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Safety Study

Emergency Evacuation of Commercial Airplanes

NTSB Report

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Cover photo: The U.S. National Transportation Safety Board (NTSB) said that this evacuation slide was used in the evacuation of an American Airlines Boeing 727 on Feb. 9, 1998, in Chicago, Illinois, U.S. "The airplane landed short of the runway threshold while attempting a landing in fog," NTSB said. "Twenty-three minor injuries were reported to [NTSB among 122 aircraft occupants]." NTSB conducted a detailed investigation of the evacuation, identified as case no. 9, among 46 evacuations discussed in "Safety Study: Emergency Evacuation of Commercial Airplanes." (NTSB photo)

Foreword

This issue of *Flight Safety Digest* presents a report on the findings of a special study of emergency evacuations of commercial airplanes.

The report is the result of a study by the U.S. National Transportation Safety Board (NTSB) of 46 emergency evacuations between September 1997 and June 1999 that involved 2,651 passengers and 18 different airplane types.

NTSB used information obtained from the passengers, flight attendants, flight crews, air carriers and aircraft rescue and fire fighting (ARFF) units to examine the following:

- Certification issues related to airplane evacuation;
- The effectiveness of evacuation equipment;
- The adequacy of air carrier and ARFF guidance and procedures related to evacuations; and,
- Communication issues related to evacuations.

Based on the findings of the study, NTSB made 20 safety recommendations and reiterated three previous safety recommendations to the U.S. Federal Aviation Administration.

The Foundation is publishing this report in an effort to give wider distribution to the useful information that NTSB has collected about factors involved in commercial airplane emergency evacuation.

— FSF Editorial Staff

Safety Study
Emergency Evacuation of Commercial Airplanes

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National Transportation Safety Board
490 L'Enfant Plaza, S.W.
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Abbreviated Terms

AASK	Aircraft Accident Statistics and Knowledge database
AC	advisory circular
AD	airworthiness directive
ADMS	accident data management system
ARFF	aircraft rescue and firefighting
APU	auxiliary power unit
ASRS	Aviation Safety Reporting System
ATC	air traffic control
ATR-42	Avions de Transport Regional ATR-42 aircraft
A300	Airbus Industrie A300 aircraft
Beech 1900	Beechcraft 1900 aircraft
CAA	Civil Aviation Authority of the United Kingdom
CAMI	Civil Aeromedical Institute of the FAA
CFR	*Code of Federal Regulations*
CRJ	Canadair Regional Jet aircraft
CRM	crew resource management
DC-9	McDonnell Douglas DC-9 aircraft
DHC-8	de Havilland DHC "Dash" 8 aircraft
EMB-145	Embraer EMB-145 aircraft
FAA	Federal Aviation Administration
F100	Fokker 100 aircraft
JAA	European Joint Aviation Authorities
Jetstream 3100	British Aerospace Jetstream 3100 aircraft
JCAB	Japanese Civil Aviation Bureau
MD-80	McDonnell Douglas MD-80 aircraft
NASA	National Aeronautics and Space Administration
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
PA	public address
POI	principal operations inspector
SDR	service difficulty report
SDR system	service difficulty reporting system of the FAA
SNPRM	supplemental notice of proposed rulemaking
TCCA	Transport Canada Civil Aviation
TSB	Transportation Safety Board of Canada
737	Boeing 737

Conversion Factors for the International System of Units (SI)

To convert from	**into**	**multiply by**
feet (ft)	meters (m)	0.3048
inches (in)	centimeters (cm)	2.54
miles (U.S. statute)	kilometers (km)	1.609344
pounds (lb)	kilograms (kg)	0.4535924

Executive Summary

Since its inception, the National Transportation Safety Board has been concerned about the evacuation of commercial airplanes in the event of an emergency. Several accidents investigated by the Safety Board in the last decade that involved emergency evacuations prompted the Safety Board to conduct a study on the evacuation of commercial airplanes.

Past research and studies on airplane evacuations have provided insight into specific factors, such as crewmember training and passenger behavior, that affect the outcome of evacuations; however, these studies had several limitations. First, in many of these studies, researchers did not examine successful evacuations; therefore, they were not always able to discuss what equipment and procedures worked well during evacuations. Second, only evacuations following serious accidents were examined and not evacuations arising from incidents. As a result, little is known about incident-related evacuations, which can provide insight into how successful evacuations can be performed and which can also identify safety deficiencies before serious accidents occur. Third, each study was a retrospective analysis of accident evacuations. This approach limited the researchers to information collected during the original investigation rather than collecting consistent information on a set of evacuations. Fourth, previous research on evacuations has not examined some of the most basic questions about how often commercial airplanes are evacuated, how many people are injured during evacuations, and how these injuries occur.

The Safety Board's study described in this report is the first prospective study of emergency evacuations of commercial airplanes. For the study, the Safety Board investigated 46 evacuations that occurred between September 1997 and June 1999 that involved 2,651 passengers. Eighteen different aircraft types were represented in this study. Based on information collected from the passengers, the flight attendants, the flight crews, the air carriers, and the aircraft rescue and firefighting units (ARFF), the Safety Board examined the following safety issues in the study:

- certification issues related to airplane evacuation,
- the effectiveness of evacuation equipment,
- the adequacy of air carrier and ARFF guidance and procedures related to evacuations, and
- communication issues related to evacuations.

As a result of this study, the Safety Board issued 20 safety recommendations and reiterated 3 safety recommendations to the Federal Aviation Administration.

Chapter 1

Introduction

Since its inception, the National Transportation Safety Board has been concerned about the evacuation of commercial airplanes in the event of an emergency. Two examples of severe accidents investigated by the Safety Board in the last decade illustrate some of the safety issues pertaining to emergency evacuations. These two severe accidents as well as the occurrence of evacuations in less severe accidents prompted the Safety Board to conduct a study on the evacuation of commercial airplanes.

On February 1, 1991, a USAir Boeing 737 (737) and a Skywest Metroliner collided on the runway at Los Angeles International Airport.[1] All passengers on the Skywest plane died on impact. None of the passengers on the 737 died on impact, but 19 passengers died from smoke inhalation and 1 died from thermal injuries. Of the 19 smoke-inhalation fatalities, 10 died in a queue to use the right overwing exit. The Safety Board discovered that two factors caused exit delays by several seconds: passengers' delay in opening the exit, and a scuffle between two passengers.

On November 19, 1996, United Express flight 5925, a Beechcraft 1900C, collided with a King Air at the airport in Quincy, Illinois, seconds after landing.[2] All 12 persons aboard the United Express flight and the 2 pilots on the King Air died from the effects of smoke and fumes from the postcrash fire even though they survived the impact. A pilot employed by the airport's fixed-base operator and a Beech 1900C-qualified United Express pilot who had been waiting for the flight to arrive were the first persons to reach the accident scene. They ran to the forward left side of the commuter's fuselage where the captain was asking them to get the door open. Both pilots attempted to open the forward airstair door but were unsuccessful. The Safety Board determined that the instructions for operating the door were inadequate for an emergency situation.[3] The Safety Board also examined the airport rescue and firefighting response to the accident. The first units of the Quincy Fire Department arrived on scene about 13 minutes after being notified of the accident. By then, both airplanes were completely engulfed by flames. The Safety Board determined that the lack of adequate aircraft rescue and firefighting services contributed to the severity of the accident and the loss of life.

The two accidents described above highlight just a few of the safety issues related to evacuation of commercial airplanes. In addition to accident investigations, studies conducted by the Safety Board, the Transportation Safety Board of Canada, the Federal Aviation Administration (FAA), and independent researchers have examined specific factors that affect the successful evacuation of commercial airplanes.[4] Although these studies provided insight into specific factors, such as

crewmember training and passenger behavior, that affect the outcome of evacuations, they had several limitations. First, in many of these studies, researchers did not examine successful evacuations; therefore, they were not always able to discuss what equipment and procedures worked well during evacuations. Second, only evacuations following accidents were examined and not evacuations arising from incidents. As a result, little is known about incident-related evacuations, which can provide insight into how successful evacuations can be performed and which can also identify safety deficiencies before serious accidents occur. Third, each study was a retrospective analysis of accident evacuations. This approach limited the researchers to information collected during the original investigation rather than collecting consistent information on a set of evacuations. Fourth, previous research on evacuations has not examined some of the most basic questions about how often commercial airplanes are evacuated, how many people are injured during evacuations, and how these injuries occur.

The Safety Board's study described in this report is the first prospective study of emergency evacuations of commercial airplanes. For the study, the Safety Board investigated 46 evacuations that occurred between September 1997 and June 1999 that involved 2,651 passengers. Eighteen different aircraft types were represented in this study. Based on information collected from the passengers, the flight attendants, the flight crews,[5] the air carriers, and the aircraft rescue and firefighting (ARFF) units, the Safety Board examined the following safety issues in the study: (1) certification issues related to airplane evacuation, (2) the effectiveness of evacuation equipment, (3) the adequacy of air carrier and ARFF guidance and procedures related to evacuations, and (4) communication issues related to evacuations. The study also compiled some general statistics on evacuations, including the number of evacuations and the types and number of passenger injuries incurred during evacuations.

Chapter 2 contains an overview of prior Safety Board activity in the area of emergency response and evacuations, information on other accident-based evacuation studies, and a review of laboratory research on evacuations. Chapter 3 contains a description of the study sources used by the Safety Board as well as an overview of the evacuation study cases. Chapter 4 discusses FAA requirements for evacuation demonstrations. Chapter 5 examines issues related to emergency exits. Chapter 6 discusses air carriers' guidance and procedures related to evacuations. Chapter 7 examines communication issues related to evacuations of commercial airplanes. The last sections of the report contain the Safety Board's findings and recommendations.

Chapter 2
Background

This chapter summarizes relevant accident-based and laboratory research related to airplane evacuations, including accident studies conducted in the United States, Canada, and the United Kingdom.

Overview of Safety Board Activity Related to Airplane Evacuation Issues

The Safety Board routinely examines cabin safety issues during its investigations of accidents. In addition, the Board has conducted several studies on airplane evacuation issues.

In 1974, the Board published a special study of the safety aspects of emergency evacuations from air carrier aircraft.[6] The study looked at 10 accidents involving emergency evacuations. As a result of the study, the Safety Board issued several recommendations that addressed the functionality of evacuation slides, the designation of flight attendants for specific duties during an evacuation, and the conveyance of safety information to passengers.[7]

In 1981, the Safety Board conducted a special study of cabin safety in large transport aircraft.[8] The study focused primarily on the inadequacy of existing crashworthiness regulations for seat and restraint systems and other cabin furnishings. One of the conclusions reached in that study was that failed seat systems and cabin furnishings trap occupants or become obstacles to rapid egress, thereby greatly increasing the potential for fatalities caused by postcrash factors such as fire and smoke inhalation.

In 1985, the Safety Board released two safety studies that addressed evacuation issues. The first study examined air carrier overwater emergency equipment and procedures.[9] The Safety Board studied 16 survivable water contact accidents that occurred between 1959 and 1984; most of these water accidents were inadvertent, occurred without warning, involved substantial airplane damage, rapid flooding of the cabin, and a high chance of injury. As a result of the study, improvements were made in life preserver design, packaging, accessibility, and ease of donning; crew postcrash survival training; and water rescue plans for airports near water.

Also in 1985, the Safety Board reviewed the methods used to present air carrier passengers with safety information.[10] That study represented the first systematic review of the content and methods used to provide safety information to passengers. It considered the merits and shortcomings of verbal briefings, demonstrations, safety cards, and videotaped briefings. The study was based on an analysis of 21 accident investigations in which passenger safety information briefings were a factor influencing survival. As a result of the study and in response to Safety Board recommendations, the FAA conducted research to determine the minimum level of acceptable comprehension of safety cards.

The Safety Board completed a special investigation report on flight attendant training in 1992.[11] That investigation found

that there was a lack of guidance to FAA inspectors regarding oversight of training, particularly flight attendant recurrent training. Some flight attendants were not proficient in their knowledge of emergency equipment and procedures—a situation compounded by a fact that most air carriers did not have standard locations for emergency equipment and most carriers did not limit the number of airplane types for which flight attendants were qualified. Another finding from the 1992 report that is particularly relevant to the current study was that many air carriers did not perform evacuation drills during recurrent training, and they were not required to conduct such training. As a result of that special investigation, several recommendations were issued to the FAA that were intended to improve flight attendant training and performance during emergency situations.

In addition to the studies summarized above, the Safety Board issued some earlier special studies that were generally more related to occupant survival.[12]

Other Studies and Research on Airplane Evacuation Issues

In 1995, the Transportation Safety Board (TSB) of Canada issued a study of air carrier evacuations that involved Canadian-registered airplanes or evacuations of foreign-registered airplanes that occurred in Canada.[13] The TSB conducted a postaccident examination of 21 evacuation events that had occurred between 1978 and 1991. As a result of the study, the TSB recommended protective breathing equipment for cabin crews, a reevaluation of escape slides, a review of the adequacy of public address systems, implementation of joint crew training, and detailed briefings to prepare passengers for unplanned emergencies.

The Japanese Civil Aviation Bureau (JCAB) created two task forces (one in 1993, another in 1996) to review emergency evacuations and develop countermeasures to reduce injury.[14] The 1993 task force examined five evacuations that occurred during the early 1990s. Based on that review, the group developed a standard package of information to improve passenger briefing systems. The JCAB requested and Japanese air carriers instituted the recommended changes. The second task force was prompted by a serious accident in 1996. That group recommended a systematic approach to the definition of exit seating and the responsibilities of the cabin crew and the passengers seated in exit rows. The group also recommended that travel group coordinators be prepared to perform special tasks in the event of an emergency.

Two research studies funded by the FAA's Civil Aeromedical Institute (CAMI) used data associated with precautionary evacuations that were acquired from airport management.[15] The first study looked at egress system use; during the 1988–1996 study period, there were 519 evacuations. The second study analyzed demographic and injury data from 1994 through 1996 and found 193 reported injuries (including 11 broken bones) from 109 emergency evacuations during that period.

Beginning in 1987, as a result of a 737 fire in Manchester, England, the Civil Aviation Authority (CAA) of the United Kingdom commissioned Cranfield University to conduct a number of experimental research studies on issues of cabin safety. In 1989, a study of passenger behavior in airplane emergencies examined the influences of cabin configuration on the rate at which passengers could evacuate the airplane.[16] Airplane cabin configurations were evaluated under conditions in which passengers were competing to evacuate (as would be expected in life-threatening accident situations) and under orderly conditions (for example, during aircraft certification testing). The results suggested that the bulkhead passageway should be wider than 30 inches and that the distance between overwing exit row seats should have a vertical seat projection of 13 to 25 inches.[17]

The CAA also commissioned Cranfield University to look at the effects of overwing exit weight and seating configuration on passengers' ability to operate a Type III overwing exit.[18] The results of that study [19] indicated that it was necessary to have a substantial reduction (50 percent) in hatch weight in addition to an increase in the available seat space in order to significantly reduce the time to operate the hatch. The combined benefits of reduced hatch weight and increased seat space were found to be more significant for females than males.

A third study conducted by Cranfield University [20] looked at the influence of the cabin crew on passenger evacuation during an emergency using both competitive and cooperative protocols. The FAA and the CAA jointly commissioned this study. The results showed that both the performance and number of cabin crewmembers significantly influenced evacuation rates and passenger behavior. The finding had implications for the selection and training of cabin crews. Additionally, evacuation times were faster from the forward exits than from the rear of the cabin.

In addition to the Cranfield studies, other organizations, including Transport Canada Civil Aviation (TCCA) and the Ente Nazionale Aviazione Civile, have studied human factor aspects of emergency evacuations.[21]

At a 1998 international conference on cabin safety research,[22] several papers were presented that focused on computer-based mathematical models describing aircraft evacuations.[23] Simulation models of evacuations are heavily dependent on real evacuation data, both in terms of quantifying development parameters and in terms of verifying the predictive accuracy of the model. For example, researchers at England's University of Greenwich[24] undertook an extensive data extraction and application project to derive the Aircraft Accident Statistics and Knowledge (AASK) database in order to develop airEXODUS.[25] The

researchers believe that such models are useful for design and development work, evaluation for certification, training, and for accident investigation.

Chapter 3

Study Sources and Overview of Evacuation Cases

To obtain information and data for this study, the Safety Board (1) conducted investigations of incidents/accidents that involved evacuations between September 1997 and June 1999, (2) surveyed all groups of participants in the evacuations, (3) conducted a review of the Board's accident/incident database for other occurrences of evacuations, and (4) examined incident reports made to the Aviation Safety Reporting System (ASRS) of the National Aeronautics and Space Administration (NASA). This chapter describes these four sources of information that were the basis for the study, and then provides an overview of the evacuation study cases.

Evacuation Investigations

Selection and Notification Policy

Operators of civil aircraft are required to notify the nearest National Transportation Safety Board field office following an evacuation of an airplane in which an emergency egress system is utilized (Title 49 *Code of Federal Regulations* (CFR) Part 830.5(a)(7)(iv)). The Safety Board accepted cases for the study that met this reporting criterion provided that the emergency egress system was used to remove passengers from the airplane for their safety. This was done to exclude cases in which passengers deplaned after an airplane became stuck after it came to a stop following landing.[26]

Basic Investigations

Safety Board investigators conducted two levels of investigation for the study: basic and detailed. Basic investigations were conducted for all evacuations that occurred in the United States that were reported to the Safety Board during the 16-month study period. Board investigators conducted the investigations through phone calls to air carrier and airport representatives.[27] Investigators traveled to the scene of the evacuation when the event followed an accident as defined by 49 CFR 830.2. The information collected during the basic investigations included airplane information, the number of passengers and crewmembers, weather, the cause of the evacuation, injury information, exits used, slide performance,[28] use of backup evacuation equipment, and any hindrances to the evacuation process.

The Safety Board included 46 basic investigations in the study (table 3–1, page 9); 42 of the 46 investigations were conducted sequentially from September 24, 1997, through January 24, 1999, the planned data collection period for the study. The four additional investigations, which were conducted after January 24, 1999, were included because they involved evacuations of special interest for the study. Two were of accidents that involved serious injuries during the evacuation. The third was of an evacuation that was videotaped from start to finish. The last investigation, of an evacuation that occurred June 22, 1999, was included in the study to support discussion on the conditions that affect a crewmember's decision to evacuate an airplane.

Detailed Investigations

Detailed investigations were conducted on a subset of the 46 evacuations; this subset of evacuations involved a fire, a suspicion of fire, or slide use. The Safety Board conducted a detailed investigation on 30 of the 46 evacuations included in this study. Detailed investigations were limited to evacuations from airplanes operated by U.S. air carriers; thus, the evacuation of two Canadian-operated airplanes and one Mexican-operated airplane in which there was fire or slide use received basic rather than detailed investigations.[29]

For the detailed investigations, Safety Board investigators collected the following information from each air carrier in addition to the basic information collected: (a) the safety briefing card(s), (b) the cabin diagram, (c) the flight crew manual pertaining to emergency evacuations, (d) the flight crew training materials and syllabi (initial and recurrent) pertaining to emergency evacuations, (e) the flight attendant manual pertaining to emergency evacuations, (f) the flight attendant training materials and syllabi (initial and recurrent) pertaining to emergency evacuations, (g) the flight crew evacuation checklists; (h) the flight attendant evacuation checklists, (i) flight crew statements, and (j) flight attendant statements. This information was received from all the air carriers involved in the 30 detailed investigations.

Surveys of Evacuation Participants

Questionnaires were developed and mailed to flight crews, flight attendants, ARFF units, and passengers who were involved in the 30 evacuations that received a detailed investigation. The crewmembers and passengers were asked what suggestions they would make to improve evacuations.

Flight Crews

Questionnaires sent to flight crews consisted of questions regarding general information about the evacuation, communication, procedures, environment, and equipment. Of 61 questionnaires mailed to flight crewmembers, 33 were returned to the Safety Board. The 33 responses were from pilots who represented 20 of the 30 evacuations in the study that

Table 3–1. Evacuations investigated by the National Transportation Safety Board for its 2000 study on emergency evacuation of commercial airplanes.

Case Number	Date of Evacuation	Location	Air Carrier	Aircraft Type	Number of Passengers
01	09/24/1997	Salt Lake City, Utah	Frontier Airlines	737	66
02	11/04/1997	Sterling, Virginia	Atlantic Coast Airlines	JS3100	2
03	11/07/1997	Charlotte, North Carolina	US Airways	F100	99
04	12/19/1997	San Francisco, California	Alaska Airlines	MD-80	69
05	12/25/1997	Eugene, Oregon	United Airlines	737	100
06	01/21/1998	Windsor Locks, Connecticut	Continental Express	ATR-42	36
07	01/22/1998	Peoria, Illinois	Trans States Airlines	ATR-72	10
08[a]	02/09/1998	Honolulu, Hawaii	Hawaiian Airlines	DC-9	139
09[a]	02/09/1998	Chicago, Illinois	American Airlines	727	115
10[a]	02/12/1998	Arlington, Virginia	Delta Air Lines	MD-88	49
11	02/22/1998	Lawton–Fort Sill, Oklahoma	American Eagle	Saab 340	3
12	03/27/1998	Chicago, Illinois	Air Canada	DC-9	27
13	03/30/1998	Fort Lauderdale, Florida	Royal Airlines	727	188
14	04/15/1998	Indianapolis, Indiana	Chautauqua Airlines	JS3100	6
15	04/18/1998	Worcester, Massachusetts	United Express	JS4100	29
16[a]	04/20/1998	Chicago, Illinois	American Airlines	27	149
17	04/23/1998	Atlantic City, New Jersey	US Airways Express	DHC-8	19
18[a]	04/25/1998	Detroit, Michigan	Trans World Airlines	DC-9	26
19[a]	05/26/1998	Indianapolis, Indiana	Northwest Airlines	DC-9	101
20[a]	06/04/1998	Huntsville, Alabama	Northwest Airlink	Saab 340	16
21[a]	06/06/1998	Evansville, Indiana	Trans States Airlines	JS4100	20
22[a]	06/28/1998	Newark, New Jersey	Continental Express	ATR-42	45
23	07/08/1998	Rochester, New York	Blue Ridge/Atlantic Coast	JS4100	10
24[a]	07/09/1998	San Juan, Puerto Rico	American Airlines	A300	234
25[a]	07/29/1998	Newark, New Jersey	Continental Airlines	737	109
26[a]	08/13/1998	Knoxville, Tennessee	Comair CRJ	46	
27[a]	08/27/1998	Phoenix, Arizona	American Airlines	MD-82	75
28[a]	09/10/1998	Newburg, New York	Atlantic Southeast Airlines	CRJ	30
29[a]	09/13/1998	Raleigh–Durham, North Carolina	US Airways Express	CRJ	40
30[a]	10/24/1998	San Juan, Puerto Rico	American Eagle	ATR-42	23
31[a]	10/30/1998	Shreveport, Louisiana	American Eagle	Saab 340	27
32[a]	11/01/1998	Atlanta, Georgia	Air Trans Airlines	737	100
33[a]	11/03/1998	Miami, Florida	Gulfstream	Beech 1900	19
34[a]	11/12/1998	Boston, Massachusetts	Allegheny Airlines	DHC-8	18
35[a]	12/26/1998	Dallas–Fort Worth, Texas	Delta Air Lines	MD-88	44
36	12/28/1998	Phoenix, Arizona	United Airlines	A320	145
37[a]	12/29/1998	White Plains, New York	Business Express	Saab 340	4
38	01/07/1999	San Diego, California	AeroMexico	MD-80	36
39[a]	01/08/1999	Covington, Kentucky	Comair	CRJ	5
40[a]	01/19/1999	St. Louis, Missouri	Trans States Airlines	ATR-72	17
41[a]	01/24/1999	Charlotte, North Carolina	American Airlines	F100	70
42[a]	01/24/1999	Newark, New Jersey	Continental Express	EMB-145	48
43[a]	02/17/1999	Columbus, Ohio	America West	A320	26
44[a]	05/08/1999	Jamaica, New York	American Eagle	Saab 340	27
45[a]	06/01/1999	Little Rock, Arkansas	American Airlines	MD-82	139
46[a]	06/22/1999	Scottsbluff, Nebraska	United Airlines	737	63

[a] The Safety Board conducted a detailed investigation of the evacuation.

received detailed investigations. Fifteen of the 20 respondents were the pilots-in-command at the time of the evacuation. For all but one of the respondents, this was their first evacuation of a commercial passenger aircraft.

