of its position that immediate-action items may be stated as policies rather than checklist items. (A-00-112);

- "Require that all pressurized aircraft certificated to operate above 25,000 feet have a clear and explicit emergency procedure associated with the onset of the cabin altitude warning that contains instructions for flight crews to don oxygen masks as a first and immediate-action item, followed by instructions appropriate to diagnose, manage and resolve the condition indicated by the warning. (A-00-113);

- "Issue guidance within six months directly to pilots operating pressurized aircraft regarding the need to don oxygen masks immediately following activation of the cabin altitude warning. (A-00-114);

- "Issue an airworthiness directive requiring Learjet Inc. to instruct operators of the Learjet Model 35/36 (and other affected models) to modify the oxygen bottle regulator/shutoff valve assembly so that flight crews can clearly and accurately verify the position of the valve during preflight visual inspections. (A-00-115);

- "Evaluate the feasibility of requiring design changes to automate the existing emergency pressurization systems on Learjet 35/36 airplanes (and other affected models) that do not have an automatic emergency pressurization system. If the automation of their existing systems is determined to be feasible, require such design changes. (A-00-116);

- "Evaluate all [FARs] Part 25 aircraft that do not have automatic emergency pressurization systems to determine if automation of their existing systems is feasible and, if warranted, require changes to affected models as soon as possible. (A-00-117);

- "Increase the frequency of unannounced inspections of [FARs] Part 135 operators to verify the accuracy and adequacy of pilot discrepancy [record-keeping procedures and entries] and maintenance logbook record-keeping procedures and entries. (A-00-118); [and,]

- "Ensure that all transport category airplanes, regardless of whether they are operated under [FARs] Parts 91, 121, 125 or 135, are included in [the FAA's] review of aging transport aircraft systems and structures. (A-00-119)."

FAA, in a letter dated March 2, 2001, made the following responses to the NTSB recommendations:

- "[Regarding NTSB safety recommendation (SR) A-00-109], FAA … in January 2001 published an article entitled 'Ready for Flight?' in *Designee Update*, Volume 13, no. 1. The article provides information to the pilot community, including FAA operations inspectors and examiners, and emphasizes the importance of pressurization and oxygen systems operations and procedures to avoid hypoxia. … The FAA also plans to revise [AC] 61-107 [to] accurately reflect the [TUC] and rate of performance degradation following decompression and highlight the effect of hypoxia on an individual's ability to perform complex tasks in a changing environment. The FAA anticipates issuing the revised AC by July 2001. Once the AC is revised, the FAA will issue a flight standards handbook bulletin directing principal operations inspectors (POIs) to ensure that applicable operators incorporate this revised information into the required general emergency training conducted under [FARs] Parts 121 and 135. The bulletin will also direct POIs to ensure that the information is incorporated into the training [manuals] and flight manuals provided to all pilots operating pressurized aircraft … ;

- "[Regarding SR A-00-110], FAA has assembled various aeromedical [specialists] and operational specialists within the FAA and military to evaluate this safety recommendation, determine what current reports or studies are already available and determine the requirements and scope of a larger government/industry panel to address this recommendation … ;

- "[Regarding SR A-00-111], FAA … will revise AC 61-107 to include guidance on the importance of a thorough functional preflight of the oxygen system, including (but not limited to) verification of supply pressure, regulator operation, oxygen flow, mask fit and communications using mask microphones. The FAA anticipates issuing the revised AC by July 2001. Once the AC is revised, the FAA will issue a flight standards handbook bulletin directing POIs to ensure that operators of all pressurized cabin aircraft provide this guidance to pilots … ;

- "[Regarding SR A-00-112], FAA … will issue a flight standards handbook bulletin to advise POIs that paragraph 2207c will be removed from FAA Order 8400.10 … ;

- "[Regarding SR A-00-113], FAA, with the assistance of the airplane manufacturers and [non-U.S.] civil airworthiness authorities, reviewed [FARs Part 25 airplane AFMs] to verify if the first crew action after a cabin altitude warning is to don the oxygen mask. The review did not include a verification of procedures to diagnose, manage and resolve the high-cabin-altitude warnings because it is standard practice to include such information in the AFM. If for some reason the information was not in the AFM, its absence would have been noticed during the review … " [The letter listed several AFMs that have been revised or were scheduled to be revised voluntarily by manufacturers or as required by ADs.];