Flight Attendants

Questionnaires sent to flight attendants consisted of questions regarding general information about the evacuation, personal injuries sustained, preflight safety briefing, communication, emergency exits, environment, passenger behavior, and training. Of 64 surveys mailed to flight attendants, 36 were returned to the Safety Board. This sample represented 18 of the 30 evacuations that received detailed investigations. Two of the 36 respondents reported being in a prior evacuation.

Aircraft Rescue and Firefighting Units

Questionnaires sent to ARFF unit chiefs consisted of questions regarding general information about the evacuation, communication, response, passenger behavior, and injuries. Of 30 questionnaires mailed to ARFF unit chiefs, 20 were returned to the Board, which represented 19 of the 30 evacuations that received detailed investigations.[30]

Passengers

Questionnaires sent to passengers consisted of questions regarding the preflight safety briefing, emergency exits, carry-on baggage, evacuation slides, passenger behavior, seat belts, communication, injury, postevacuation events, and personal information. Of 1,043 questionnaires mailed to passengers, 457 (44 percent) were returned to the Safety Board.[31] These passengers were from 18 of the 30 evacuations that received detailed investigations.[32]

Safety Board Accident/Incident Database

For the 10-year period from January 1990 through December 1999, the Safety Board recorded in its accident database 344 accidents involving Part 121 operations and an additional 461 incidents. Although the database does not currently have a specific code for evacuation events,[33] these events are often reported in the brief narrative that is included in each record. A search of the brief narratives for the past decade revealed 27 incidents and 21 accidents that included evacuation. Nine additional accidents/incidents that include evacuations are currently under investigation. Information from evacuation events contained in the Board's database was used, where appropriate, to provide context for data collected specifically for this study.

NASA Aviation Safety Reporting System

The Safety Board requested a search of the ASRS database[34] for all records pertaining to evacuations of airplanes operated by Part 121 air carriers. At the time of the search, the database contained 66,590 full-form reports, that is, reports that contained the reporter's narrative. The search yielded 202 reports that reference airplane evacuations between January 1995 and January 1999. The Safety Board reviewed these reports to support data collected for this study.

Overview of Evacuation Study Cases

General information about the 46 evacuations is presented in this section. Additional information will be presented in the appropriate chapters that follow. A brief description of the circumstances surrounding each evacuation is contained in appendix B.

Number of Evacuations

There were 42 evacuations during the 16-month study period in which the Safety Board recorded all evacuations. On average, an evacuation for the study cases occurred every 11 days. An average of 336,328 departures occurred every 11 days in 1998 by scheduled aircraft operating under Part 121.

Evacuation Cause

The most frequent event leading to an evacuation was an engine fire, accounting for 18 (39 percent) of the 46 evacuations included in the study cases; 15 involved an actual engine fire, and 3 involved a suspected but not actual fire. Eight of the 46 evacuations resulted from indications of fire in the cargo hold; none of these eight events, which occurred on regional airplanes, involved the presence of an actual fire. Gear failure and smoke in the cabin led to four evacuations each. All events causing the evacuations are listed in table 3–2 (page 11).

Aircraft Type

The evacuations investigated for this study occurred on a wide variety of aircraft. The Boeing 737 and Saab 340 were represented the most, with five evacuations for each type. The Canadair Regional Jet (CRJ) and McDonnell Douglas DC-9 were represented in four evacuations each. Only one wide-bodied airplane, the Airbus Industrie A300, was represented in the study cases. All 18 aircraft types involved in the study cases are listed in table 3–3 (page 11); a configuration of each type is presented in appendix C.

Injuries

The Safety Board obtained information on passenger injuries from two sources during the study. First, information provided by the air carrier during the basic investigations included injury information. Second, for the detailed investigations, the Safety Board also obtained injury information from passenger

Table 3-2. Events that led to the emergency evacuations in the 46 study cases.

Event	Number of cases
Engine fire/suspected engine fire	18[a]
Cargo smoke/cargo fire indication	8
Smoke in cabin	4
Gear failure	4
Smoke in cockpit	3
Overran runway	3
Bomb threat	2
Landed short of runway	1
Lavatory smoke warning	1
Baggage cart collision	1
APU torch[b]	1

[a] An engine fire was present in 15 of these cases.

[b] As described in Boeing's *Airliner* magazine (April/June 1992), "The APU provides both electrical power and bleed air for the air conditioning system and main engine starting. A torching start may result from excess fuel accumulation in the APU combustor assembly and exhaust duct. The torching start has a characteristic 'orange flash'."

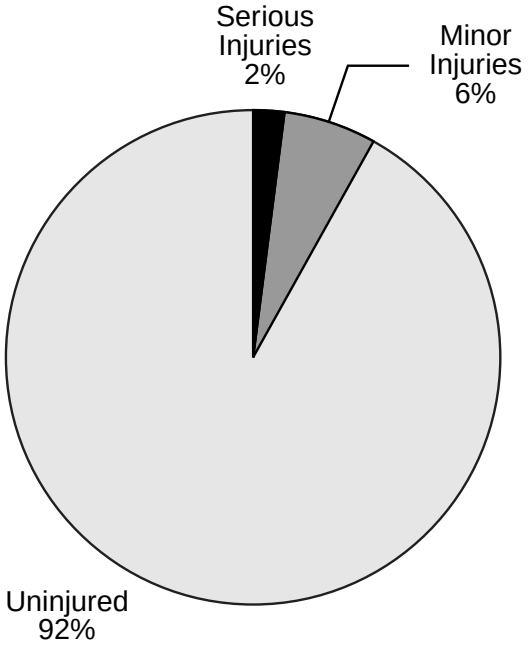


Figure 3–1. Percent of crew and passengers who sustained serious or minor Injuries In the 46 study cases.

questionnaires. In the 46 study cases, 92 percent (2,614) of the 2,846 occupants on board were uninjured, 6 percent (170) sustained minor injuries, and 2 percent (62) sustained serious injuries (figure 3–1).

In the 46 study cases, 2,651 passengers and 195 crewmembers evacuated from planes. There were no accident- or evacuation-related injuries in 28 of the cases (table 3–4, page 12). Accident- or evacuation-related injuries occurred in 18 of the cases; 208 passengers and 13 crewmembers were injured, and 10 passengers and 1 crewmember were killed (table 3–5, page 13). One of the cases (case 45, in Little Rock, Arkansas), accounted for the most injuries (65 minor, 45 serious) and all the fatalities (11). Two of the fatalities were evacuation-related: one passenger died from smoke inhalation in the rear of the airplane; a second passenger died 16 days after the accident

Table 3-3. Aircraft types involved in the 46 emergency evacuations investigated by the National Transportation Safety Board for its 2000 study.

Aircraft Type	Seating Capacity	Number of Evacuations
Boeing 737	108–189	5
Saab 340	20–39	5
Canadair Regional Jet	50	4
McDonnell Douglas DC-9	139	4
Avions de Transport Regional ATR-42	42–74	3
Boeing 727	70	3
British Aerospace Jetstream 4100	29	3
Airbus Industrie 320	164–179	2
Avions de Transport Regional ATR-72	64–74	2
de Havilland DHC-8	37	2
Fokker 100	107–119	2
British Aerospace Jetstream 3100	19	2
McDonnell Douglas MD-80	137–172	2
McDonnell Douglas MD-82	137–172	2
McDonnell Douglas MD-88	137–172	2
Airbus Industrie 300	220–375	1
Beechcraft 1900	19	1
Embraer EMB-145	55	1

Table 3-4 . Number of occupants injured in the 46 study cases, by case.[a]

Case Number	Date of Evacuation	Air Carrier	Uninjured	Minor	Serious	Fatal	Total
01	09/24/1997	Frontier Airlines	70	1	0	0	**71**
02	11/04/1997	Atlantic Coast Airlines	4	0	0	0	**4**
03	11/07/1997	US Airways	104	0	0	0	**104**
04	12/19/1997	Alaska Airlines	66	8	0	0	**74**
05	12/25/1997	United Airlines	105	0	0	0	**105**
06	01/21/1998	Continental Express	38	1	0	0	**39**
07	01/22/1998	Trans States Airlines	14	0	0	0	**14**
08[b]	02/09/1998	Hawaiian Airlines	144	0	0	0	**144**
09[b]	02/09/1998	American Airlines	99	23	0	0	**122**
10[b]	02/12/1998	Delta Air Lines	54	0	0	0	**54**
11	02/22/1998	American Eagle	6	0	0	0	**6**
12	03/27/1998	Air Canada	32	0	0	0	**32**
13	03/30/1998	Royal Airlines	177	14	3	0	**194**
14	04/15/1998	Chautauqua Airlines	8	0	0	0	**8**
15	04/18/1998	United Express	32	0	0	0	**32**
16[b]	04/20/1998	American Airlines	153	2	1	0	**156**
17	04/23/1998	US Airways Express	22	0	0	0	**22**
18[b]	04/25/1998	Trans World Airlines	30	1	0	0	**31**
19[b]	05/26/1998	Northwest Airlines	106	0	0	0	**106**
20[b]	06/04/1998	Northwest Airlink	19	0	0	0	**19**
21[b]	06/06/1998	Trans States Airlines	22	1	0	0	**23**
22[b]	06/28/1998	Continental Express	48	1	0	0	**49**
23	07/08/1998	Blue Ridge/Atlantic Coast	13	0	0	0	**13**
24[b]	07/09/1998	American Airlines	224	28	0	0	**252**
25[b]	07/29/1998	Continental Airlines	93	9	0	0	**102**
26[b]	08/13/1998	Comair	48	0	0	0	**48**
27[b]	08/27/1998	American Airlines	79	0	0	0	**79**
28[b]	09/10/1998	Atlantic Southeast Airlines	33	0	0	0	**33**
29[b]	09/13/1998	US Airways Express	43	0	0	0	**43**
30[b]	10/24/1998	American Eagle	22	3	0	0	**25**
31[b]	10/30/1998	American Eagle	30	0	0	0	**30**
32[b]	11/01/1998	Air Trans Airlines	94	11	0	0	**105**
33[b]	11/03/1998	Gulfstream	21	0	0	0	**21**
34[b]	11/12/1998	Allegheny Airlines	21	0	0	0	**21**
35[b]	12/26/1998	Delta Air Lines	49	0	1	0	**50**
36	12/28/1998	United Airlines	145	0	0	0	**145**
37[b]	12/29/1998	Business Express	7	0	0	0	**7**
38	01/07/1999	AeroMexico	42	1	0	0	**43**
39[b]	01/08/1999	Comair	8	0	0	0	8
40[b]	01/19/1999	Trans States Airlines	18	0	0	0	**18**
41[b]	01/24/1999	American Airlines	73	1	0	0	**74**
42[b]	01/24/1999	Continental Express	51	0	0	0	**51**
43[b]	02/17/1999	America West	31	0	0	0	**31**
44[b]	05/08/1999	American Eagle	29	0	1	0	**30**
45[b]	06/01/1999	American Airlines	24	65	45	11	**145**
46[b]	06/22/1999	United Airlines	63	0	0	0	**63**
Total			**2,614**	**170**	**51**	**11**	**2,846**

[a] Includes accident- and evacuation-related injuries.

[b] The Safety Board conducted a detailed investigation of the evacuation.

Table 3-5. Number of crew and passengers injured in the 46 study cases, by severity of injuries.[a]

Person on Board	Uninjured	Minor	Serious	Fatal	Total
Crew	181	9	4	1	**195**
Passenger	2,433	161	47	10	**2,651**
Total	**2,614**	**170**	**51**	**11**	**2,846**

[a] Includes accident- and evacuation-related injuries.

as a result of thermal injuries suffered while evacuating from an overwing exit. The type of injuries that occurred in this accident included smoke inhalation, burns, and fractures.

In addition to the serious injuries in the Little Rock case, six serious injuries occurred in four other cases (13, 16, 35, and 44). One passenger broke an arm jumping off a wing, and five passengers sustained broken ankles: one jumping out of an airplane exit that did not have a slide, one using an evacuation slide, and three sliding to the ground from the wing flap trailing edge.

Locations of Evacuations

As mentioned previously, the Safety Board accepted evacuation cases from throughout the United States and its territories. Every one of the evacuations in the study occurred on airport property. Chicago O'Hare and Newark International each had three evacuations occur on its property. Indianapolis, Charlotte, Phoenix, and San Juan had two evacuations each (see table 3–1).

Passenger Demographics

Only 17 of the 457 passenger respondents indicated being involved in a prior evacuation. The average age (mean and median) of passengers who responded to the Safety Board's questionnaire was 43 years old. Forty-five percent of these passengers were female. The passengers averaged 5 feet 7 1/2 inches in height and weighed an average of 165 pounds.[35]

Passengers reported on the injuries they sustained during their evacuations. No attempt was made to confirm each passenger's self-assessment. There appeared to be no relationship between age and the injury incurred: 34 percent of the respondents older than the median age of 43 reported injuries whereas 35 percent younger than the median reported injuries. Reports of injuries were similar (39 percent) for passengers older than 60 years.

Despite the lack of differences with regard to injury, the older passengers (older than 43) had different perceptions of how their physical abilities affected their evacuation. Older passengers were more likely to disagree with statements that their physical size or condition assisted their evacuation [$\chi^2(4) = 12.44$, $p < 0.05$] (figure 3–2, page 14). Further, they tended to disagree with statements that indicated their age assisted them (figure 3–3, page 14). Overall, older passengers were no more likely to sustain an injury, but they perceived their condition and age to hinder their evacuation.

Although age apparently had no effect on injuries, the injury rate for females was greater than the injury rate for males. Thirty-eight percent (64) of the female respondents reported injuries whereas 27 percent (54) of the male respondents reported injuries [$\chi^2(1) = 5.80$, $p < 0.05$]. Yet, perceptions of how physical size, condition, and age affected their evacuation were the same for males and females.

The Safety Board surveyed passengers involved in the study evacuations on the competitive behaviors they exhibited or observed during evacuations to gain insight on how often passengers exhibit these behaviors. Passengers were asked to rate how much they agreed with the statement that passengers were cooperative during the evacuation. Seventy-five percent (331) of the passengers who responded to the statement agreed or strongly agreed with the statement, 13 percent (56) disagreed or strongly disagreed, and 12 percent (53) were neutral. The majority (62 percent, or 33) of the 56 passengers who indicated uncooperative behavior were involved in three evacuations (cases 16, 24, and 32). These cases included evacuations involving an auxiliary power unit [36] (APU) torching, an engine fire, and an airplane that overran the runway and impacted a grass embankment. Although these three cases included flames or substantial airplane damage, the severity of an event is not necessarily indicative of uncooperative behaviors. In the most serious accident in the study (case 45), only 6 percent of the passengers indicated disagreement with the statement that passengers were cooperative.

The competitive behaviors passengers reported seeing included pushing, climbing seats, and disputes among passengers. These behaviors were reported in many of the study cases, but not all. Overall, 12.1 percent (53) of the responding passengers reported that they climbed over seats whereas 20.4 percent (90) observed someone climbing seats. Many (80 percent, or 42) of the passengers who indicated that they climbed over seats were from case 45, the most serious accident in the study and which involved several broken seats. Of all the passengers who responded to the questionnaire, 29 percent (129), reported seeing passengers pushing; 18.7 percent (83) indicated actually being pushed, and 5.6 percent (25) indicated pushing another passenger. Slightly more than 10 percent (46) of the responding passengers reported seeing passengers in disputes with other passengers.

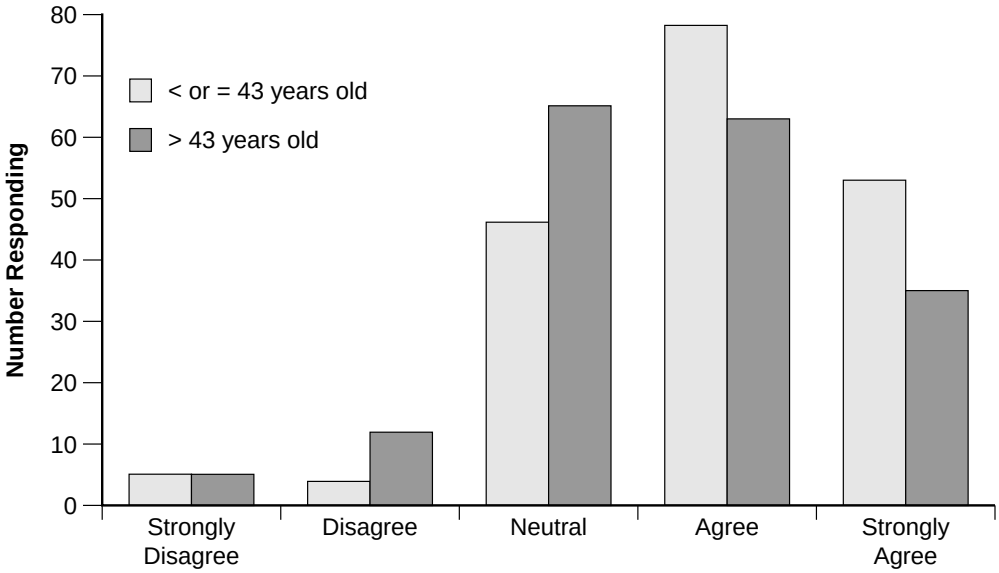


Figure 3–2. Passenger agreement with the statement that their physical condition assisted their evacuation.

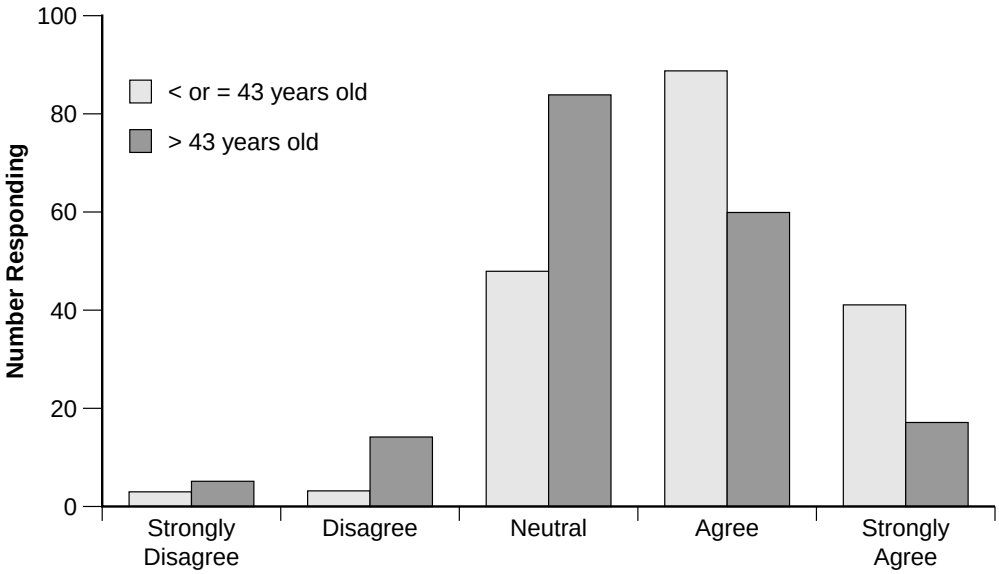


Figure 3–3. Passenger agreement with the statements that their age assisted their evacuation.

Aircraft Rescue and Firefighting Response

Aircraft rescue and firefighting (ARFF) units responded in 42 of the 46 evacuations investigated in the study. The Safety Board examined the ARFF unit's role in these evacuations through questionnaires sent to the unit's chief. In addition, the Safety Board asked flight crews about their interaction with the ARFF unit that responded to the evacuation.

Federal regulations determine the size of ARFF support at each certificated airport (14 CFR 139.315). The length of aircraft serving the airport determines the ARFF Index for an airport. For the study, questionnaires were received from eight Index E airports (which are defined by serving airplanes at least 200 feet long), four Index D airports (airplanes 159–200 feet), four Index C airports (airplanes 126–159 feet), and three Index B airports (airplanes 90–126 feet).[37] The Safety Board did not receive information from any Index A airports (airplanes less than 90 feet).

In 15 of the 46 cases, the ARFF unit was notified of the event via the air traffic control (ATC) tower crash phone. In four

cases (21, 26, 33, 46), the unit received advanced notification of the incident and emergency equipment was waiting for the incoming airplane.[38] In responding to the scene, ARFF units indicated that ATC was effective in clearing traffic for the response and keeping traffic from the scene. The first ARFF vehicles arrived in under 2 minutes and 10 seconds for all cases except the McDonnell Douglas MD-82 accident in Little Rock (case 45), in which low visibility, among other factors currently being investigated by the Safety Board, delayed arrival of the ARFF vehicles to over 10 minutes. ARFF personnel assisted passengers in evacuating the airplane in 14 cases by opening doors, helping passengers out of exits, helping passengers at the bottom of evacuation slides, directing passengers away from the airplane, and treating injured passengers and crewmembers. In cases 18, 24, and 30, the ARFF crew extinguished the fire during the evacuation.

Chapter 4

FAA Requirements for Evacuation Demonstrations

Evacuation demonstrations are FAA-required tests to evaluate the emergency egress capabilities of airplanes. The requirement began in 1965 as a method of evaluating air carriers' emergency training programs. In 1967, the requirement was expanded to include airplane manufacturers. Since then, the specific requirements have undergone many changes (table 4–1, page 16). Currently, the FAA requires that these tests be done by manufacturers of airplanes certified to Part 23 standards,[39] and by manufacturers of airplanes certified to Part 25 standards if the airplane contains 44 or more passenger seats. In addition, the FAA requires air carriers operating under Part 121 to conduct a modified evacuation demonstration on each type of airplane in their fleet that has 44 or more passenger seats to satisfy operating certificate requirements.

Type Certification Requirements for Airplane Manufacturers

The FAA may require airplane manufacturers to perform full-scale evacuation demonstrations in order to acquire type certification for new airplanes, and also for derivative models of currently certificated airplanes when the cabin configuration is unique or when a significant number of passenger seats have been added. A full-scale demonstration is a simulated emergency evacuation in which a full complement of passengers deplane through half of the required emergency exits, under dark-of-night conditions (14 CFR 25.803). A trained crew directs the evacuation, and the passengers are required to meet certain age/gender specifications (14 CFR Part 25, Appendix J).[40] In order for manufacturers to pass the full-scale demonstrations, all passengers and crew must evacuate the aircraft and be on the ground in 90 seconds or less.

The full-scale demonstration determines certain operating requirements that must be met by all operators of the airplane type. For example, the number of passenger seats on the airplane during the demonstration dictates the maximum number allowable on any subsequent airplane of the same type. Similarly, the interior configuration cannot be altered significantly from the one used for the demonstration. In addition, the number and placement of flight attendants within the cabin, as well as the training program used to train them for the demonstration, cannot be unilaterally altered by subsequent operators. If a manufacturer or operator wants to change any of these characteristics, they must appeal to the FAA, and they may be required to perform another full-scale or partial evacuation demonstration to show that the same level of safety is maintained.

In recent years, full-scale demonstrations have been criticized by airplane manufacturers because of potential danger to the passenger participants. Although the potential for injury is real, the only published research on injuries to participants has indicated that most injuries incurred in the demonstrations are minor.[41] The Safety Board notes, however, that serious injuries do occur, and a serious injury was sustained during the MD-11 evacuation certification demonstration on October 26, 1991. In correspondence to the FAA, the Safety Board stated that full-scale demonstration provides a method to identify strengths and weaknesses in the evacuation capabilities of an airplane before it goes into service.[42] The Safety Board further stated that as a result of past demonstrations, inadequate evacuation slide designs have been identified and subsequently remedied, and the number and locations of cabin crew have been altered.

In lieu of the full-scale demonstrations, the FAA sometimes allows a manufacturer to use data from previous demonstrations or a combination of data and subsystem test results to meet certification requirements. This analytical method uses averages of passenger flow rates through exits, slide preparation times, and exit opening times to calculate the number of passengers that should reasonably be expected to evacuate the airplane within the 90-second time limit. Historically, this method to meet certification requirements was allowed by the FAA only for passenger seating capacity increases of 5 percent or less; however, an FAA policy change in 1998 removed the 5-percent limitation.

Subsystem tests are often required by the FAA when previously untested apparatus (such as a new evacuation slide design) is added to an existing or derivative model of airplane. The subsystem tests resemble full-scale evacuation demonstrations but are more limited in scope. The data from subsystem tests are often used in conjunction with known data for an evacuation analysis.

Researchers have proposed using computer programs to simulate the dynamics of emergency evacuations as a method of satisfying evacuation demonstration requirements.[43]

Table 4–1. Highlights of changes made by the Federal Aviation Administration to the requirements for evacuation demonstrations.

Source of Change	Effective Date	Description of Change
Amendment 121–2[a]	March 3, 1965	Required air carriers operating under 14 *Code of Federal Regulations* Part 121 to conduct full-scale evacuation demonstrations using half the required floor level airplane exits in 120 seconds or less. Applicable for initial introduction of aircraft type and model into service, a major change in interior configuration, or an increase in passenger capacity equal to or exceeding 5 percent.
Amendment 25–15	October 24, 1967	Required Part 25 aircraft manufacturers to conduct a full-scale evacuation demonstration for aircraft with 44 seats or more in 90 seconds or less. Did not require repeated demonstration for configuration changes, and allowed use of analysis in lieu of actual demonstration for capacity increases not exceeding 5 percent.
Amendment 121–30	October 24, 1967	Revised Part 121 to reduce demonstration time limit to 90 seconds for operators.
Amendment 25–46	December 1, 1978	Revised Section 25.803 to allow use of methods other than an actual demonstration to show evacuation capability. Replaced existing Part 25 demonstration conditions with conditions that would satisfy requirements in both Parts 25 (airworthiness and certification) and 121 (operational). Removed the limitation about 5-percent capacity increases for using analysis. Required approval of the FAA Administrator for an operator to use analysis.
Amendment 121–149	December 1, 1978	Revised Part 121 to accept the results of demonstrations conducted by airplane manufacturers. Allowed operators to use partial evacuation demonstrations to satisfy training requirements.
FAA Advisory Circular 25.803–1	November 13, 1989	Presented detailed instructions on fulfilling requirements for evacuation demonstrations and criteria for indicating when the demonstrations must be conducted.
Amendment 25–72	August 20, 1990	Placed the demonstration conditions from Section 25.803(c) into Appendix J of Part 25.
ARAC[b] Performance Standards Working Group Report, "Emergency Evacuation Requirements and Compliance Methods that Would Eliminate or Minimize the Potential for Injury to Full Scale Evacuation Demonstration Participants"	1993	Background material for FAA Policy ANM 98–2.
Amendment 25–79	September 27, 1993	Revised Appendix J of Part 25 to change the age/gender mix, to allow ramps or stands to be used to help participants off wings, and to prohibit flight crew from taking an active role in the demonstration.

Table 4–1. Highlights of changes made by the Federal Aviation Administration to the requirements for evacuation demonstrations. (Continued)

Source of Change	Effective Date	Description of Change
FAA Policy ANM 98–2	March 17, 1998	Emphasized the use of analysis instead of full-scale evacuation demonstrations for type certification of aircraft in order to decrease injuries to participants.
Advisory Circular 25.803 1A	August 31, 1998 (Draft)	Removed the requirement to conduct a full-scale demonstration when there is 5-percent or greater increase in passenger seats on a derivative aircraft model. Removed specific language that stated the conditions for when a full-scale demonstration should be conducted. Expanded the section on presentation of data when using analysis and testing for certification.
FAA Technical Standard Order C-69c, "Emergency Evacuation Slides, Ramps, Ramp/Slides, and Slide/Ramps" (new version)	August 18, 1999	Required escape slide manufacturers to conduct slide rate tests under conditions similar to those required by Part 25.803 and AC 25.803 1A. Increased minimum passenger slide rate from 60 passengers per minute per lane to 70.

[a] Amendment 121–2 is the first amendment pertinent to the 1965 regulations.

[b] An ARAC (Aviation Rulemaking and Advisory Committee) is a group of industry and government representatives convened by the FAA to facilitate the FAA's rulemaking process. The group is charged with examining issues pertinent to a particular area of concern and developing recommendations for advisory material and/or revisions to current regulations.

Computer modeling attempts to integrate the complicated interactions of passengers and their individual behaviors with the physical attributes of the airplane cabin. Sets of algorithms are used to impose "characteristics" such as age, mobility, gender, and personality onto the programmed "passengers," which affect their movement within the cabin. Included in the program are physical attributes of the cabin such as seat pitch, aisle width, exit size and availability, smoke, fire, and other characteristics that influence the passengers' movements. Any or all of these variables, if data are available, can be varied by the programmer to examine their effects on the evacuation.

The researchers who proposed using computer programs to simulate evacuations have also suggested that using computer modeling techniques offers several advantages over full-scale demonstrations. For instance, it is more economical, from a data gathering standpoint, to develop a computer program that can be run many times than it is to hire "passengers" to participate in singular evacuation demonstrations. Moreover, the modeling program can easily be altered to examine different passenger behaviors or cabin configurations. And, modeling eliminates any risk of personal injury to participants of evacuation demonstrations.

Computer modeling is not recognized by the FAA as an allowable method of demonstrating evacuation capability of airplanes. Although it is generally accepted by industry that computer modeling will have a role in evacuation certification in the future, more traditional methods will continue to be used until the models are validated.

Operating Certificate Requirements for Air Carriers

Air carriers are required to obtain operating certificates from the FAA in order to begin scheduled passenger transportation. Among the many requirements an air carrier must fulfill in order to receive an operating certificate is evidence that its crew training program sufficiently prepares crewmembers to evacuate passengers in an emergency.

Since 1965, the FAA has required air carriers to demonstrate the evacuation efficacy of their flight attendants upon initial startup of the company, or when a new type of aircraft is introduced into service. Originally, this was accomplished through a full-scale demonstration, similar to the ones described above. In 1978, the regulations were modified to allow partial (or mini) evacuation demonstrations to be used as evidence of adequate crewmember training for evacuations. A partial demonstration differs from a full-scale demonstration in that there are no passengers on board the airplane during the demonstration, and the demonstration must be accomplished in 15 seconds or less. To successfully accomplish a partial demonstration, trained flight attendants

must, from a start signal, get up from their seats, assess conditions, open their assigned exits if appropriate, and inflate the evacuation slides within the allotted times. Ostensibly, the partial demonstration provides evidence that the flight attendant training program effectively prepares the flight attendants to respond to an emergency situation, that the airplane configuration is functional for an evacuation, and that the equipment is reliable. As with full-scale demonstration, specific characteristics such as the minimum number of flight attendants and their duty stations within the cabin, the number of passenger seats, and portions of the training program cannot be altered by the operator after the partial demonstration has been accomplished. To alter any of these factors, the air carrier would have to perform another demonstration.

Safety Oversight in the Evacuation Demonstration Requirements

Although Parts 25 and 121 outline requirements for airplane manufacturers and operators to evaluate the evacuation capabilities of airplanes and crewmembers, these regulations apply only to airplanes having 44 or more passenger seats. Therefore, it is possible for a passenger to board an airplane that had no tests of the evacuation efficacy of the airplane or its crew (table 4–2). In the study cases, 13 of the 46 airplanes (transporting 200 total passengers) were not required to undergo an evacuation demonstration.[44] Similarly, an airplane that is type-certificated under Part 23 is required to perform a full-scale evacuation demonstration, but if the airplane is operated under Part 135, or under Part 121 and has fewer than 44 passenger seats, the FAA does not require the air carrier to perform a partial evacuation demonstration to obtain an operating certificate.

Commercial airplanes with fewer than 20 seats are not required to operate with flight attendants on board. Therefore, the pilots have the dual role of flying the airplane and evacuating passengers when it becomes necessary. However, there is no FAA requirement to perform a partial evacuation demonstration on these airplanes in order to assess the evacuation training of the pilots. The Safety Board concludes that the FAA does not evaluate the emergency evacuation capabilities of transport-category airplanes with fewer than 44 passenger seats or the emergency evacuation capabilities of air carriers operating commuter-category and transport-category airplanes with fewer than 44 passenger seats.

In its 1994 study on commuter airline safety,[45] the Safety Board stated that the standards for safety should be based on the characteristics of the flight operations, not the seating capacity of the airplane, and that passengers on commuter airplanes should be afforded the same regulatory safety protection granted to passengers flying on Part 121 airplanes. Consequently, the Safety Board recommended that the FAA

Revise the Federal Aviation Regulations such that:

- All scheduled passenger service conducted in aircraft with 20 or more passenger seats be conducted in accordance with the provisions of 14 CFR Part 121. (A-94-191)

- All scheduled passenger service conducted in aircraft with 10 to 19 passenger seats be conducted in accordance with 14 CFR Part 121, or its functional equivalent, wherever possible. (A-94-192)

The Safety Board is concerned that existing regulations which exempt certain airplanes and operations because of passenger seating capacity is not consistent with the goal of providing "one level of safety" for all passenger-carrying commercial airplanes.[46] The Safety Board further concludes that in the interest of one level of safety, all passenger-carrying commercial airplanes and air carriers should be required to demonstrate emergency evacuation capabilities. Therefore, the Safety Board believes that the FAA should require all newly certificated commercial airplanes to meet the evacuation demonstration requirements prescribed in 14 CFR Part 25, regardless of the number of passenger seats on the airplane.

Table 4-2. Overview of evacuation demonstrations required for aircraft type certification and air carrier operating certification.[a]

Airplanes Certified to the Standards in—	Air Carriers Operating Under—	Number of Passenger Seats on Airplane	Full-scale Demonstration Required (of Manufacturer)[b]	Partial Demonstration Required (of Air Carrier)
Part 23 (commuter-category airplanes)	Part 135	Fewer than 44	Yes	**No**
Part 23	Part 121	Fewer than 44	Yes	**No**
Part 25 (transport-category airplanes)	Part 135	Fewer than 44	**No**	**No**
Part 25	Part 121	Fewer than 44	**No**	**No**
Part 25	Part 121	44 or more	Yes	Yes

[a] Details of evacuation demonstration requirements for airplane manufacturers and air carriers are contained in Title 14 *Code of Federal Regulations* Parts 23, 25, 135, and 121.

[b] In lieu of the full-scale demonstrations, the Federal Aviation Administration sometimes allows a manufacturer to use data from previous demonstrations or a combination of data and subsystem test results to meet certification requirements.

Also, the FAA should require all commercial operators to meet the partial evacuation demonstration requirements prescribed in 14 CFR Part 121, regardless of the number of passenger seats on the airplane.

Chapter 5

Exits

Regulations for emergency exits are contained in 14 CFR 25.807. The exits range from the largest, a "Type A" (a floor level exit door with dimensions of at least 42 inches wide and 72 inches high), to the smallest, a "Type IV" (an overwing exit with dimensions of at least 19 inches wide and 26 inches high). Figure 5–1 shows "Type III" exits (an exit, typically overwing, with dimensions of at least 20 inches wide and 36 inches high). The cases in the evacuation study included a variety of the exit types.[47]

Federal regulations further mandate that "the means of opening emergency exits must be simple and obvious and may not require exceptional effort" (14 CFR 25.809(c)). Crewmembers are required to operate each exit type on their aircraft during initial training and every 2 years thereafter (14 CFR 121.417). Passengers will likely never have occasion to open an airplane emergency exit prior to an actual evacuation.

Access to Exits

Exit location, aisle width, bulkhead width, and seating density are factors in the design of an airplane that can influence passengers' access to exits and, consequently, the success of an emergency evacuation. Past research has referred to these as configurational factors.[48] Factors such as aisle width or exit location are governed by Federal regulations to ensure passenger safety. Past evacuations have prompted changes to some of these regulations. The report of a 1985 evacuation of a 737 in Manchester, England, indicated two configurational factors that needed to be reexamined: bulkhead passageways and seat pitch in exit rows. Passenger reports of getting stuck at the bulkhead and exit rows led to CAA research that found that both passageways needed widening.

In 1989, CAMI conducted evacuation trials to examine the effects of exit path width—the distance between the forward-most point on an exit row seat and the aft-most point on the seat directly in front of it (figure 5–2, page 20)—on the evacuation rate at Type III overwing exits.[49] Participants were required to evacuate through a Type III exit or open a Type III exit hatch using four different seating conditions: a 6-inch unobstructed passageway, a 10-inch unobstructed passageway, a 20-inch passageway with 5 inches of the seat encroaching on the exit, and a central seat placement with the outboard seat removed. The researchers reported that egress times were quicker for the seating conditions using the 20-inch passageway and the outboard seat removed than were egress times using the 6-inch passageway. However, the various exit widths did not affect exit hatch removal time. As a result of these CAMI trials and the 1991 accident in Los Angeles (described in chapter 1 of this report), the FAA issued a notice of proposed rulemaking (NPRM) that required air carriers to increase the exit path width in exit rows from 6 inches to 20 inches. The

Figure 5-1. Type III Exits.

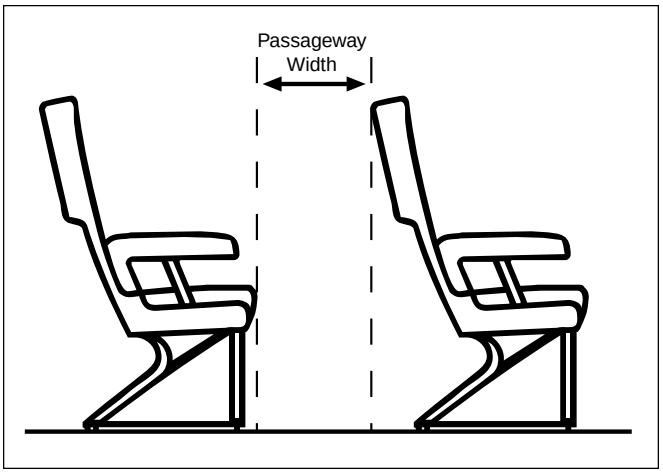


Figure 5–2. Type III exit row passageway width.

Safety Board commented in support of this proposed rule change in a letter dated October 8, 1991.

Industry comments questioning the need for such a substantial change led CAMI to conduct a study in 1992 to examine alternatives to the proposed requirement.[50] In that CAMI study, participants were required to exit through a Type III overwing exit using four different seating conditions: a 10-inch unobstructed passageway with the seat in front of the exit row displaced forward 15°, a 10-inch unobstructed passageway with two seats instead of three seats, a 20-inch passageway with 5 inches of the seat encroaching on the exit, and three 6-inch passageways leading to two exits in which the outboard seats closest to the two exits were removed. The researchers reported that total egress time, hatch opening time, and individual egress times were fastest for evacuations to a single exit using the 20-inch passageway. However, no inferential statistics were reported to support the claims that a 20-inch passageway provided for the best performance.

Nevertheless, based upon these studies and comments received, the FAA published the final rule on May 4, 1992 (14 CFR 25.813, included in appendix D of this report), which increased the exit path width to 20 inches. In response to the rule, the Air Transport Association and several air carriers petitioned for an exemption to the rule indicating that some distance between a 6-inch exit path and a 20-inch exit path might provide for equivalent performance to that using a 20-inch pathway. To examine this possibility, CAMI conducted another series of trials in 1995 to examine the effects of five exit path widths and three seat encroachments on egress through Type III overwing exits.[51] The researchers concluded that narrow egress paths (6 and 10 inches) result in slower egress than wider egress paths (13, 15, and 20 inches). Unlike the previous CAMI studies on exit path width, this study did not measure exit hatch removal times for the various seating conditions. Further, the study included a flight attendant just forward of the overwing exit, a situation not examined in the previous studies or likely to occur in an emergency evacuation. As a result of the flight attendant giving instructions not included in the study protocol, several trials involving older participants were dropped; however, no mention is made of how many trials were dropped and from which seating conditions. Finally, participants in this experiment evacuated through the Type III exit 30 times during the course of the experiment. This number represents a dramatic increase over previous studies in which each participant performed in four evacuations, and it may not reflect the performance of a novice evacuee in an actual emergency evacuation. Based upon this research, the FAA granted air carriers an exemption to the 20-inch width requirement and issued an NPRM on January 30, 1995, proposing an amendment to the rule that would reduce the exit path width in exit rows to 13 inches.[52]

The Safety Board is concerned that the CAMI research used as a basis for the proposed rule change contains a number of significant design flaws—such as the use of a flight attendant at the exit and no consideration given to exit hatch removal times—that bring into question the applicability of the research to an actual emergency evacuation situation. Further, the Board is unaware of any other study that examines both exit hatch removal and egress speed and compares the 20-inch exit path width with the proposed 13-inch width. The Safety Board concludes that adequate research has not been conducted to determine the appropriate exit row width on commercial airplanes. Therefore, the Safety Board believes that the FAA should conduct additional research that examines the effects of different exit row widths, including 13 inches and 20 inches, on exit hatch removal and egress at Type III exits. The research should use an experimental design that reliably reflects actual evacuations through Type III exits on commercial airplanes. The Safety Board also believes that the FAA should issue, within 2 years, a final rule on exit row width at Type III exits based on the research just described.

Accident severity will also play a role in how easily passengers will be able to reach an exit. Severe damage to the fuselage, for example, can cause interior furnishings to be dislodged and become obstacles for passengers attempting to exit an airplane. For the study cases, questionnaire statements from passengers and flight attendants provided insight on how easily passengers were able to access exits and what interior furnishings impeded their access.

In the MD-82 accident in Little Rock, Arkansas (case 45), the crash forces caused seats to break free from their seat tracks and block aisles. In the forward portion of the cabin, passengers had to navigate around fallen overhead bins and across a severely deformed floor. Fortunately, the crash caused several gaps in the fuselage that passengers were able to use for egress. As seen in figure 5–3 (page 21), the crash forces split the cabin in two separate sections divided at the wing.

In the 727 accident in Chicago (case 9), the aircraft landed short of the runway, striking a light structure and the runway

Figure 5–3. View of the McDonnell Douglas MD-82 accident scene that involved evacuation on June 1, 1999, Little Rock, Arkansas (case 45).

threshold. A liferaft ceiling panel door[53] fell open, blocking the main aisle to the L1 exit.[54] The flight attendant assigned to the L1 exit decided not to use the exit because the ceiling panel blocked access to the exit. Passengers evacuated through the R1, overwing, and L2 exits (figure 5–4).