- "[Regarding SR A-00-114], FAA … will revise AC 61-107 to include information regarding the need to don oxygen masks immediately following activation of the cabin altitude warning. It is anticipated that the AC will be issued in July 2001. Once the AC is issued, the FAA will issue a flight standards handbook bulletin directing POIs to ensure that operators of all pressurized-cabin aircraft advise pilots on the need to don oxygen masks immediately following activation of the cabin altitude warning … ;

- "[Regarding SR A-00-115], a review of the oxygen bottle regulator/shutoff valve assembly showed that flight crews can clearly and accurately verify the position of the valve during preflight visual inspections. … A modification of the oxygen bottle regulator/shutoff valve assembly is not necessary … ;

- "[Regarding SR A-00-116], FAA has reviewed the design of the pressurization system and concluded that, while it is technically feasible to automate the existing manual emergency pressurization system on the Learjet Model 35/36 airplanes (and other affected models), it is not reasonable to mandate such a design change. … The AFM requires the flight crew to don oxygen masks as the first step in the emergency procedure when a cabin reaches 10,000 feet, just as it does on the airplanes with automatic emergency pressurization. A flight crew following the AFM procedures should be provided adequate protection from hypoxia following an annunciated 10,000-foot cabin altitude … ;

- "[Regarding SR A-00-117], FAA's review revealed that no U.S.-manufactured large commercial transport category airplane with an environmental control system featuring two or more air-cycle machines incorporates an automatic emergency pressurization system into the cabin environmental control system design. Typically, the smaller modern executive business jets with a single air-cycle machine do incorporate an automatic emergency pressurization system. … The lack of a definite unsafe design feature and the cost of modifying existing large commercial transport airplane systems to accommodate an automatic emergency pressurization system would make retroactive rule making in this area difficult to achieve. … The current regulations governing environmental control system design, coupled with crew adherence to the revised procedures to don the oxygen masks immediately after a cabin altitude warning, provide an adequate measure of safety in this area. The FAA does not plan to issue ADs or engage in a rule-making effort at this time … ;

- "[Regarding SR A-00-118], FAA … will issue a joint flight standards information bulletin [directing] POIs and principal maintenance inspectors to increase the frequency of unannounced inspections of [FARs] Part 135 operators to verify the accuracy and adequacy of pilot discrepancy [record-keeping procedures and entries] and maintenance logbook record-keeping procedures and entries. It is anticipated that the bulletin will be issued by July 2001 … ; [and,]

- "[Regarding SR A-00-119], … the original focus of ATSRAC [Aging Transport Systems Rulemaking Advisory Committee] was prioritized on wiring concerns of the larger transport airplanes operated under [FARs] Parts 91, 121, 125 and 129. Many smaller transport airplanes operated under [FARs] 135 were not included in the data-collection efforts of ATSRAC. … FAA has scheduled another meeting to determine, in part, if ATSRAC is the appropriate forum to resolve any aging systems concerns on the smaller transport airplanes. … At the conclusion of the ATSRAC meeting, the FAA will notify [NTSB] of the process it plans to use to respond to this recommendation."♦

[FSF editorial note: This article, except where specifically noted, is based on U.S. National Transportation Safety Board (NTSB) *Aircraft Accident Brief*, accident no. DCA00MA005 (35 pages); NTSB *Safety Recommendation*, Dec. 20, 2000, A-00-109 through –119 (17 pages); and U.S. Federal Aviation Administration letter to NTSB, March 2, 2001 (15 pages).]

References

1. U.S. National Transportation Safety Board (NTSB) Accident/Incident Database (AID) report no. IAD97FA060.

2. NTSB AID report no. CHI96IA157.

3. U.K. Air Accidents Investigation Branch. *AAIB Bulletin No.: 6/99, Ref: EW/C98/8/6*.

Accident Prevention
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