Based on the circumstances of the evacuation in this accident, the Safety Board recommended that the FAA

> Identify all airplanes operated under Title 14 *Code of Federal Regulations* Part 121 with liferaft ceiling

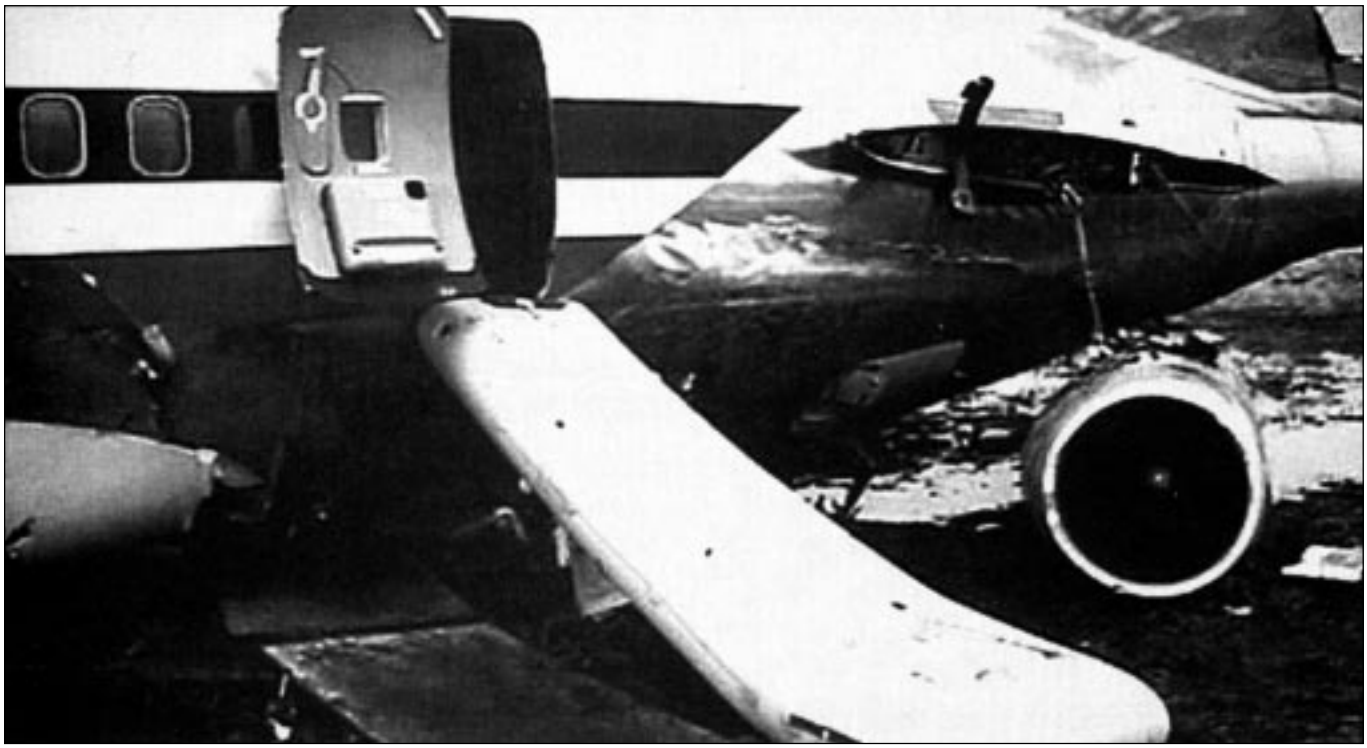


Figure 5–4. View of a slide used in the Boeing 727 evacuation on February 9, 1998, Chicago, Illinois (case 9).

stowage compartments or compartments that formerly stored liferafts that open downward and issue an airworthiness directive to limit the distance that those compartments can open. (A-99-10)[55]

The FAA responded favorably to this recommendation by requesting that its aircraft certification office identify airplanes affected by this recommendation and by sending a request to the applicable manufacturers for information regarding the installation of liferaft ceiling stowage compartments. On February 3, 2000, Safety Recommendation A-99-10 was classified "Open—Acceptable Response." The Safety Board will continue to monitor the FAA's progress on this issue.

The Safety Board asked passengers and flight attendants in the 30 cases receiving detailed investigations to indicate from a list what hindered the evacuation. The majority of responses came from the Little Rock and Chicago cases described above; of the 46 study cases, the airplanes in those two cases experienced the most severe crash forces. Five passengers and 1 flight attendant mentioned bulkheads, 39 passengers and 1 flight attendant mentioned broken interiors, 16 passengers mentioned overhead bins, and 16 passengers mentioned the seatback in front of them.

In the 28 other cases for which questionnaires were distributed, one flight attendant mentioned that her seat obstructed the evacuation, and two other flight attendants reported galley items obstructing passenger evacuation. Eleven passengers indicated that the seatback in front of them slowed their movement, six passengers mentioned overhead bins, five passengers mentioned the bulkhead, and one passenger mentioned the aisle width.

In general, passengers in the Safety Board's study cases were able to access airplane exits without difficulty, except for the Little Rock, Arkansas, accident that occurred on June 1, 1999, in which interior cabin furnishings became dislodged and were obstacles to some passengers' access to exits.

Emergency Exit Lighting

Federal regulations require that an emergency lighting system, independent of the main lighting system, must be installed on airplanes. The emergency lighting system must include the following: illuminated emergency exit marking and locating signs, sources of general cabin illumination, interior lighting in emergency exit areas, floor proximity escape path marking, and exterior emergency lighting (14 CFR 25.812). Many of these requirements were the result of previous Safety Board recommendations that addressed emergency exit lights for utilization during darkness or smoke (A-72-133), improved visual guidance to emergency exits (A-73-53), emergency lighting for passenger evacuation from smoke-filled cabins (A-83-79), and requirements for all emergency lighting to be illuminated during evacuations (A-90-95). All of these safety recommendations have been classified "Closed—Acceptable Action" as a result of positive action by the FAA.

The Safety Board assessed the effectiveness of the emergency lighting systems in the study cases by reviewing crew statements from returned questionnaires. Of the 36 flight attendants who responded, there were only two reports of failed lights, both from flight attendants in the Little Rock accident.[56] Further, 5 flight crewmembers and 10 flight attendants reported that emergency lighting systems assisted evacuations in which visibility was restricted. All of these crewmembers were involved in five night evacuations. The Safety Board concludes that emergency lighting systems functioned as intended in the 30 evacuations cases investigated in detail.

Floor Level Exits

Floor level exits were used in all 46 evacuations; 67 such exits were opened during these evacuations. In the questionnaires, the Safety Board asked flight attendants, flight crews, and passengers about the ease of opening floor level exit doors.

Only two flight attendants reported any difficulty with opening floor level exit doors. These two attendants were on the MD-82 that incurred severe structural deformation when it crashed in Little Rock (case 45). One flight attendant reported that both of the forward floor level exit doors were inoperable because of crash forces. The second flight attendant reported that the floor level exit door leading to the tailcone exit could not be opened initially because of a deformation in the floor of the airplane. The door was eventually opened through the combined efforts of the flight attendant and two male passengers.

One flight attendant, in a postincident statement following the evacuation of a 737 in Eugene, Oregon (case 5), reported being unable to open her floor level exit door. She explained how the exit door operated to a passenger, and the passenger proceeded to open the door. A second flight attendant reported difficulty keeping a floor level exit door latched open during the evacuation of another 737, in Salt Lake City, Utah (case 1).

None of the flight crewmembers indicated any difficulty in opening or using floor level exit doors.

Seven passengers reported that they had difficulty attempting to open an airplane floor level exit door during their evacuation: five were involved in the evacuation of the MD-82 in Little Rock, Arkansas (case 45); one was involved in the evacuation of an A300 in San Juan, Puerto Rico (case 24); and the last was in the evacuation of a 727 in Chicago, Illinois (case 16). Three Little Rock passengers attempted to open a floor level exit door leading to the tailcone; the door exit could not be opened because of a deformation in the floor of the airplane. The two other Little Rock passengers attempted to open inoperable forward floor level exit doors. The 727 passenger reported opening the L2 door 10 inches before it "jammed."

Finally, the A300 passenger attempted to open the R3 door that had not opened as intended after a flight attendant first tried to open the door (figure 5–5).

The floor level exit door problems in the MD-82 evacuation were associated with airplane and exit deformation that resulted from the impact sequence. The floor level exit door problem in the A300 case was determined to be the result of the slide pack and will be discussed in the section on evacuation slides. Finally, no determination could be made as to why the floor level exit door on the 727 jammed. In summary, in 43 of the 46 of evacuation cases in the Safety Board's study, floor level exit doors were opened without difficulty.

Type III Overwing Exits

Trained crewmembers are expected to operate most of the emergency equipment on an airplane, including most floor level exit doors. Overwing exits, on the other hand, are expected to be and will primarily be opened by passengers. Even in airplanes where flight attendants are assigned the responsibility for overwing exits, passengers are likely to make the first attempt to open overwing exit hatches because the flight attendants are not physically located near the overwing exits.

In the study cases, Type III overwing exits were used in 13 of the 46 evacuations. In all, 36 overwing hatches were opened during these evacuations. Specific information on overwing exit operation was collected for 6 of the 13 evacuations.[57] For two of these evacuations—the A320 in Columbus, Ohio (case 43) and the 737 in Scottsbluff, Nebraska (case 46)—overwing exits were operated by flight attendants with no reported difficulties. In a 727 evacuation at Chicago, Illinois (case 9), two passengers who were interviewed indicated that they had no problems opening the overwing exit hatch. In the three other cases, there were reported problems with opening the overwing exit hatches. In an evacuation of a 737 in Atlanta, Georgia (case 32), one passenger reported that a woman had been unable to open one exit hatch and eventually allowed another passenger to open it. In an evacuation of a 727 in Chicago, Illinois (case 16), the passengers who opened the exit hatch reported "struggling to maneuver the heavy exit" to throw the hatch out of the airplane.[58] In an MD-82 evacuation at Little Rock, Arkansas (case 45), two passengers, ages 74 and 22, attempted to open two overwing exit hatches but were unable to do so. One of these passengers abandoned the exit whereas the other allowed another passenger in his row an attempt to open it. Both overwing exits were eventually opened. A 22-year-old passenger in the Little Rock accident attempted to open a third overwing exit by pushing the hatch out of the airplane after pulling the release handle. He stated he put his shoulder into the hatch and pushed, even though the design of the overwing exit was such that the hatch was to be pulled into the airplane.

In each of the 13 evacuations in which overwing emergency exits were used, all the exits were eventually opened. However, in three of the four cases for which data were available and a passenger opened an overwing exit hatch, the exit hatches were not always easy for passengers to open. Passenger difficulty in opening these exits unnecessarily caused passengers to wait

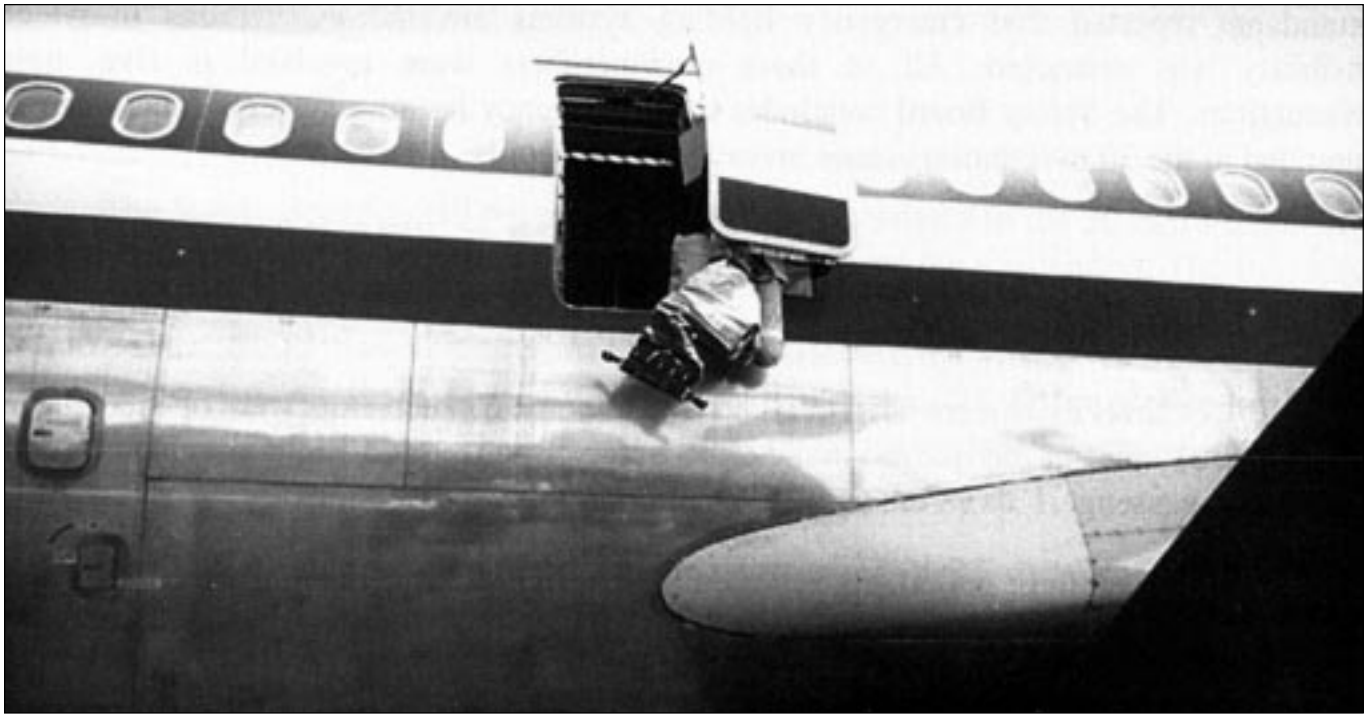


Figure 5–5. View of the R3 door that failed to operate as intended following the Airbus 300 accident on July 9, 1998, in San Juan, Puerto Rico (case 24).

to use the exits. While these delays did not appear to result directly in any additional injuries, there exists the potential that future difficulties could result in injuries, as occurred in the 1985 evacuation of a 737 in Manchester, England, in which the window exit passenger attempted to open the overwing exit by pulling on the handle of the seat adjacent to the exit. Another passenger reached over the window exit passenger and pulled on the release handle. The exit hatch fell inward, trapping the passenger next to the exit. Only with the help of another passenger was the hatch able to be moved. The exit was reported to be opened 45 seconds after the aircraft had stopped rolling. (The R2 exit was opened 6 seconds prior to stopping.)

Although regulations require passengers to be screened for exit row seating,[59] according to information obtained from this study, the screening does not guarantee that the passenger has read the safety briefing card or understands how to open or stow Type III overwing exit hatches after reading the card. Many passengers, even those seated in exit rows who are instructed that they may be called upon to help in an emergency evacuation, admit to not reading the briefing card that might help them understand how to operate and open overwing exits. Of the 42 passengers seated in overwing exit rows who responded to the Safety Board's questionnaire, 22 passengers (52 percent), representing eight cases, indicated that they had not read the briefing card.[60]

As case 16 (a 727 in Chicago) illustrated, the weight of the overwing exit hatch has also been a problem for some passengers. One air carrier acknowledges on its safety briefing card for an airplane type with Type III overwing exits the weight and awkwardness of this type of exit. The safety briefing card states in the introduction to the exit row seating requirements that "emergency exits are often heavy, awkward to lift, push, pull, and maneuver when opening. Because of this and for the safety of all passengers, Federal law requires that we only seat qualified passengers next to exits." Further, it is not intuitively obvious that after pulling the latch, the hatch is to be turned and either placed on the exit row seats or thrown out the opening. The opening and maneuvering of this exit is also difficult to display graphically. The Safety Board concludes that passengers continue to have problems opening overwing exits and stowing the hatch. The manner in which the exit is opened and the hatch is stowed is not intuitively obvious to passengers nor is it easily depicted graphically. Boeing has designed a new overwing exit for its 737 series airplanes based on human factors principles.[61] The exit is hinged and opens outward as passengers would intuitively expect (figure 5–6). This design also eliminates the problem of where to stow the exit hatch because it moves up and out of the egress route. In short, the design eliminates any guesswork about how the exit operates or what to do with the exit hatch once it is opened. The Safety Board believes the FAA should require Type III overwing exits on newly manufactured aircraft to be easy and intuitive to open and have automatic hatch stowage out of the egress path.

Figure 5–6. View of the newly designed Type III exit for the Boeing 737-600, -700, -800, -900.

Exit Row Passenger Tasks

Passengers seated in an exit row may be called upon to assist in an evacuation. Upon crew command or a personal assessment of danger, these passengers must decide if their exit is safe to use and then open their exit hatch for use during an evacuation. These passengers must be ready to act quickly in an emergency. However, unlike the crew, these passengers receive no formal training on performing these tasks.

As required by the FAA, air carriers provide pictorial instructions on the safety briefing card and adjacent to the emergency exit. In addition, Federal regulations (14 CFR 121.585(b)) provide guidelines to the air carriers as to which passengers to restrict from exit row seating. These guidelines are reiterated on exit row briefing cards or on the general safety cards.

Federal regulations (14 CFR 121.585(d)) also require air carriers to list the tasks that an exit row passenger may be called upon to perform: the passenger must be able to locate and operate the emergency exit, assess conditions outside an exit, follow instructions of crewmembers, open and stow the exit hatch, assess the condition of and stabilize a slide, and pass quickly through an exit. Passengers who report that they are unable or unwilling to perform any of these tasks must be reseated in a nonexit row prior to airplane movement.

The Safety Board examined passenger performance in exit rows for the six cases for which the Board received information

on the overwing exit operation. In these six cases, 42 passengers were seated in exit rows. Responses on the questionnaires indicate that the first task with which exit row passengers had difficulties was the decision to open the exit. In two cases, passengers opened overwing exits that should have remained closed. In one of those cases (case 16), an APU torched and passengers began to scream, "Fire." The aft flight attendant reported that she instructed passengers to remain seated, yet passengers still opened the exit. In the other case (case 19), the flight crew ordered an evacuation using only the forward exits; however, the exit row passengers opened the overwing exits. In neither case had the flight crew lowered the flaps for safe egress off the wing, and in one of these cases, a child sustained a broken arm jumping off the wing.

The second task for which problems occurred for exit row passengers was assessing conditions outside of the exit. In one case, a passenger opened an overwing exit and smoke began billowing into the cabin (case 45). The passenger then had to jump through fire to get away from the airplane. Although his traveling companion was also able to safely egress using this route, the other two passengers who used this exit received severe burns. In a second case, one passenger stopped another passenger from opening an overwing exit on the fire side of an airplane (case 16).

As previously discussed, one reason for these difficulties was passenger inattention to the safety materials provided. The air carriers are required to ensure that all passengers seated in an exit row meet the requirements contained in regulations previously cited. Although no exit row passenger was younger than age 15, two passengers were older than age 70, one of whom was unable to open an exit (case 45). In addition, three passengers seated in exit rows did not speak the language in which briefings and oral commands were given by the crew.

Some of the air carriers make a point to individually brief passengers on the exit row tasks. In the six study cases for which the Safety Board received overwing exit operation information, 9 of the 42 exit row passengers reported receiving such a briefing (figure 5–7). Four of these passengers reported examining their safety card. Twenty-four passengers reported receiving no briefing, and only two of these passengers had examined their briefing card. The two briefed passengers who opened overwing exits reported no difficulties. Four passengers who did not receive a briefing opened overwing exits. Two of these passengers reported no difficulty with the exit whereas the other two reported difficulties with their exit.

The benefit of exit row passengers' receiving oral briefings from flight attendants is demonstrated in the runway collision in Los Angeles, California, on February 1, 1991. The Safety Board's report of that accident contained the following information:

> Passengers seated around row 10 stated that prior to departure, the flight attendant assigned to the R1 position interviewed a young passenger who was seated in 10D about whether he could fulfill the duties of an able-bodied person in the event of an emergency. The passenger advised the flight attendant that he was 17 years old. However, to be sure the youth understood his responsibilities, the flight attendant conducted a special oral briefing for the persons seated in and around row 10. Passengers stated that the instructions provided by the R1 flight attendant aided in their evacuation.

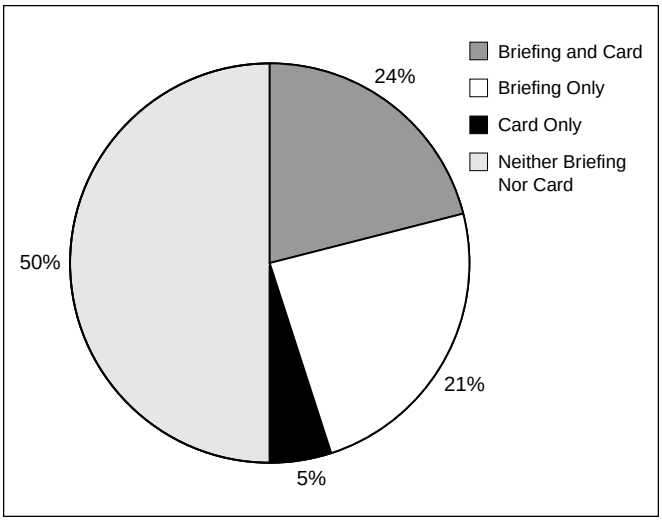


Figure 5–7. Percentage of exit row passengers who indicated whether or not they paid attention to safety information.

Exit procedures for emergency evacuations are critical and if not followed could lead to tragedy. The Safety Board concludes that most passengers seated in exit rows do not read the safety information provided to assist them in understanding the tasks they may need to perform in the event of an emergency evacuation, and they do not receive personal briefings from flight attendants even though personal briefings can aid passengers in their understanding of the tasks that they may be called upon to perform. Therefore, the Safety Board believes the FAA should require air carriers to provide all passengers seated in exit rows in which a qualified crewmember is not seated a preflight personal briefing on what to do in the event the exit may be needed.

Flight Attendant Exit Assignment

The exit configuration of some Fokker airplanes is unique among jet airplanes in that it does not have any exits in the rear of the airplane. On the Fokker 100 (F100), the forward flight attendant is responsible for the L1 and R1 floor level exits, which are adjacent to the jumpseat where the flight attendant is seated. The aft flight attendant is responsible for opening the forward overwing exits 10 rows and 47 passengers forward of the rear jumpseat where the flight attendant is seated (figure 5–8, page 26).[62] A flight attendant involved in the

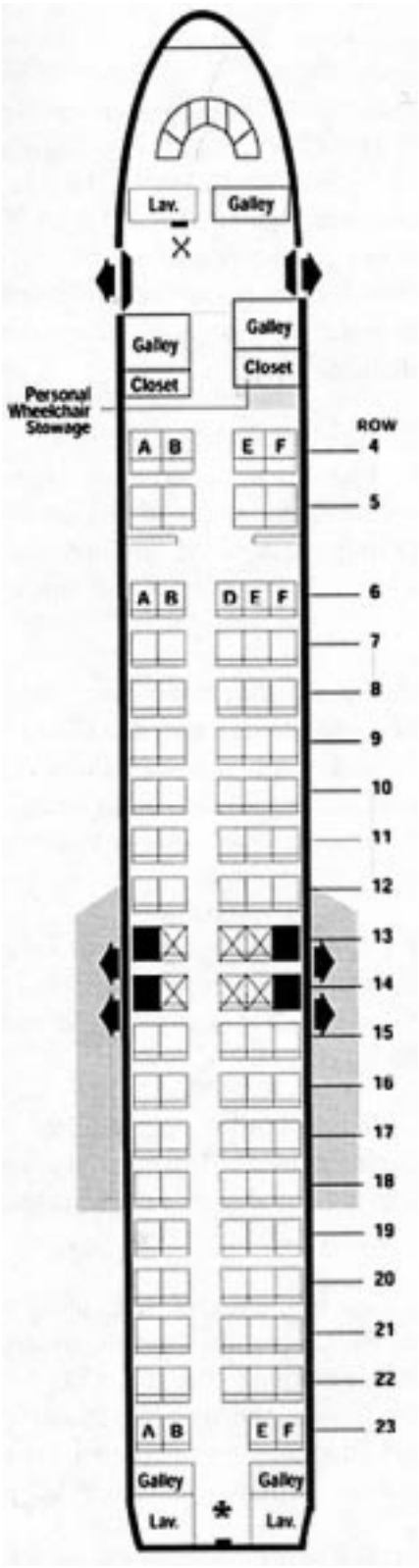


Figure 5–8. The Fokker 100 exit configuration. The aft flight attendant position is marked by the ✱. The forward flight attendant position is marked by the X.

evacuation of an F100 in Charlotte, North Carolina (case 41) indicated that passenger evacuation in this case would have been helped had there been an emergency exit in the rear of the aircraft. The F100 on which the flight attendant was working was equipped with floor level exits in the forward part of the cabin and four overwing exits. The aft flight attendant's assigned primary exit was a forward overwing exit. The two right overwing exits were blocked by a fire on the right main gear. Passengers from the middle and rear of the airplane were evacuating from the two left overwing exits. The passengers at these exits operated their exits prior to the flight attendant reaching the overwing area.

Positioning a flight attendant in the rear of this airplane can limit the crewmember's usefulness and seems inconsistent with the requirements of 14 CFR 121.391(2)(d). According to the regulation, "during takeoff and landing, flight attendants required by this section shall be located as near as practicable to required floor level exits and shall be uniformly distributed throughout the airplane in order to provide the most effective egress of passengers in the event of an emergency evacuation." Research conducted by CAMI shows significant differences in evacuation times based on flight attendants' initial position.[63] Evacuations with flight attendants 24 feet aft of their primary emergency exits proceeded significantly slower than evacuations with a flight attendant next to the exit. Delays resulting from passenger inability to open the exit or indecisiveness can be reduced if flight attendants are available to assist. The Safety Board concludes that on some Fokker airplanes, the aft flight attendant is seated too far from the overwing exits, the assigned primary exits, to provide immediate assistance to passengers who attempt to evacuate through the exits. Therefore, the Safety Board believes that the FAA should require the flight attendants on Fokker 28 and Fokker 100 airplanes to be seated adjacent to the overwing exits, their assigned primary exits. In requiring the aft flight attendants on Fokker 28 and Fokker 100 airplanes to be seated adjacent to the overwing exits, their assigned primary exits, consideration should be given to the flight attendants' view of the cabin and other safety duties.

Evacuation Slides

The FAA requirement that all exits higher than 6 feet off the ground be accompanied by an assist means for allowing passengers to reach the ground quickly and safely during an emergency (14 CFR 25.810) has been met through the use of self-supporting, inflatable escape slides. The slides must be (a) automatically deployed, (b) automatically erected in 6 seconds for all but Type C exits,[64] (c) long enough for the lower end to be self-supporting on the ground regardless of gear collapse, and (d) usable in a 25-knot wind with the assistance of only one person. Further, to ensure reliability, five consecutive deployment and inflation tests must be conducted, one time only, without failure for each system installation.

The Safety Board investigated 19 evacuations that involved slide use;[65] 7 evacuations included slides that did not operate as expected. On February 9, 1998, a DC-9 (case 8) sustained a contained engine failure during takeoff. The tower informed the flight crew that there was fire in the area of the airplane's No. 2 engine. The crew stopped on a high-speed taxiway and began to complete the engine fire and emergency evacuation checklist.

Based on the possibility of an engine fire, the captain elected to order an evacuation using the forward two exits (L1 and R1). The flight attendant assigned to the R1 door opened the door; the slide deployed but did not inflate, nor did the slide inflate after the manual inflation handle was pulled. The evacuation then proceeded out the L1 door where the airstairs had been deployed. All passengers and crewmembers used the airstairs to leave the airplane.

An FAA cabin safety inspector examined the failed R1 slide. The specialist found the slide not inflated, hanging outside the aircraft, and noted that the pressure gauge on the inflation bottle read zero. After the slide was removed and attached to a fully charged bottle, it inflated fully with no leaks.

Daily checks of the inflation bottle were required by the air carrier;[66] however, recent changes to the air carrier manuals led to confusion over who was required to perform these checks. The carrier has subsequently adjusted the procedures in its manual to eliminate this confusion.

The failure of the R1 slide in the above evacuation reduced to one the number of exits originally selected by the flight crew for the 144 passengers and crew to evacuate the airplane. This occurrence was not unique to the study. On July 9, 1998, an A300 (case 24) experienced a fire in its No. 1 engine shortly after takeoff. The airplane returned to the airport and an emergency evacuation was executed on the runway. The captain ordered the evacuation on the right side of the airplane. The flight attendants were able to open and deploy the slides at R1, R2, and R4. However, there was a delay in deploying the R1 slide because of a failure of the power assist in the door. Also, the R3 door partially opened before jamming. The flight attendant tried repeatedly to open the door, but reported that he "knew [the slide] was caught up" in the pack. Postincident testing conducted by the Safety Board indicated that the malfunction might have been caused by a Velcro® fastener that became hooked on a clip on the inside of the decorative cover. In addition, the slide deployed at R4 was unusable for a period of time because winds were blowing the slide against the airplane (figure 5–9). During this time, the 234 passengers were exiting from only two of the eight exits on the A300.

In addition to the two evacuations described above, slides were difficult to deploy in five other evacuations in the Safety Board's study. On January 7, 1999, an MD-80 in San Diego, California (case 38) was evacuated in response to a bomb threat. Three door slides operated as designed. However, the aft tailcone slide failed to automatically inflate after the tailcone

Figure 5-9. View of the wind's effect (25-knot gusts) on the evacuation slide used following the Airbus 300 accident on July 9, 1998, in San Juan, Puerto Rico (case 24). Passengers were able to use this exit after a person on the ground held the slide in place.

was opened. The air carrier determined that the lanyard for inflating the slide was not attached to the tailcone girt bar. On an F100 that was evacuated on January 24, 1999 (case 41), a flight attendant reported that the slide became temporarily jammed in the slide pack. The attendant pulled the door closed and then shoved the door past the "jam." The slide eventually inflated and was used in the evacuation. The captain of an MD-82 that was evacuated on August 27, 1998 in Phoenix, Arizona (case 27) reported that a slide failed to inflate automatically. A flight attendant reported a similar occurrence during the evacuation of an MD-80 on December 19, 1997 (case 4). The flight attendant was able to manually inflate the slide. Finally, a 737 was evacuated on November 1, 1998, with slides that were incorrectly placarded automatic (case 32); the slides were, in fact, manual inflation only.

Overall, in 37 percent (7 of 19) of the evacuations with slide deployments in the Safety Board's study cases, there were problems with at least one slide. The Safety Board concludes that a slide problem in 37 percent of the evacuations in which slides were deployed is unacceptable for a safety system. Slide failure is not a new problem. In a December 9, 1999, letter to the FAA regarding the A300 accident in San Juan (case 24 in the Safety Board's evacuation study), the Board discussed evacuation system failures, including slide failures, that occurred in eight incidents prior to this study. A review of the accident briefs in the Safety Board's accident database yielded 37 accidents or incidents that mentioned slide evacuations during the 1990s (January 1, 1990, to September 24, 1997) prior to the study. Of those 37 accidents/incidents, 7 (19 percent) mentioned a failure of one or more slides.

The Safety Board has addressed the proper functioning of escape slides on several occasions in the past. For the overall reliability of slides, the Safety Board's 1974 special study on emergency evacuations recommended that the FAA develop a maintenance surveillance program to ensure greater reliability of evacuation slide systems (A-74-106).[67]

Following the Safety Board's investigation of the A300 accident in San Juan on July 9, 1998, described earlier, the Board recommended that the FAA,

> For a 12-month period, require that all operators of transport-category aircraft demonstrate the on-airplane operation of all emergency evacuation systems (including door opening assist mechanisms and slide or slide/raft deployment) on 10 percent of each type of airplane (minimum of one airplane per type) in their fleets. These demonstrations should be conducted on an airplane in a controlled environment so that the entire evacuation system can be properly evaluated by qualified personnel. The results of the demonstrations (including an explanation of the reasons for any failures) should be documented for each component of the system and should be reported to the FAA. (A-99-100)

> Revise the requirements for evacuation system operational demonstrations and maintenance procedures in air carrier maintenance programs to improve the reliability of evacuation systems on the basis of an analysis of the demonstrations recommended in A-99-100. Participants in the analysis should include representatives from aircraft and slide manufacturers, airplane operators, and crewmember and maintenance associations. (A-99-101)

The FAA responded to the Safety Board's recommendations on February 11, 2000, stating,

> The FAA believes, in part, that some of the issues raised by the Board are addressed in existing regulations. This is especially true of the process suggested by Safety Recommendation A-99-100. 14 CFR 121.703(a)(17) states, in part, that "…each certificate holder shall report the occurrence or detection of emergency evacuation systems or components, including all exit doors, passenger emergency evacuation lighting systems, or evacuation equipment that are found defective, or that fail to perform the intended functions during an actual emergency or during training, testing, maintenance, demonstrations, or inadvertent deployments." The FAA has reviewed the data submitted in accordance with 14 CFR 121.703 and believes that these data can be used to begin the process of determining the actions necessary to address the Board's concerns for these recommendations. A preliminary analysis of these data has identified at least six issues requiring resolution. These issues involve evacuation system design, age-related concerns, evacuation system certification basis, scheduled maintenance, and slide/raft packing and installation. These issues are further divided into maintenance manual procedures and personnel training/qualification issues. These issues will be addressed by the FAA/industry task group.

The Safety Board has indicated in its reply to the FAA that the Board does not believe that data submitted in accordance with 14 CFR 121.703(a)(17), which requires that problems with evacuation systems be reported to the service difficulty reporting (SDR) system, will be sufficiently detailed to address the issues raised in the Board's recommendations. Consequently, on May 11, 2000, the Safety Board classified Safety Recommendation A-99-100 "Open—Unacceptable Response." However, based on the FAA's submission to an FAA/industry task force of several issues related to slide reliability, the Safety Board classified Safety Recommendation A-99-101 "Open— Acceptable Response." The Board will continue to monitor the FAA's progress in this area. In the meantime, the Safety Board reiterates Safety Recommendations A-99-100 and A-99-101.

Exit Height From Ground

Although the number of serious injuries was small in the evacuations investigated for the study, the most serious

evacuation-associated injuries were the result of jumping out of exits or off of wings, with the exception of the injuries sustained in the Little Rock accident. Four of the six serious injuries, excluding Little Rock, were sustained by passengers who jumped from the wings: a 10-year-old, two elderly people, and a female of short stature weighing 200 pounds. One injury occurred when a passenger jumped from an exit door.

The incidence of injury was likely reduced because passengers were unwilling to jump and returned to the airplane cabin or because passengers received assistance from ground personnel. In the 727 evacuation in Chicago following an APU torching (case 16), passengers waited on the wings because they were afraid to jump from the wings; they reentered the cabin to exit via the aft stairs. Passengers that used an overwing exit in a 737 evacuation in Eugene, Oregon (case 5) also reentered the cabin because they were afraid to jump from the wings. In an evacuation of a DC-9 in Indianapolis (case 19), a resourceful ground crewmember brought a luggage cart to the wing to enable the passenger to more easily get off the wing. In a 727 evacuation in Fort Lauderdale, Florida (case 13), a flight crewmember who exited after all the passengers had exited noticed a dozen passengers standing on the wing moving toward the wingtips. In this case, the crewmember ran to the passengers and redirected them to the rear of the wing near the cabin to slide down.

As previously mentioned, current Federal regulations require an approved means to assist passengers in descending to the ground from an exit that is higher than 6 feet from the ground. For overwing exits, this height can be measured with the flaps in either a takeoff or landing condition, whichever is higher. There are many airplanes whose wings are less than 6 feet from the ground, such as the 727, 737, and CRJ. The Safety Board questions the wisdom of this rule and believes there is a need to revisit the rationale for the 6-foot designation. An above-ground exit without a means of assistance to the ground can alter the flow of an evacuation; some passengers in the study cases exited onto a wing and then stayed on the wing, thus interfering with the smooth evacuation of passengers onto and then off the wing. Passengers exiting via a door without a slide also hesitated before jumping to the ground. Flight crewmembers in both a DC-9 evacuation in Indianapolis (case 19) and a 737 evacuation in Eugene, Oregon (case 5) indicated in statements that they did not want passengers to use overwing exits because of the likelihood for injury. The Safety Board's study cases (5, 13, 16, 19) suggest that exit assist means are needed for some exits that are less than 6 feet from the ground. The Safety Board concludes that the majority of serious evacuation-related injuries in the study cases, excluding the Little Rock, Arkansas, accident of June 1, 1999, occurred at airplane door and overwing exits without slides. Therefore, the Safety Board believes that the FAA should review the 6-foot height requirement for exit assist means to determine if 6 feet continues to be the appropriate height below which an assist means is not needed. The review should include, at a minimum, an examination of injuries sustained during evacuations.

Chapter 6

Evacuation Guidance and Procedures

Two of the 35 flight crewmembers who returned surveys indicated being in a prior evacuation. Two of the 36 flight attendants who returned surveys reported prior evacuation experience. In general, a crew conducting an emergency evacuation will be doing so for their first and likely only time. The difference between a successful and an unsuccessful evacuation can be a matter of minutes or seconds. Therefore, clear and precise procedures must be in place and readily available to assist the crew.

Federal regulations require that each air carrier have in place approved training programs for flight crews and flight attendants (14 CFR 121.401). The FAA principal operations inspector (POI) assigned to an air carrier is responsible for evaluating an air carrier's "initial training plan and devices." After granting initial approval, the POI reevaluates the training program. If crewmembers are adequately trained to perform their duties, the POI will issue a final approval of the program.

Guidance to Flight Crews on When to Evacuate

The decision to evacuate the aircraft will most likely be made by the flight crew or the flight attendants. In the Safety Board's cases, the flight crew initiated 43 of the 46 evacuations.[68] The reasons for initiating these evacuations were predominately the presence or suspected presence of fire (see chapter 3).

The Safety Board asked flight crewmembers to indicate from a list what situations would require an emergency evacuation according to company procedures. The Safety Board examined responses from the 14 cases in which the flight crewmember pair (captain and first officer) returned questionnaires. Excluding the category "other,"[69] only four crew pairs indicated the same situations as requiring evacuation (table 6–1, page 30). For the 11 remaining crew pairs, the crewmember responses differed on what situations required evacuation according to company procedures. For example, one crewmember in the 737 evacuation in Scottsbluff (case 46) indicated company procedures called for evacuation in situations of fire in the airplane, fire outside the airplane, smoke in the airplane, and smoke outside the airplane whereas the other crewmember indicated only fire in the airplane and smoke in the airplane.

Flight crews receive some guidance from the flight operations manuals or safety manuals. The safety manual for the A300 crew that evacuated in San Juan (case 24) lists "initiate ground evacuation procedure (if required)" at the end of most

Table 6-1. Responses to the question "According to company policy, what constitutes a need for an evacuation?" for the study cases in which two flight crewmembers responded.[a]

Crew pair	Fire inside airplane	Fire outside airplane	Smoke inside airplane	Smoke outside airplane	Fuel leak	Other[b]
Case 10	X	X	X	X		
Case 10	X		X			X
Case 18	X	X	X			X
Case 18	X					
Case 19	X	X	X	X		X
Case 19	X	X	X			X
Case 20	X		X			
Case 20	X	X	X			
Case 21						X
Case 21	X	X	X			
Case 26	X	X	X	X		X
Case 26	X	X	X	X		
Case 28	X	X	X	X	X	
Case 28						X
Case 31	X					X
Case 31	X					
Case 33						X
Case 33	X	X	X			
Case 34	X	X	X			
Case 34						X
Case 35						
Case 35						X
Case 37	X	X	X	X		
Case 37	X	X	X			
Case 42	X		X			
Case 42	X		X			
Case 46	X		X			
Case 46	X	X	X	X		X

[a] The shading highlights the situations for which the crewmember responses differed on what required evacuation according to company procedures.

[b] "Other" generally included any other situation that the captain or first officer judges to be a risk to passenger safety.

checklists that might lead to an evacuation. Checklist procedures that direct flight crews to initiate or consider evacuation include emergency landing, fire (engine, APU, avionics, and cargo), smoke (in cabin equipment, in air conditioning, and smoke removal), abnormal landing gear, ditching, and aircraft sabotage. Similar guidance is found in the flight operations manual for the air carrier involved in the 737 evacuation in Newark (case 25). Other air carriers (the operator of the Avions de Transport Regional ATR-42 in case 22, and the operator of the 737 in case 32), however, direct flight crews to initiate or consider evacuation only for gear-up landings, ditchings, or forced landings; and while the manuals mention procedures for clearing smoke from the cabin, there is no mention of evacuation in these procedures.

In the Safety Board's review of ASRS reports, there were seven reports during the study period of evacuations that were considered but not conducted. Pilots reported considering evacuations for opaque smoke in the cabin, tailpipe fires, engine fire indications, cargo smoke

indications, and smoke in the cockpit. Conditions or indications that led to the evacuations in the study cases were similar to the conditions or indications reported in the ASRS that prompted pilots to consider an evacuation but not conduct one.

Based on the ASRS reports, the flight crews' responses to the questionnaire, and a review of crew safety manuals, the Safety Board concludes that pilots are not receiving consistent guidance, particularly in flight operations and safety manuals, on when to evacuate an airplane. The Safety Board therefore believes that the FAA should require flight operations manuals and safety manuals to include on abnormal and emergency procedures checklists a checklist item that directs flight crews to initiate or consider emergency evacuation in all emergencies that could reasonably require an airplane evacuation (for example, cabin fire or engine fire).

Planned Evacuations

Each of the air carrier flight attendant manuals reviewed by the Safety Board made a distinction between planned evacuations and unplanned evacuations. Planned evacuations allow the crew to review procedures and to prepare passengers in flight for the landing and an orderly evacuation. Passengers can be given brace instructions, guidance on exit usage, and information on how and when exits should be operated. Unplanned evacuations occur suddenly with little time to prepare. Most manuals indicate that these unplanned evacuations occur most often after emergencies that occur during takeoffs and landings. Further, the manuals indicate that unplanned evacuations are far more common than planned evacuations.

The majority (31) of cases in this study were reported to be unplanned evacuations; 14 evacuations were carried out following crew planning for a possible evacuation. The Safety Board was unable to determine the level of planning for case 17.[70] The majority (24) of the unplanned evacuations were the result of an event that occurred when the airplane was at the gate, taxiing, in the takeoff roll, or in the landing roll; however, 7 were the result of an in-flight event.

For the planned evacuations, the amount of planning varied from case to case. At a minimum, passengers were told they would be evacuating upon landing and to examine their safety card. The most comprehensive planning took place for the A320 that had an unsafe nosegear (case 43, Columbus, Ohio). The flight attendants briefed passengers on the appropriate bracing positions and the location of exits. Passengers were reseated to be near the overwing exits, and flight attendants were positioned next to the overwing exits to ensure that the exits would be opened quickly. In addition, passengers were asked to remove potentially hazardous objects prior to landing. One passenger indicated "the amount of info and the timing of the information was outstanding—no one panicked too much." Another passenger indicated that the crew "deserves medals." There were no injuries to the 26 passengers during the evacuation.

In case 26, a CRJ that had an in-flight cargo smoke indication, passengers were also supportive of the crew who briefed the passengers regarding the emergency prior to landing. One passenger stated, "They kept us well informed." Another stated, "They acted professionally and efficiently." A third wrote, "I appreciated how they kept us updated on what was happening." All passenger comments on the crew were favorable. There were no injuries to the 46 passengers during the evacuation.

The same positive comments toward crew communication with passengers cannot be said for the in-flight occurrences that did not include preparing passengers for possible evacuation. In case 32, passengers were informed in-flight that a maintenance problem had occurred and the airplane would be returning to Atlanta. The crew also informed passengers that airport fire trucks would meet the airplane but that their presence was normal. Passengers indicated that although the crew reassured them that there was nothing to worry about, the crew gave no emergency landing or evacuation instructions and did not prepare them for an emergency. Passengers in cases 21 and 24 made similar reports. Passengers sustained minor injuries in these cases: 11 in case 32, 1 in case 21, and 28 in case 24.

Planning for evacuations allows for more than just keeping passengers calm. Reviewing brace positions improves the chance that passengers will be properly braced for the emergency landing. Passengers in case 32 (a 737 with hydraulic problems) and case 11 (a Saab 340 with unsafe gear indications) received no briefings on brace position despite conditions on the airplane indicating a potentially dangerous landing. Planned evacuations also allow flight attendants the time to inform passengers of what to expect, thereby avoiding surprises that could possibly delay the evacuation. For example, passengers in case 33 (a Beech 1900) reported that they were surprised that there were no slides at the exits. Likewise, passengers in case 24 (an A300) indicated they were surprised to find slides instead of stairs at their exits, even though safety briefing cards depicted slides.

Inadequate time is one reason why planned evacuations are not conducted. Many air carriers have planned evacuation procedures that can take upwards of 30 minutes. One carrier (case 21), however, includes in its manual two different types of planned evacuations. One plan assumes that more than 15 minutes are available whereas the other assumes less than 15 minutes. Another carrier (case 43) includes plans for under/over 10 minutes. However, many carriers do not specify the time to conduct a briefing in the manual and provide little direction on how to provide a short briefing.

The Safety Board's investigation of seven evacuations indicated that there was adequate time for abbreviated briefings to

passengers but no briefing was given. For the three cases for which flight attendant manuals were obtained, two cases (24 and 32) had no procedures in place for quick briefings of passengers. In case 21, where procedures were in place, the flight crew's failure to inform the flight attendant of the seriousness of the event or their intent to evacuate prevented an adequate briefing. The Safety Board concludes that passengers benefit from precautionary safety briefings just prior to emergency occurrences. Therefore, the Safety Board believes the FAA should review air carriers' procedures to ensure that for those situations in which crews anticipate an eventual evacuation, adequate guidance is given both to pilots and flight attendants on providing passengers with precautionary safety briefings.

Exit Selection

Once a decision to evacuate is made, the crews must decide which exits to use in evacuating the airplane. In an ideal situation, all exits would be used to get passengers off the airplane as quickly as possible; however, this ideal is rarely achieved because exits are blocked by hazards such as fire or smoke. Only 4 of the 46 evacuations in the study were conducted using every exit available in the airplane cabin. Overall for evacuations in the study, 67 of the 125 floor level exits were used, and 44 of the 121 Type III overwing exits were used. The Safety Board was able to identify a reason for 66 exits (32 Type III, 34 floor level) not being opened; for the remaining 69 exits (45 Type III, 24 floor level), however, the Board could not determine a reason.

Flight attendants are trained to assess which exits are usable, and in no study case did a flight attendant open an exit that increased the potential harm to a passenger. The flight crew for many air carriers will provide assistance to the flight attendants on exit use based on their knowledge of the problem. The procedure for this varies among air carriers. The air carriers involved in cases 24 and 29 instruct the flight crews to communicate which exits not to use. The air carriers involved in cases 25 and 34 instruct the flight crews to communicate which exits to use. Other air carriers (cases 18 and 46) indicate that flight attendants will determine which exits to use.[71]

A factor that influences what exits to use is perceived passenger safety during the evacuation. The air carrier in case 21 has what is described as an expeditious deplaning procedure in which only the airplane entry door is used with its stairs in place. Expeditious deplaning is to be used only when there is no imminent threat to passengers. The air carrier in case 46 has a similar procedure that calls for portable airstairs to be brought to the airplane when passenger safety will not be compromised. Two of this air carrier's three evacuations involved the use of portable airstairs.

Some air carriers without specific procedures for limited evacuations will also limit exit use for passenger safety. Three carriers (cases 10, 22, and 25) indicated in their flight attendant manuals that certain exits are preferable (typically those lowest to the ground) in the event of landing gear failure. Three regional carriers (cases 20, 28, and 37) indicated in their safety manuals that floor level exits are preferable to use instead of overwing exits.

In case 10 (an MD-88 in Arlington, Virginia), passengers exited only via the L1 slide even though other exits, including floor level exits, were available for safe use. This air carrier has used this same method on other occasions (October 19, 1996; March 14, 2000).[72] In case 19, the crew ordered the evacuation only through floor level exits to prevent injuries associated with overwing exit use.

In the F100 evacuation following a right main gear failure in Charlotte, North Carolina (case 3), the flight crew asked both a flight attendant and ATC if any fire was present on or around the airplane. After receiving no report of fire, the flight crew ordered an evacuation of the 99 passengers using only the R1 exit. After 15 passengers had evacuated, the first officer exited the airplane using the R1 slide. Upon looking back at the airplane, he noticed a fire around the left main gear. He shouted to the flight attendant to evacuate using all of the right exits.

In the 737 evacuation following an engine fire in Honolulu, Hawaii (case 8), the captain ordered an evacuation using the forward two exits indicating that he "initially did not want to use any other exits, in the event that the wrong engine was indicated by the tower." As a result of a slide failure on the R1 exit, 139 passengers had to evacuate the airplane using only one exit. The captain indicated that he "should have been informed" when the slide failed and only one exit was then available for use.

Limiting the number of exits used during an evacuation can have a dramatic effect on evacuation times. The Safety Board used the airEXODUS evacuation model (version 2) to simulate an evacuation from a widebody[73] aircraft with eight exits and 440 passengers to examine the issue of limiting exit use. The number of exits used in the simulation runs were one, two, four, or eight exits. Ten simulations were run for each exit number condition. The mean time for the last person to exit the aircraft model was 238.4 seconds using one exit, 188.8 seconds using two exits, 69.1 seconds using four exits, and 51.7 seconds using eight exits. Similar results would be expected with smaller aircraft, although not as dramatic.

In none of the cases in which exit use was limited were any passengers injured because of delays exiting the airplane. However, limiting exit use during an evacuation raises several safety concerns. First, the procedure for when to use a limited number of exits during an evacuation was not outlined in any air carrier procedures examined in this study. Consequently, flight attendants were not likely trained or were not likely to have received any guidance on evacuating an airplane using limited exits. Air carriers that have used limited exits for

evacuations have contended that this is done to minimize potential passenger harm and panic. However, the Safety Board is unaware of any evidence or data to suggest that fewer injuries occur or that panic is minimized when a limited number of exits are used. The Safety Board concludes that limiting exit use during evacuations in its study was not in accordance with the respective air carrier's existing evacuation procedures and that, at a minimum, all available floor level exits that are not blocked by a hazard should be used during an evacuation. Therefore, the Safety Board believes that the FAA should review air carrier training programs to ensure that evacuation procedures call, at a minimum, for evacuation through all available floor level exits that are not blocked by a hazard.

Slide Commands

Once an evacuation is underway, flight attendants are trained to begin to shout commands to the passengers to assist in the evacuation. For an airplane equipped with slides, these commands will include how to use the slides. For all but two air carriers involved in the study cases, the command is "jump" or "jump and slide." For the air carrier in case 32, the command is "slide"; for the air carrier in case 10, the command is "sit and slide." In two additional cases (3 and 12), flight attendants reported using the command "sit and slide."

The Safety Board is not aware of any aircraft type being certificated using a "sit and slide" procedure. The process of sitting to board the slide slows the flow at the exit location such that certification test success would be difficult if not impossible. A procedure that requires sitting before sliding would not allow slide manufacturers to reach the current required slide rate of 70 people per lane per minute.[74] Speed is the primary reason air carriers command "jump and slide." The air carrier in case 10 recognizes in its flight attendant manual the effect of speed on evacuation and mentions a rapid slide procedure that includes the command "jump and slide"; however, the manual does not define when to use this more rapid slide procedure. Further, the air carrier's passenger briefing cards illustrate only the sit-and-slide procedure. The Safety Board understands that the purpose of the procedure is to minimize injuries, but as the data in this study indicate, very few serious injuries occurred as a result of using the jump-and-slide procedure to board the slides. Further, the one serious injury from a slide resulted during an evacuation using the sit-and-slide command. Although this occurrence is more coincidence than trend, it does demonstrate that the sit-and-slide procedure does not preclude injury. The Safety Board concludes that evacuations involving slide use could be delayed if passengers sit at exits before boarding a slide or if crew commands do not direct passengers how to get onto a slide. Therefore, the Safety Board believes the FAA should review air carrier procedures and training programs to ensure that the commands used for slide evacuations are consistent with the commands used for slide evacuations during certification.

Airplane Familiarization for ARFF Personnel

ARFF units expressed concern in the questionnaires that they lack the opportunity to receive hands-on airplane familiarization and egress training. Eight ARFF units suggested hands-on familiarization training to better prepare them to assist in airplane evacuations. Four of these suggestions came from ARFF units at Index E airports, two from units at Index D airports, and two from units at Index C airports. In addition to suggesting more hands-on training, four ARFF units indicated that they had never received familiarization training for the airplane type that was evacuated at their airport, and an additional two units stated that they had received no training on shutting down engines for the airplane type that was evacuated at their airport.

Through past accident investigations, the Safety Board is aware that many ARFF personnel, especially at some of the smaller airports, are not afforded adequate opportunity to receive hands-on familiarization training specific to the airplane types that frequent their airports because of the lack of availability of those airplanes from air carriers. The Safety Board also realizes that making those airplane types available to ARFF personnel is often difficult and burdensome to air carriers at some locations. However, the Safety Board believes that additional effort needs to be applied by the FAA and industry to make the airplanes available for hands-on familiarization training of ARFF personnel. The Safety Board concludes that without hands-on training specific to the airplane types that frequent their airports, ARFF personnel may be hindered in their ability to quickly and efficiently assist during evacuations. Therefore, the Safety Board believes that the FAA should establish a task force to address the issue of providing periodic hands-on familiarization training, or the equivalent, for ARFF personnel at all 14 CFR Part 139 certified airports on each airplane type that serves the airport on a scheduled basis.

Chapter 7

Communication

Successful evacuations are dependent on good communication between all airplane crewmembers and between the crew and the passengers.

Crew-to-Crew Communication

In case 21 (a British Aerospace Jetstream 4100), the flight crew received an indication of a cargo fire. They declared an emergency to ATC and returned to the airport in Evansville, Indiana. The flight crew taxied off the runway and commanded "easy victor left."[75] The flight attendant released his seat belt and proceeded to the left exit. Upon seeing the propeller still rotating on the left side of the airplane, the flight attendant decided to exit through the right exit. The flight attendant was

not aware of an emergency until he heard the command for evacuation. Both flight crewmembers reported on the questionnaire that the flight attendant had not been adequately briefed on the emergency.

In case 11, a Saab 340 evacuation in Lawton, Oklahoma, the flight crew was diagnosing a gear extension problem and asked the assistance of the flight attendant. The flight attendant visually inspected the gear and reported to the flight crew that the gear was down. The flight crew indicated to the flight attendant that the gear might not have locked and that they would be making a precautionary landing. The flight attendant was not informed that ARFF units would be waiting for the airplane and prepared for a normal landing. As a result, passengers also were not informed of the possible emergency situation or that ARFF units would be waiting upon landing. At a minimum, passengers should have been briefed on how to assume brace position. The gear collapsed on landing and the airplane overran the runway. ARFF crews opened the overwing exit and the passengers evacuated.

The questionnaire asked flight crews and flight attendants about the quality of crew communication. Overall, 20 flight crewmembers indicated that their communication was excellent with flight attendants. Eight flight crewmembers rated their communication with the flight attendants as adequate, with some glitches. One flight crewmember rated the communication inadequate (case 21). In four cases, the flight crews listed communication as "other." These included no communication (cases 16 and 45), no flight attendant (case 33), and unable to contact aft flight attendant but indicated that the flight attendant followed the lead of the forward flight attendants (case 18).

The flight crews in evacuations that received detailed investigations were asked on the questionnaire what changes could be implemented to improve emergency evacuation of passengers. One crewmember in case 21 mentioned more emphasis on crew resource management (CRM). Four flight crewmembers (cases 19, 21, and 35) mentioned joint training with flight attendants. In addition, two flight attendants (cases 21 and 37) recommended joint training with the flight crew on evacuation procedures.

Twenty-three of 34 flight crewmembers indicated on the questionnaire that they have some form of joint CRM training with flight attendants. One flight crewmember (case 35) indicated that his joint CRM training with flight attendants was invaluable and must continue. Included in his CRM program were simulated evacuation exercises with flight attendants. However, only 10 of the 34 having joint CRM training with flight attendants participated in joint evacuation exercises with flight attendants. The flight crew in case 21 did not report joint evacuation training with flight attendants. In this case, one flight crewmember reported that communication with flight attendants was inadequate. The situation was similar for the flight attendants: only 3 of the 35 flight attendants who responded to the questionnaire stated that they had participated in joint evacuation exercises with flight crews.

The Safety Board discussed the importance of good communication between crewmembers in its special investigation on flight attendant training[76] and subsequently issued the following recommendations to the FAA:

> Amend 14 CFR Part 121.417 to require an evacuation and/or wet ditching drill group exercise during recurrent training. Ensure that all reasonable attempts are made to conduct joint flight crew/flight attendant drills, especially for crewmembers operating on airplanes with two-person cockpit crews. (A-92-74)
>
> Require that flight attendants receive crew resource management (CRM) training that includes group exercises to improve crewmember coordination and communication. (A-92-77)

With respect to A-92-77, the FAA responded by including flight attendants as a group that would benefit from CRM in Advisory Circular (AC) 120-51B, which outlines CRM training for the air carriers. The FAA further expanded CRM training for flight attendants in AC 120-51C, which states that flight attendants should conduct CRM training with flight crews covering shared issues such as evacuations and ditching. With respect to A-92-74, the FAA issued Information Bulletin 95-04, "Emergency Evacuation and Ditching Drills," on February 14, 1995. The bulletin directed POIs to ensure that their assigned certificate holders are aware of the performance benefits that result when flight crews and flight attendants perform emergency evacuation and ditching drills together. However, the FAA did not require air carriers to conduct joint exercises between flight attendants and flight crews.[77]

The FAA stated in AC 120-51C that "communication and coordination problems between cockpit crewmembers and flight attendants continue to challenge air carriers and the FAA." Several cases (19, 21, and 35) in the Safety Board's study emphasize that point. In the AC, the FAA states that it is considering several methods to improve this problem. These methods include observation flights for flight attendants, including flight attendants in line-oriented flight training, month-long pairings of flight crew and flight attendants, and providing experienced flight crewmembers to teach new-hire orientation classes. The Safety Board recognizes the benefits that each of these methods would provide. However, the Safety Board continues to believe that joint exercises for flight crews and flight attendants on evacuation would solve many of the CRM-related communication problems that currently exist. Further, such training is currently being conducted and is seen as beneficial by crewmembers that have participated in both the training and an actual evacuation (for example, case 35). The Safety Board concludes that communication and

coordination problems continue to exist between flight crews and flight attendants during airplane evacuations. Joint exercises for flight crews and flight attendants on evacuation have proven effective in resolving these problems. Therefore, the Safety Board believes that the FAA should require air carriers to conduct periodic joint evacuation exercises involving flight crews and flight attendants.

Crew-to-Passenger Communication

As previously stated, how passengers perform during an evacuation is dependent, in part, on how the crews prepare them for an evacuation. Two different methods of communication are typically used by the air carriers to inform passengers what they should do if an evacuation is conducted: the preflight verbal briefing from the crew, and a written safety briefing card. The Safety Board examined these methods of communication.

Preflight Safety Briefing

Federal regulations require that passengers receive a briefing prior to takeoff on safety aspects of the upcoming flight (14 CFR 121.571). This briefing must include information on smoking, emergency exit location, seat belts, compliance with signs, and the location and use of flotation means. In addition, if the flight operates above 25,000 feet mean sea level, the briefing must include information on the emergency use of oxygen.

The FAA published AC 121-24B to guide air carriers in the development of their safety briefings. Primarily, the AC lists the material that must be covered and offers suggestions for material that should be covered. The AC also indicates the difficulty in motivating passengers to attend to the safety information and suggests making the briefing as attractive and interesting as possible to increase passenger attention. Further, the AC directs that flight attendants be animated, speak clearly and slowly, and maintain eye contact with the passengers. Finally, the AC suggests the use of recorded videotape because it ensures a complete briefing with good diction and allows for additional visual information to be presented to the passengers.

Thirty-five flight attendants (representing 18 cases) indicated on their questionnaires that the preflight safety briefing on their airplane in the evacuation study was conducted by a flight attendant. The briefing for the one wide-bodied airplane in the study was the only reported use of a recorded video briefing. This video briefing was conducted in Spanish and English. All 36 flight attendants who responded to the questionnaire indicated no problems with the briefing.

The passengers' questionnaire asked about passenger attention to the safety briefing. Of the 377 passengers who reported whether they watched the briefing, 13 percent (50) indicated they watched none of the briefing, and 48 percent (182) reported that they watched at least 75 percent of the briefing.

Of the 457 passengers who returned questionnaires, 54 percent (247) reported that they had not watched the entire briefing because they had seen it before. An additional 70 passengers indicated that the briefing was common knowledge, and therefore there was no need to watch the briefing. Table 7–1 lists all the passengers' reasons for not watching the entire briefing.

Table 7–1. Reasons given by passengers for not watching the entire preflight safety briefing.

Reason	Number of Passengers
Saw it before	247
It's basic knowledge	70
Other	44
Reading	28
Sleeping	15
Obstructed view	10
Distracted by other person	8
Distracted by child	2
Listening to music/audio tapes	1
Too long	1

Passengers (141) who watched more than half of the briefing were divided evenly on the effectiveness of the briefing: 71 who reported watching the entire briefing indicated that the briefing was not helpful for their evacuation; the remaining 70 believed it was helpful. The primary concern expressed by passengers was that the briefing covered situations that did not apply to their evacuation. Passengers reported that they would have preferred information regarding exit routes or information such as how to slide or how to get off of wings. Those that believed the briefing was helpful believed that they were more aware of the exit locations because of the briefing.

The Safety Board has issued several recommendations with the intent of improving passenger attention to preflight safety briefings. In 1974, the Safety Board recommended that the FAA

> Issue an advisory circular that would provide standardized guidance to the air transport industry on effective methods and techniques for conveying safety information to passengers. (A-74-113)

Eleven years later, in 1985, the Safety Board recommended that the FAA

> Require that recurrent flight attendant training programs contain instructions on the use of the public address (PA) system and techniques for maintaining effective safety briefings and demonstrations which will

improve the motivation of passengers to pay attention to the oral briefings and to the demonstrations (A-85-101).[78]

Now, 15 years later, the information obtained from the Safety Board's current study indicates that the problem of passenger inattention to briefings continues to exist. The Safety Board concludes that despite efforts and various techniques over the years to improve passenger attention to safety briefings, a large percentage of passengers continue to ignore preflight safety briefings.

As previously mentioned, 54 percent of the responding passengers (247 of 457) did not watch the entire briefing because they had seen it on previous flights. However, safety information for one airplane may differ from the safety information for the next airplane, which is why exit locations, floor path lighting, and oxygen systems are all discussed in the oral briefing. Passengers need to be made more aware of the existence of such differences and the need to pay attention to the safety information. With the exception of videotaping, there has been little change over the years in how safety information has been presented to passengers. Creative methods that use today's state-of-the-art technology should be explored to improve passenger attention to safety information. Therefore, the Safety Board believes that the FAA should conduct research and explore creative and effective methods that use state-of-the-art technology to convey safety information to passengers. The presented information should include a demonstration of all emergency evacuation procedures, such as how to open the emergency exits and exit the aircraft, including how to use the slides.

Safety Briefing Card

The FAA requires that oral briefings be supplemented with printed safety briefing cards that pertain only to that make and model of airplane and are consistent with the air carrier's procedures (14 CFR 121.571(b)). The safety cards must contain diagrams and methods of operation for all emergency exits and any instructions for operating other emergency equipment. Advisory Circular 121-24B provides guidelines for air carriers in the development of their safety cards.

Passenger use of the safety cards on the airplanes in the study cases was consistent with previous findings that passengers tend not to look at the cards.[79] Of the 431 passengers who reported about reading the safety card, 68 percent (293) indicated that they did not read the safety card. Of those, 89 percent (259) indicated that they had read the card on previous flights. Of particular concern is that 44 percent (175) of 399 responding passengers reported that they neither examined the safety card nor listened to the safety briefing (figure 7–1).

Of the passengers who reported reading the card, 59 percent (82) indicated that the card was useful. The primary benefit of the card was for identifying exit location, as reported by 77

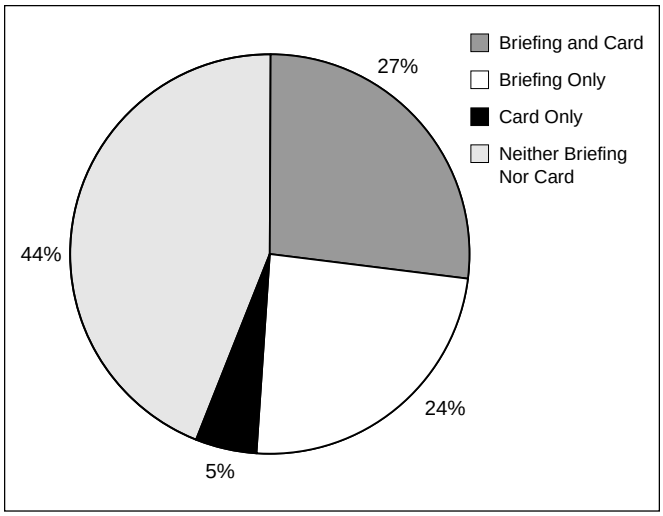


Figure 7-1. Percentage of all passengers who indicated whether or not they paid attention to safety information.

passengers. Other benefits reported by passengers included how to use slides, which exits had slides, and the location of emergency lights.

The Safety Board examined 22 safety briefing cards representing 25 of the 30 cases investigated in detail: 60 percent of the cards consisted of color drawings; 8 percent were color photos; and 8 percent were black, white, and red drawings. According to AC 120-51B, the cards should be sufficiently large to compete with magazines for attention. Twenty of the cards were as large or larger than a standard magazine.

The Safety Board also examined the content of the safety briefing cards. All of the cards contained information on brace positions. Thirteen of the cards included additional brace positions, such as brace positions for children, for a parent holding an infant, and for a pregnant passenger. Fifteen of the cards presented bracing positions for both high- and low-density seat areas. The inclusion of bracing information is not mandatory for safety cards.

All of the safety cards examined included instructions on operating emergency exits. For the majority of the cards, the instructions for an exit included a clear indication of the exit location. In cases 18 and 19 (DC-9s), exit instructions only named the exit ("door exit") but did not indicate its location on the airplane. The quality of the instructions for exit operation varied widely. In cases 20, 21, and 40, the procedures depicted to open an exit were not enhanced by enlargements or the use of color. In cases 10, 18, 19, 32, and 43, the card provided an enlarged view of the exit to clearly depict exit operation. For overwing exits, all the safety cards depicted the procedure for stowing the exit hatches: 10 cards indicated that the exit hatch was to be stowed inside the airplane, and 11 cards indicated that the hatch was to be stowed outside the airplane. How to go through an exit was also communicated in various ways:

11 cards illustrated how to move from the wing to the ground; 1 card (in case 9) used a photo showing how to slide off the wing; and 6 cards did not show how passengers should get off the wing. Slide use information was likewise varied: 4 cards did not indicate either jumping or sitting before sliding; 1 card depicted that passengers should sit and then slide; and 4 cards depicted that passengers should jump and slide.

The Safety Board did not test passenger comprehension of the safety cards; however, two 1997 studies found passenger comprehension of safety cards to be low. In the first study,[80] 113 subjects were asked the meaning of 36 pictorials taken randomly from 50 safety briefing cards: 12 of 36 pictures were understood by more than 67 percent of the subjects whereas 20 of the 36 pictures were understood by less than 50 percent of the subjects. In the second study,[81] 120 subjects were shown a briefing card for an MD Super 80 and were asked the meaning of the 40 pictorials. Two-thirds (67 percent) of the subjects understood the meaning of only half (21) of the 40 pictures.

The Safety Board has previously recommended that the FAA

> Develop tests and standards which describe the minimum level of acceptable comprehension and performance to measure whether persons who represent typical passengers understand the safety information presented during oral briefings and demonstrations, on safety cards, and in videotaped briefings, and whether these persons actually are able to perform the actions described, such as using supplemental oxygen systems, using life preservers, and opening of exits. (A-85-94)

The FAA responded that comprehension research had been conducted and that the results of this research were included in AC 121-24A. The FAA further responded that safety cards are developed by a small number of firms that conduct comprehension testing of their material.[82] The Safety Board is aware of firms that conduct comprehension testing for safety cards; however, the Board is also aware that not all of the firms that develop safety cards conduct comprehension testing. Further, this testing is not required by the FAA. The Safety Board concludes that despite guidance in the form of FAA advisory circulars, many air carrier safety briefing cards do not clearly communicate safety information to passengers. Therefore, the Safety Board believes the FAA should require minimum comprehension testing for safety briefing cards.

Retrieval of Carry-on Luggage

Currently, air carriers use two methods to instruct passengers not to take personal belongings during an evacuation. The first method is the safety briefing card. All but two of the safety briefing cards reviewed for this study indicated that carry-on luggage should not be taken during an evacuation. The pictogram used to indicate "leave baggage" was a suitcase in the center of a slashed circle. The second method is flight attendants' commanding "leave everything" during the evacuation. Twenty-three of 37 flight attendants indicated that they commanded passengers to leave everything behind. Despite these methods, passengers often took their belongings.

Three flight attendants indicated that one way to prevent passengers from removing carry-on baggage would be to include a statement in the preflight safety briefing. Passengers likewise indicated the necessity of a preflight announcement regarding carry-on baggage in emergencies. When asked how the safety briefing could be improved, 16 passengers indicated that the preflight briefing should mention leaving carry-on luggage behind.

Once the decision to evacuate the airplane is made, flight attendants will begin their evacuation procedures. The speed at which passengers evacuate is highly dependent on the actions of the flight attendants.[83] Flight attendants receive both initial and recurrent training on methods to maintain a constant flow of passengers out an emergency exit. However, flight attendants reported that their attempts were often thwarted by passengers' insistence on retrieving their carry-on luggage before evacuating.

The majority of passengers who replied to the Safety Board's questionnaire were carrying at least one piece of carry-on luggage. Only 25 passengers (6 percent) reported having no bags with them in the cabin. Of the 419 passengers who reported that they carried on bags, 208 (nearly 50 percent) reported attempting to remove a bag during their evacuation. The primary reason that passengers stated for grabbing their bags was for money, wallet, or credit cards (111 passengers). Other reasons included job items (65), keys (61), and medicines (51). Most passengers exited the airplane with their bags.

Passengers exiting with carry-on baggage were the most frequently cited obstruction to evacuation. Twenty-four of the 36 flight attendants who responded listed carry-on baggage as an obstruction. Overall, 37 percent of the passengers indicated that retrieving carry-on baggage slowed the evacuation; however, in five of the evacuations (cases 9, 16, 24, 27, and 32), a majority of passengers believed that the evacuation was slowed by carry-on baggage. Further, 70 passengers and 8 flight attendants reported arguments between passengers and flight attendants regarding luggage.

Although not everyone attempts to retrieve and take carry-on baggage during an evacuation, everyone in the airplane could potentially be affected by these attempts. One passenger wrote that she convinced her grandchildren not to take their toys and coloring books only to wait in the aisle for passengers who were retrieving luggage from overhead bins. Another passenger without luggage reported waiting behind a passenger trying to maneuver a garment bag through an overwing exit.

To understand what is being taught to flight attendants on the issue of carry-on luggage during evacuations, the Safety Board

reviewed flight attendant training materials received from 15 air carriers. The materials varied from air carrier to air carrier but included syllabi for the training, overhead projections used in training, instructor notes, home study packets, and in one case a video used for home study. All 15 air carriers address in training the issue of passengers' retrieving carry-on luggage in one of two ways. In the lessons and drills conducted by most air carriers, flight attendants are instructed to shout the command "leave everything" to the passengers when an evacuation command is given. Some air carriers take the extra step of explaining to the flight attendants why these commands are important. For example, the air carrier in case 10 (an MD-88 in Arlington, Virginia) explains on its lesson overhead projections that carry-on luggage slows the evacuation, can damage the escape slide, and can injure other passengers at the bottom of the slide.

The Safety Board's review of the material received indicates that the training that flight attendants receive with regard to passengers' retrieving carry-on luggage does not address what to do when passengers do not follow the command to leave everything behind. Eight flight attendants reported arguing with passengers over the baggage. One flight attendant (case 5), who had been taking bags from passengers, reported having to throw bags out the exit to clear clutter at the exit. Another flight attendant (case 25) reported throwing bags against the cockpit door. In an evacuation of a 737 in Burbank, California,[84] a flight attendant threw bags in front of the unopened but usable R2 exit, thus blocking the exit. All of the attendants were using commands such as "leave everything" to the passengers.

The Safety Board understands the importance to passengers of having identification, money, keys, wallets, and medicines following an emergency evacuation given the initial uncertainty of when or if passengers will get their possessions returned if they leave the items behind. However, passengers who attempt to take their luggage during evacuations continue to present undue risks and delays to a successful evacuation. By retrieving luggage during an evacuation, passengers increase the potential for serious injuries or loss of life. The Safety Board concludes that passengers' efforts to evacuate an airplane with their carry-on baggage continue to pose a problem for flight attendants and are a serious risk to a successful evacuation of an airplane. Techniques on how to handle passengers who do not listen to flight attendants' instructions need to be addressed. Therefore, the Safety Board believes that the FAA should develop advisory material to address ways to minimize the problems associated with carry-on luggage during evacuations.

Auxiliary Power Unit Torching

On April 20, 1998, at about 8:30 p.m., a Boeing 727 (case 16) was completing its passenger boarding at Chicago O'Hare International Airport. In preparation for the flight, the flight crew started the airplane's APU. Along the right side of the airplane, an orange flame appeared that extended from the APU exhaust port forward as the APU "torched."

The cabin lights went off just before the torching, and because the ambient light was limited, the flame was more noticeable in the cabin. Several passengers screamed "fire" and began to evacuate the airplane. The left overwing exit was opened and passengers began to evacuate via the overwing and the jetway. The flight attendant in the rear of the airplane, who reported seeing flames coming out of the right engine, attempted to stop the evacuation, but as the rush of passengers approached her, she decided that opening the tailcone was a more prudent action. While the flight attendant was opening the exit, two passengers decided to open the L2 door. When the passengers finally opened the door, they noticed the slide had failed to deploy.[85] In this case, one passenger was lowered out of the airplane by another passenger and sustained ankle injuries as a result of being lowered out of the airplane.

Two flight attendants in the forward part of the cabin were uncertain of the reason passengers were evacuating. One reported to the flight crew that "we have a problem," while the other assisted passengers out onto the jetway. A fourth flight attendant in the middle of the airplane reported seeing flames and was thinking that it could be the APU torching. However, because she was not positively certain, she went to the cockpit to inform the captain of the engine flames.

The flight crew, when it learned of the evacuation, issued an announcement over the public address (PA) system to remain seated. The combined efforts of the crewmembers were able to control the passengers for an orderly exit through the tailcone exit. Passengers on the wing then reentered the airplane and left via the aft airstairs. However, control was not reestablished before a 10-year-old boy broke his arm jumping off the wing of the airplane. Several other passengers also sustained injuries.

The problem of uncommanded evacuations following an APU torching in a 727 is not new. The Safety Board's 1974 study included a similar evacuation.[86] In 1992, the Board investigated another torching that led to an evacuation.[87] As a result of that investigation, the Safety Board recommended that the FAA

> Issue an Air Carrier Operations Bulletin to require that Boeing 727 cockpit crewmembers make a public address announcement about auxiliary power unit (APU) starts immediately prior to starting the APU. (A-93-125)

In its October 14, 1993, letter issuing the recommendation, the Safety Board stated that

> The highest percentage of unwarranted passenger-initiated evacuations have occurred on 727 airplanes. The Safety Board believes that these frequent occurrences are linked to the location of the 727 APU exhaust outlet, which is clearly visible to passengers in the right overwing area.

In response to the Safety Board's recommendation, the FAA issued Flight Standards Information Bulletin for Air Transportation 95-04. The bulletin directed POIs to encourage their respective certificate holders to develop procedures that include an announcement from the flight crew before starting the APU on the 727. The bulletin also directed POIs to review their respective certificate holders' training program and emergency evacuation procedures to ensure that the flight crews and flight attendants are aware that the 727 APU starts can result in a momentary orange flash from the vicinity of the APU exhaust near the right wing root.[88]

The FAA updated bulletin 95-04 with Handbook Bulletin for Air Transportation 96-03, which asked POIs to reemphasize emergency evacuation procedures on unwarranted evacuations. In particular, crews should know the appropriate actions to take on airplanes with APUs that have a tendency to torch. The Safety Board is concerned that the POIs' past efforts to encourage and to reemphasize to their certificate holders to implement adequate procedures that would prevent unwarranted evacuations from an APU torching have proven unsuccessful. The Board believes that these procedures should now be required. The Safety Board concludes that unwarranted evacuations following 727 APU torching continue to exist despite past efforts by the FAA to address this issue. Therefore, the Safety Board believes that the FAA should require air carriers that operate 727s to include in the APU procedures instructions that when passengers are on board, the flight crew will make a PA announcement about APU starts immediately prior to starting the APU.

ARFF-to-Crew Communication

The Safety Board asked ARFF units and flight crewmembers about the communication between the two groups: five ARFF units and four flight crewmembers reported the communication as exceptional, six ARFF units and four flight crewmembers listed the communication as adequate, and three ARFF units and two flight crewmembers listed the communication as inadequate. Responses to the questionnaire indicated that the primary information ARFF units pass on to crews is the status of the airplane. One ARFF unit at the evacuation of a Jetstream 4100 at Evansville, Indiana (case 21) indicated not being able to communicate to the crew that no smoke or fire was present. Another unit at the evacuation of an MD-88 at Dallas–Fort Worth, Texas (case 35) indicated a desire to have known more details of the airplane problem. Both flight crewmembers for an MD-88 in Arlington, Virginia (case 10) and three flight crewmembers for a Saab 340 in Huntsville, Alabama (case 20) indicated that they would have liked to receive information from ARFF units on the condition of the exterior of the airplane.

The Safety Board asked the firefighters and flight crewmembers what recommendations they would suggest to improve evacuations. Three of the ARFF units mentioned the need for a dedicated frequency at the airport for ARFF-to-flight crew communication. Further, five crewmembers indicated that the lack of a dedicated frequency for communication hindered the evacuation.

The Safety Board has previously addressed the need for a dedicated frequency for ARFF-to-crew communication. On April 28, 1997, an MD-82 sustained a left engine turbine section failure and tailpipe fire shortly after takeoff and returned to the Tucson International Airport at Tucson, Arizona, where the passengers and crew evacuated the airplane. As a result of its investigation of this incident, the Safety Board issued recommendations that asked the FAA to

> Establish a designated radio frequency at all airports certified under Title 14 CFR Part 139 that allows direct communication between airport rescue and firefighting (ARFF) personnel and flight crewmembers in the event of an emergency and take appropriate measures to ensure that air traffic control personnel, ARFF personnel, and pilots are aware of its designation. (A-98-41)
>
> Develop a universal set of hand signals for use between airport rescue and fire fighting personnel and flight crews and flight attendants for situations in which radio communication is lost. (A-98-42)

On July 1, 1999, and in response to the recommendations, the FAA issued a revision to AC 150-5210-7C, "Aircraft Rescue and Fire Fighting Communications." The AC contained recommended procedures for establishing direct flight crew/ARFF incident commander/ATC tower communications on an aeronautical radio frequency (discrete emergency frequency) designated by ATC from the operational frequencies assigned to that facility. The AC also included standardized hand signals to be used for emergency communication between ARFF personnel and airplane crews (flight crews and flight attendants) for situations in which communication is lost.[89]

Five of the ARFF units that responded to the questionnaire indicated that their airport had a dedicated frequency in place for ARFF-to-crew communication. Four of these airports were Index E, and one was Index D. However, because many of the responses to questionnaires from ARFF units and flight crews were obtained before AC 150-5210-7C was issued, the Safety Board is unable to evaluate the success of the implementation of these dedicated frequencies. However, the Board has learned that difficulties establishing the frequency with tower controllers exist at several airports.[90] The Board considers these dedicated frequencies to be vital for assisting airplane crews to conduct successful evacuations and encourages the rapid implementation of these frequencies at all certificated airports. On May 10, 2000, the Safety Board staff requested an update from the FAA on efforts to implement AC 150-5210-7C. The Safety Board will continue to monitor the progress on this issue.

Communication Equipment

To assist crewmembers with communication, all passenger-carrying airplanes with more than 19 seats are required to have a PA system (14 CFR 121.318) and an interphone system (14 CFR 121.319). The PA system enables the airplane crews to disseminate safety information to the passengers and to initiate evacuations. The interphone system provides a method for the crewmembers to communicate with the cockpit or any passenger compartment without having to leave the immediate area. In addition, each passenger-carrying airplane must have a portable battery powered megaphone (14 CFR 121.309f).[91]

Crewmember responses to questions about use of the PA system (representing 24 of the 30 evacuations investigated in detail) indicated that the PA system was used to initiate 18 of the 24 evacuations. In these 24 evacuations, crewmembers in 9 cases reported using the interphone system to prepare for the evacuation. The PA system was not functional for three evacuations. On the MD-82 that overran the runway in Little Rock (case 45) and the 727 that landed short of the runway in Chicago (case 9), the PA systems were rendered inoperable by crash forces. In both of these cases, the flight attendants initiated the evacuation by shouting commands to evacuate. For a Saab 340 evacuation in White Plains, New York (case 37), the crew reported that an electrical failure prevented the use of the PA system, but the flight crew was able to shout over the engine noise to the flight attendant to prepare for the evacuation.

In 2 of the 18 cases for which the PA system was used to initiate the evacuation, not all flight attendants heard the PA announcement. In a DC-9 evacuation in Detroit, Michigan (case 18), the flight attendant located at the L1 exit did not hear the PA evacuation announcement. She had heard a flight crew conversation about an engine fire and then saw passengers get up and begin to evacuate. In a DC-9 evacuation in Indianapolis, Indiana (case 19), the aft flight attendant did not hear the announcement but began evacuating upon seeing passengers in the forward section evacuating.

The interphone system failed to operate in the same three cases in which the PA system was not functional (case 9, a 727 in Chicago; case 37, a Saab 340 in White Plains; and case 45, an MD-82 in Little Rock). A flight attendant in the 727 crash in Chicago reported attempting to call the cockpit but received no response. A flight attendant in a 727 evacuation following an APU torching (case 16) also reported attempting to call the flight crew on an interphone but no one answered; however, the air carrier did not report the interphone system as having any problems in this case.

Following the collision of an ATR-42 with a ground power unit in San Juan, Puerto Rico (case 30), the flight attendant attempted to contact the flight crew using the interphone 11 seconds after the collision to report a fire outside the airplane. The flight attendant call chimes can be heard in the cockpit for 14 seconds. During this time, the flight crew used the PA system to command passengers to remain seated. The flight attendant decided to initiate an evacuation after failing to contact the flight crew. Eight seconds later, the flight crew became aware of the fire outside the airplane.

The Safety Board expressed concerns about failed communication systems in its accident report of the July 6, 1996, MD-88 uncontained engine failure in Pensacola, Florida.[92] In the accident, the flight attendant in the rear of the airplane attempted to call the flight crew to report debris, smoke, and injuries in the back of the cabin, and to inform them that the flight attendant was beginning an evacuation. The interphone system was not functioning; therefore, the flight attendant began to evacuate passengers in the back of the airplane while the flight crew, unaware of the situation in the back, instructed passengers to remain seated.

> As a result of the Pensacola accident, the Safety Board recommended that the FAA
>
> Require all newly manufactured passenger-carrying airplanes operated under 14 *Code of Federal Regulations* Part 121 to be equipped with independently powered evacuation alarm systems operable from each crewmember station, and establish procedures and provide training to flight and cabin crews regarding the use of such systems. (A-98-22)

In a December 22, 1999, letter to the Safety Board, the FAA stated it has concluded that sufficient rules already exist to address this safety concern. The FAA related that under the existing rules, the crew and other passenger cabins can be notified of an impending emergency. Also, the flight attendants can notify the flight crew utilizing the crew interphone which has aural and visual indications in the cockpit. In addition, the FAA related that flight attendants can notify the passenger cabin utilizing the PA system.

The FAA stated that the crew interphone and the PA systems are redundant to an evacuation alarm, especially if used in accordance with approved training procedures. The FAA further stated that if training procedures are not followed, neither the PA system nor the proposed evacuation alarm would be effective. Both the PA and interphone systems are required by 14 CFR Part 121. Finally, the FAA stated that because it believes that existing rules sufficiently address the concern identified by this safety recommendation, it considered its action to be completed.

As a result of the FAA's position, the Safety Board classified Safety Recommendation A-98-22 "Closed—Unacceptable Action" on March 23, 2000. The Safety Board continues to investigate incidents that are hampered by inefficient methods of communication. On March 15, 2000, a flight attendant on a 737 in Tampa, Florida,[93] witnessed an engine fire and proceeded to call the cockpit via the crew interphone; she received no answer. Thirteen persons evacuated via the R2 exit while the engines were running. For the 737 that overran the runway in

Burbank, California, on March 5, 2000 (previously mentioned), the flight crew mistakenly gave the command to remain seated to the ATC tower instead of the cabin and never issued a command over the PA system to evacuate. Had evacuation alarms been in place for case 16 (the APU torching in Chicago) and the Tampa and Burbank incidents, no communication problems would likely have occurred.

The FAA contends that evacuation alarms are redundant to current communication systems. The Safety Board agrees that in ideal situations this may be true; however, as situations from the study cases indicate, the ideal is often not achieved during an evacuation. A second criticism of evacuation alarms involves a concern that flight attendants will initiate unwarranted evacuations. In the Safety Board's 46 study cases, there were no unwarranted evacuations initiated by flight attendants. Further, if a flight attendant were to initiate an unwarranted evacuation using an evacuation alarm, the flight crew would immediately become aware of the situation and would likely be able to take action to stop the evacuation.

An evacuation alarm unequivocally and immediately delivers a message throughout the airplane that an evacuation needs to begin. The alarm operates on a system separate from normal communications, thereby removing the possibility of selecting the wrong channel for communicating the command. Consequently, the Safety Board concludes that evacuations continue to occur that are hampered by inefficient communication and that current evacuation communication would be significantly enhanced by the installation of independently powered evacuation alarms on all newly manufactured transport-category airplanes. The Safety Board therefore recommends that the FAA require all newly manufactured transport-category airplanes operating under 14 CFR Part 121 to be equipped with independently powered evacuation alarm systems operable from each crewmember station, and establish procedures and provide training to flight crews and flight attendants regarding the use of such systems.

Airplane Cargo Smoke/Fire Indications

The May 11, 1996, crash of ValuJet Airlines flight 592 in the Everglades illustrated the importance of rapid detection of smoke or fire in cargo bays.[94] The accident resulted from a fire in a class D cargo compartment that went undetected until electrical systems started to be affected and smoke had penetrated the cabin. As a result of its investigation of that accident, the Safety Board recommended that the FAA

> Expedite final rulemaking to require smoke detection and fire suppression systems for all class D cargo compartments. (A-97-56)

The FAA decided to eliminate the class D cargo compartment designation for future airplanes and to require installation of fire or smoke detection systems on previously certificated aircraft by 2001. As a result of this action, the Safety Board classified Safety Recommendation A-97-56 "Closed—Acceptable Action" on August 13, 1998.

The effectiveness of a warning system is degraded when the system has a propensity for false indications. Eight evacuations in the study cases were the result of an indication of a cargo fire, but all were false indications. As a result of these false indications, 205 passengers were evacuated, and 1 passenger was injured. In each of these cases, ARFF units were unable to find any evidence of a fire in the airplane. ASRS reports during the study period indicated an additional four evacuations for false smoke indications. Because passengers in these four evacuations used only the main cabin door, the evacuations were not reported to the Safety Board.[95] All of these false indications occurred in regional aircraft operations.

The operators of the regional airplanes that had the false smoke cargo indications in the study cases were aware of the tendency for false indications to occur on their airplanes. The captain of the CRJ that evacuated in Knoxville, Tennessee, on August 13, 1998 (case 26) reported suspecting a false indicator but evacuated the aircraft as a precaution. The operator of the Saab 340 that evacuated in Huntsville, Alabama, on June 4, 1998 (case 20) had issued a notice to pilots reminding them that warm weather often led to an increase in false cargo smoke indications. However, pilots were reminded to treat all indications as if they were actual.

The Safety Board reviewed the FAA's SDR system for reports of false indications on smoke detectors. The database contained 30 reports of false cargo smoke indications involving Saab 340s and 15 reports involving CRJs for the period from October 1998 to November 1999.[96] The actual number of events is probably much higher; only four of the eight false indications that were documented in this study were reported to the FAA. However, for the entire Boeing fleet of 3,259 airplanes, the SDR database reported only 16 false indications for the period from October 1998 to November 1999.

The Safety Board agrees with a policy that requires passengers to be evacuated when an indication exists of a cargo fire. However, the Safety Board concludes that the frequency of false indications on the two regional airplanes in the Board's study cases— the Saab 340 and the Canadair Regional Jet—is too high.[97] Because only four of the eight false indications in the Board's study cases were reported to the FAA, the Safety Board is also concerned that all false indications are not being reported in the FAA's SDR system. The Safety Board further concludes that there are insufficient data, however, to determine if the frequency of false smoke indications is peculiar to the two regional airplanes in the Safety Board's study or if the problem is more widespread. Therefore, the Safety Board believes that the FAA should document the extent of false indications for cargo smoke detectors on all airplanes and improve the reliability of the detectors.

FAA's Service Difficulty Reporting System

In conjunction with this study, the Safety Board examined the FAA's SDR system with respect to problems with evacuation systems not being reported to the SDR system, as discussed in chapter 5, and with respect to false indications of smoke detectors not being reported to the SDR system, as discussed in the previous section. On several occasions in the past, the Safety Board has expressed concern with the adequacy of information being reported to the SDR system. Most recently, on January 9, 1998, the Safety Board asked the FAA to

> Modify the service difficulty reporting system so that it contains more complete and accurate information about component failures; for example, (a) revise the various Service Difficulty Report (SDR) forms and database to include cycles and times since last inspection for failed components; (b) relate to the operators who submit SDRs the need for complete and accurate information when they report component failures; and (c) remind Federal Aviation Administration inspectors assigned to Part 121 and Part 135 operators of their need to review the component failure reports for accuracy and completeness. (A-97-125)

On April 15, 1999, the FAA issued a supplemental notice of proposed rulemaking (SNPRM), the objective of which, according to the FAA, is to update and improve the reporting system to collect and disseminate clear and concise safety information to the aviation industry. The Safety Board reviewed the SNPRM, and in a letter dated October 26, 1999, stated that the Board believes that the SNPRM, if published as a final rule, would significantly improve the SDR process. Pending issuance of a final rule, the Safety Board classified Safety Recommendation A-97-125 "Open—Acceptable Response."

In view of the information collected in this study regarding the inadequate reporting of evacuation system failures and false indications for cargo smoke detectors, the Safety Board concludes that air carriers do not always make reports to the FAA's SDR system, or reports are inadequate, to identify the extent of component problems or failures. Therefore, the Safety Board is reiterating Safety Recommendation A-97-125 in conjunction with this study. In reiterating Safety Recommendation A-97-125, the Safety Board urges the FAA to consider the inadequate reporting of evacuation system failures and false indications for cargo smoke detectors in developing a final rule on the SDR system.

Findings

1. On average, an evacuation for the study cases occurred every 11 days. An average of 336,328 departures occurred every 11 days in 1998 by scheduled aircraft operating under Title 14 *Code of Federal Regulations* Part 121.
2. In the 46 study cases, 92 percent (2,614) of the 2,846 occupants on board were uninjured, 6 percent (170) sustained minor injuries, and 2 percent (62) sustained serious injuries.
3. The Federal Aviation Administration does not evaluate the emergency evacuation capabilities of transport-category airplanes with fewer than 44 passenger seats or the emergency evacuation capabilities of air carriers operating commuter-category and transport-category airplanes with fewer than 44 passenger seats. In the interest of providing one level of safety, all passenger-carrying commercial airplanes and air carriers should be required to demonstrate emergency evacuation capabilities.
4. Adequate research has not been conducted to determine the appropriate exit row width on commercial airplanes.
5. In general, passengers in the Safety Board's study cases were able to access airplane exits without difficulty, except for the Little Rock, Arkansas, accident that occurred on June 1, 1999, in which interior cabin furnishings became dislodged and were obstacles to some passengers' access to exits.
6. Emergency lighting systems functioned as intended in the 30 evacuation cases investigated in detail.
7. In 43 of the 46 evacuation cases in the Safety Board's study, floor level exit doors were opened without difficulty.
8. Passengers continue to have problems opening overwing exits and stowing the hatch. The manner in which the exit is opened and the hatch is stowed is not intuitively obvious to passengers nor is it easily depicted graphically.
9. Most passengers seated in exit rows do not read the safety information provided to assist them in understanding the tasks they may need to perform in the event of an emergency evacuation, and they do not receive personal briefings from flight attendants even though personal briefings can aid passengers in their understanding of the tasks that they may be called upon to perform.
10. On some Fokker airplanes, the aft flight attendant is seated too far from the overwing exits, the assigned primary exits, to provide immediate assistance to passengers who attempt to evacuate through the exits.
11. Overall, in 37 percent (7 of 19) of the evacuations with slide deployments in the Safety Board's study cases, there were problems with at least one slide. A slide problem in 37 percent of the evacuations in which slides were deployed is unacceptable for a safety system.
12. The majority of serious evacuation-related injuries in the Safety Board's study cases, excluding the Little Rock,

Arkansas, accident of June 1, 1999, occurred at airplane door and overwing exits without slides.

13. Pilots are not receiving consistent guidance, particularly in flight operations and safety manuals, on when to evacuate an airplane.

14. Passengers benefit from precautionary safety briefings just prior to emergency occurrences.

15. Limiting exit use during evacuations in the Safety Board's study was not in accordance with the respective air carrier's existing evacuation procedures. At a minimum, all available floor level exits that are not blocked by a hazard should be used during an evacuation.

16. Evacuations involving slide use could be delayed if passengers sit at exits before boarding a slide or if crew commands do not direct passengers how to get onto a slide.

17. Without hands-on training specific to the airplane types that frequent their airports, aircraft rescue and firefighting personnel may be hindered in their ability to quickly and efficiently assist during evacuations.

18. Communication and coordination problems continue to exist between flight crews and flight attendants during airplane evacuations. Joint exercises for flight crews and flight attendants on evacuation have proven effective in resolving these problems.

19. Despite efforts and various techniques over the years to improve passenger attention to safety briefings, a large percentage of passengers continue to ignore preflight safety briefings. Also, despite guidance in the form of Federal Aviation Administration advisory circulars, many air carrier safety briefing cards do not clearly communicate safety information to passengers.

20. Passengers' efforts to evacuate an airplane with their carry-on baggage continue to pose a problem for flight attendants and are a serious risk to a successful evacuation of an airplane. Techniques on how to handle passengers who do not listen to flight attendants' instructions need to be addressed.

21. Unwarranted evacuations following Boeing 727 auxiliary power unit (APU) torching continue to exist despite past efforts by the Federal Aviation Administration to address this issue.

22. Evacuations continue to occur that are hampered by inefficient communication. Current evacuation communication would be significantly enhanced by the installation of independently powered evacuation alarms on all newly manufactured transport-category airplanes.

23. The frequency of false indications on the two regional airplanes in the Safety Board's study cases—the Saab 340 and the Canadair Regional Jet—is too high. There are insufficient data, however, to determine if the frequency of false smoke indications is peculiar to the two regional airplanes in the Safety Board's study or if the problem is more widespread.

24. Air carriers do not always make reports to the Federal Aviation Administration's service difficulty reporting system, or reports are inadequate, to identify the extent of component problems or failures.

Recommendations

As a result of this safety study, the National Transportation Safety Board made the following safety recommendations to the Federal Aviation Administration:

Require all newly certificated commercial airplanes to meet the evacuation demonstration requirements prescribed in Title 14 *Code of Federal Regulations* Part 25, regardless of the number of passenger seats on the airplane. (A-00-72)

Require all commercial operators to meet the partial evacuation demonstration requirements prescribed in Title 14 *Code of Federal Regulations* Part 121, regardless of the number of passenger seats on the airplane. (A-00-73)

Conduct additional research that examines the effects of different exit row widths, including 13 inches and 20 inches, on exit hatch removal and egress at Type III exits. The research should use an experimental design that reliably reflects actual evacuations through Type III exits on commercial airplanes. (A-00-74)

Issue, within 2 years, a final rule on exit row width at Type III exits based on the research described in Safety Recommendation A-00-74. (A-00-75)

Require Type III overwing exits on newly manufactured aircraft to be easy and intuitive to open and have automatic hatch stowage out of the egress path. (A-00-76)

Require air carriers to provide all passengers seated in exit rows in which a qualified crewmember is not seated a preflight personal briefing on what to do in the event the exit may be needed. (A-00-77)

Require the aft flight attendants on Fokker 28 and Fokker 100 airplanes to be seated adjacent to the overwing exits, their assigned primary exits. (A-00-78)

Review the 6-foot height requirement for exit assist means to determine if 6 feet continues to be the appropriate height

below which an assist means is not needed. The review should include, at a minimum, an examination of injuries sustained during evacuations. (A-00-79)

Require flight operations manuals and safety manuals to include on abnormal and emergency procedures checklists a checklist item that directs flight crews to initiate or consider emergency evacuation in all emergencies that could reasonably require an airplane evacuation (for example, cabin fire or engine fire). (A-00-80)

Review air carriers' procedures to ensure that for those situations in which crews anticipate an eventual evacuation, adequate guidance is given both to pilots and flight attendants on providing passengers with precautionary safety briefings. (A-00-81)

Review air carrier training programs to ensure that evacuation procedures call, at a minimum, for evacuation through all available floor level exits that are not blocked by a hazard. (A-00-82)

Review air carrier procedures and training programs to ensure that the commands used for slide evacuations are consistent with the commands used for slide evacuations during certification. (A-00-83)

Establish a task force to address the issue of providing periodic hands-on familiarization training, or the equivalent, for aircraft rescue and firefighting personnel at all Title 14 *Code of Federal Regulations* Part 139 certified airports on each airplane type that serves the airport on a scheduled basis. (A-00-84)

Require air carriers to conduct periodic joint evacuation exercises involving flight crews and flight attendants. (A-00-85)

Conduct research and explore creative and effective methods that use state-of- the-art technology to convey safety information to passengers. The presented information should include a demonstration of all emergency evacuation procedures, such as how to open the emergency exits and exit the aircraft, including how to use the slides. (A-00-86)

Require minimum comprehension testing for safety briefing cards. (A-00-87)

Develop advisory material to address ways to minimize the problems associated with carry-on luggage during evacuations. (A-00-88)

Require air carriers that operate Boeing 727s to include in the auxiliary power unit (APU) procedures instructions that when passengers are on board, the flight crew will make a public address announcement about APU starts immediately prior to starting the APU. (A-00-89)

Require all newly manufactured transport-category airplanes operating under Title 14 *Code of Federal Regulations* Part 121 to be equipped with independently powered evacuation alarm systems operable from each crewmember station, and establish procedures and provide training to flight crews and flight attendants regarding the use of such systems. (A-00-90)

Document the extent of false indications for cargo smoke detectors on all airplanes and improve the reliability of the detectors. (A-00-91)

Also as a result of this safety study, the National Transportation Safety Board reiterated the following safety recommendations to the Federal Aviation Administration:

For a 12-month period, require that all operators of transport-category aircraft demonstrate the on-airplane operation of all emergency evacuation systems (including door opening assist mechanisms and slide or slide/raft deployment) on 10 percent of each type of airplane (minimum of one airplane per type) in their fleets. These demonstrations should be conducted on an airplane in a controlled environment so that the entire evacuation system can be properly evaluated by qualified personnel. The results of the demonstrations (including an explanation of the reasons for any failures) should be documented for each component of the system and should be reported to the FAA. (A-99-100)

Revise the requirements for evacuation system operational demonstrations and maintenance procedures in air carrier maintenance programs to improve the reliability of evacuation systems on the basis of an analysis of the demonstrations recommended in A-99-100. Participants in the analysis should include representatives from aircraft and slide manufacturers, airplane operators, and crewmember and maintenance associations. (A-99-101)

Modify the service difficulty reporting system so that it contains more complete and accurate information about component failures; for example, (a) revise the various Service Difficulty Report (SDR) forms and database to include cycles and times since last inspection for failed components; (b) relate to the operators who submit SDRs the need for complete and accurate information when they report component failures; and (c) remind Federal Aviation Administration inspectors assigned to Part 121 and Part 135 operators of their need to review the component failure reports for accuracy and completeness. (A-97-125)

By The National Transportation Safety Board

James E. Hall, Chairman
John A. Hammerschmidt, Member
John J. Goglia, Member
George W. Black, Jr., Member
Carol J. Carmody, Member
Adopted: June 27, 2000♦

Notes

1. National Transportation Safety Board, *Runway Collision of USAir Flight 1493, Boeing 737 and Skywest Flight 5569, Fairchild Metroliner, Los Angeles International Airport, Los Angeles, California, February 1, 1991*, Aircraft Accident Report NTSB/AAR-91/08 (Washington, DC: NTSB, 1991).
2. National Transportation Safety Board, *Runway Collision, United Express Flight 5925 and Beechcraft King Air A90, Quincy Municipal Airport, Quincy, Illinois, November 19, 1996*, Aircraft Accident Report NTSB/AAR-97/04 (Washington, DC: NTSB, 1997).
3. The Safety Board recommended that the Federal Aviation Administration (FAA) immediately issue a telegraphic airworthiness directive (AD) directing all Beechcraft 1900 operators to improve the markings on exit operations on the exterior of the airplanes. On February 4, 1997, the FAA issued AD 97-04-02 to require installation of new exterior operating instructions, markings, and placards for the airstair door, cargo door, and emergency exits on Beechcraft airplanes. Safety Recommendation A-97-1 was classified "Closed— Acceptable Action" on April 25, 1997.
4. A brief overview of past research on emergency evacuation of commercial airplanes is contained in chapter 2 of this report.
5. As used in this report and consistent with definitions in Title 14 *Code of Federal Regulations* (CFR) Part 1, the term "flight crew" is used to refer to the cockpit crew; "flight attendants" refers to the cabin crew; and "crew" and "crewmembers" are used to refer to all airplane crewmembers.
6. National Transportation Safety Board, *Safety Aspects of Emergency Evacuations from Air Carrier Aircraft*, Special Study NTSB/AAS-74/03 (Washington, DC: NTSB, 1974).
7. Appendix A contains relevant National Transportation Safety Board safety recommendations issued over the years that pertain to cabin safety and evacuation issues. The status of each recommendation is also listed. Pertinent recommendations and the actions taken by the FAA in response to these recommendations are discussed where appropriate in later chapters of this report.
8. National Transportation Safety Board, *Cabin Safety in Large Transport Aircraft*, Special Study NTSB/AAS-81/02 (Washington, DC: NTSB, 1981).
9. National Transportation Safety Board, *Air Carrier Overwater Emergency Equipment and Procedures*, Safety Study NTSB/SS-85/02 (Washington, DC: NTSB, 1985).
10. National Transportation Safety Board, *Airline Passenger Safety Education: A Review of Methods Used to Present Safety Information*, Safety Study NTSB/SS-85/04 (Washington, DC: NTSB, 1985).
11. National Transportation Safety Board, *Flight Attendant Training and Performance During Emergency Situations*, Special Investigation Report NTSB/SIR-92/02 (Washington, DC: NTSB, 1992).
12. (a) National Transportation Safety Board, *Passenger Survival in Turbojet Ditchings (A Critical Case Review)*, Special Study NTSB/AAS-72/02 (Washington, DC: NTSB, 1972). (b) National Transportation Safety Board, *In-Flight Safety of Passengers and Flight Attendants Aboard Air Carrier Aircraft*, Special Study NTSB/AAS-73/01 (Washington, DC: NTSB, 1973). (c) National Transportation Safety Board, *Chemically Generated Supplemental Oxygen Systems in DC-10 and L-1011 Aircraft*, Special Study NTSB/AAS-76/01 (Washington, DC: NTSB, 1976).
13. Transportation Safety Board of Canada, *A Safety Study of Evacuations of Large, Passenger-Carrying Aircraft*, Report SA9501 (Quebec, Ontario: TSB, 1995).
14. Hiroaki Tomita [Japanese Civil Aviation Bureau, Ministry of Transport], "For Less Injuries After Emergency Evacuations," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).
15. Michael K. Hynes [Western Oklahoma State College], "Human Factors Research on 519 Recent U.S. Air Carrier Passenger Evacuation Events," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).
16. H. Muir, C. Marrison, and A. Evans, *Aircraft Evacuations: The Effect of Passenger Motivation and Cabin Configuration Adjacent to the Exit*, CAA Paper 89019 (London: Civil Aviation Authority, 1989).
17. Vertical seat projection is defined as the distance between two rows of seats as marked by a vertical plumb line from the seat back of the front row and the seat cushion of the following row.

18. Emergency exit types are defined in 14 CFR 25.807. Type III exits are rectangular openings of not less that 20 inches wide by 36 inches high with a step up from inside the airplane of not more than 20 inches and a step down outside the plane of not more than 27 inches. Exit types are discussed later in the report.

19. P.J. Fennell and H.C. Muir, *The Influence of Hatch Weight and Seating Configuration on the Operation of a Type III Hatch*, CAA Paper 93015 (London: Civil Aviation Authority, 1993).

20. H.C. Muir and A.M. Cobbett, *Influences of Cabin Crew During Emergency Evacuations at Floor Level Exits*, CAA Paper 95006: Part A; FAA No. DOT/FAA/AR-95/52 (London: Civil Aviation Authority, 1996).

21. (a) H. Muir, C. Marrison, and A. Evans, *Aircraft Evacuations: The Effect of Passenger Motivation and Cabin Configuration Adjacent to the Exit*, CAA Paper 89019 (London: Civil Aviation Authority, 1989). (b) G. Sacco [Ente Nazionale Aviazione Civile] "Dimensions of Aircraft Occupants' Motivation and Behaviour," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999). (c) Neal S. Latman [NSL Associates], "The Human Factor in Simulated Emergency Evacuations of Aircraft Cabins: Psychological and Physical Aspects" *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).

22. *The 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).

23. (a) E.R. Galea, M. Owen, P.J. Lawrence, and L. Filippidis [University of Greenwich], "Computer Based Simulation of Aircraft Evacuation and its Application to Aircraft Safety," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999). (b) Richard W. Bukowski, R.D. Peacock, and Walter W. Jones [National Institute of Standards and Technology], "Sensitivity Examination of the airEXODUS Aircraft Evacuation Simulation Model," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999). (c) E.R. Galea and M. Owen [University of Greenwich], "The AASK Database: A Database of Human Experience in Evacuation Derived from Air Accident Reports," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).

24. E.R. Galea, M. Owen, P.J. Lawrence, and L. Filippidis [University of Greenwich], "Computer Based Simulation of Aircraft Evacuation and its Application to Aircraft Safety," Proceedings, *1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).

25. AirEXODUS is a computer program developed at Greenwich University that simulates passengers evacuating from an airplane.

26. These cases were excluded because passengers were not deemed to be in imminent danger.

27. The National Transportation Safety Board routinely conducts limited investigations by telephone. For limited investigations, Safety Board investigators will conduct a desk investigation by calling appropriate local officials, rescue response units, FAA personnel, and other persons and organizations that may have knowledge of the incident. From 1995 through 1999, there were 10,323 aircraft accidents investigated by the Board, of which 8,297 were limited investigations.

28. The term "slide" as used in this report refers to both evacuation slides and sliderafts.

29. Detailed investigations were limited to U.S. carriers because in the detailed investigations, the Safety Board requested passenger information from air carriers; the Board does not have the authority to request such information from foreign carriers.

30. The ARFF unit at the airport in case 35 returned two questionnaires.

31. Average response rates for surveys are usually between 10 and 15 percent. Response rates over 40 percent are rare (Fred N. Kerlinger, *Foundations of Behavior Research* (Chicago: Holt, Rinehart, and Winston, Inc., 1986)).

32. Passenger information was not available for nine cases. Passenger information provided by air carriers was inadequate to determine mailing addresses in three cases.

33. With implementation of ADMS-2000 (accident data management system), scheduled for October 1, 2000, evacuation events will be more easily identified in the Safety Board's accident/incident database.

34. The ASRS was established in 1975 under a Memorandum of Agreement between the Federal Aviation Administration and the National Aeronautics and Space Administration. The ASRS collects, analyzes, and responds to voluntarily submitted aviation safety incident reports in order to reduce the likelihood of aviation accidents. Pilots, air traffic controllers, flight attendants, mechanics, ground personnel, and others involved in aviation operations submit reports to the ASRS when they are involved in or observe an incident or situation in which aviation safety was compromised.

35. The age of these passengers ranged from 5 to 84 years, their height ranged from 44 to 81 inches, and their weight ranged from 45 to 285 pounds.

36. As described in Boeing's *Airliner* magazine (April/June 1992), "The APU provides both electrical power and bleed air for the air conditioning system and main engine starting. A torching start may result from excess fuel accumulation in the APU combustor assembly and exhaust duct. The torching start has a characteristic 'orange flash'."

37. Except as provided in Part 139.319(c), Index is determined as follows: If there are five or more average daily departures of air carrier airplanes in a single Index group serving the airport, the longest Index group with an average of five or more daily departures is the Index required for the airport. If there are fewer than five average daily departures in a single Index group serving the airport, the next lower Index from the longest Index group with air carrier airplanes in it is the Index required for the airport.

38. This includes case 46, which was the only case in which off-airport ARFF units were among the first units to assist the airplane.

39. Part 23 contains the airworthiness standards for commuter-category airplanes.

40. Appendix D of this report contains excerpts from 14 CFR Part 25, including Appendix J of Part 25.

41. Sharon A. Barthelmess, *An FAA Analysis of Emergency Evacuation Demonstrations*, SAE Paper 821486 (Warrendale, PA: Society of Automotive Engineers, 1982).

42. National Transportation Safety Board letter dated May 15, 1998, to the FAA Administrator regarding FAA Policy ANM 98–2 (see table 4–1).

43. E.R. Galea, M. Owen, P.J. Lawrence, and L. Filippidis [University of Greenwich], "Computer Based Simulation of Aircraft Evacuation and its Application to Aircraft Safety," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ*, DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).

44. As of January 1, 1999, near the end of the planned data collection period for this study, there were 846 airplanes in operation by regional carriers in the United States that did not require evacuation certification testing.

45. National Transportation Safety Board, *Commuter Airline Safety*, Safety Study NTSB/SS-94/02 (Washington, DC: NTSB, 1994).

46. On July 15, 1996, the Safety Board classified Safety Recommendations A-94-191 and A-94-192 "Closed—Acceptable Action" based on FAA's commuter rule that required scheduled passenger operations in airplanes of 10 or more passenger seats and all turbojets to be conducted according to the requirements of 14 CFR Part 121.

47. Appendix D contains excerpts from 14 CFR 25.807 and a description of all exit types.

48. C.C. Snow, J.J. Carroll, and M.A. Allgood, *Survival in Emergency Escape From Passenger Aircraft*, AM 70-16 (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, 1970).

49. Paul G. Rasmussen and Charles B. Chittum, *The Influence of Adjacent Seating Configurations on Egress Through a Type III Emergency Exit*, DOT/FAA/AM-89/14 (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, 1989).

50. G.A. McLean, C.B. Chittum, G.E. Funkhouser, and others, *Effects of Seating Configuration and Number of Type III Exits on Emergency Aircraft Evacuation*, DOT/FAA/AM-92/27 (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, 1992).

51. (a) G.A. McLean, M.H. George, C.B. Chittum, and G.E. Funkhouser, *Effects of Seat Placement at the Exit, Part I of Aircraft Evacuations Through Type-III Exits*, DOT/FAA/AM-95/22 (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, 1995). (b) G.A. McLean and M.H. George, *Effects of Individual Subject Differences, Part II of Aircraft Evacuations Through Type-III Exits*, DOT/FAA/AM-95/25 (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Medicine, 1995).

52. The Safety Board did not comment on the 1995 rulemaking.

53. The 727 is equipped with four single door liferaft ceiling stowage compartments that contain liferafts when the airplane is being operated as an extended overwater flight. For flights that are not operated over water, the stowage

compartments are usually empty. The 4-foot by 2-foot door panels are hinged along their aft edges and latched along their forward edges; however, the doors were not equipped with any device to prevent them from swinging all the way down and blocking the aisle.

54. Floor level exit doors are labeled with a letter indicating which side the exit is on facing forward and a number indicating the ordinal position the exit from fore to aft. For example, L1 indicates the exit located most forward on the left side of the aircraft.

55. The Safety Board had issued a similar recommendation in 1990 that was applicable only to 747s. That recommendation (A-90-59) was classified "Closed—Acceptable Action" on May 15, 1992, after the FAA issued AD 91-22-05 applicable to 747s. Rather than issue a new recommendation applicable only to 727s, the Safety Board decided to ask the FAA to identify all airplanes with liferaft ceiling stowage compartments.

56. The two flight attendants reported on questionnaires that "nothing worked basically" and both flight attendants indicated that the escape path lighting was not adequate. However, the Safety Board received information from firefighters and passengers that at least some lights were working. The Safety Board's investigation of that accident is continuing.

57. Questionnaires were mailed to passengers in a seventh case (case 27), but all of the passengers who returned questionnaires had used slides at their exits. The remaining 6 of the 13 evacuations for which overwing exit use was known were not included in the detailed investigations; consequently, questionnaires were not mailed to the passengers in those cases.

58. The Type III overwing exit hatch can weigh as much as 65 pounds, have a width of 20 inches, and a height of 36 inches.

59. 14 CFR 121.585 requires each certificate holder to determine the suitability of each person it permits to occupy an exit seat.

60. Exit row passenger tasks are discussed in more detail in the next section.

61. This issue relates to Boeing's intent to increase the passenger count on the 737-600/700/800 series aircraft. The European Joint Aviation Authorities (JAA) determined that they would only agree to an increased passenger count if there was a significant change to the cabin configuration. Boeing developed the new Type III hatch in order to meet the JAA position.

62. The configuration of the Fokker 28 is similar with respect to the aft flight attendant's position away from the overwing exits.

63. Mark George and Cynthia Corbett [CAMI], "Effects of Cabin Crew Location and Passenger Motivation on Aircraft Evacuations," *Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ,* DOT/FAA/AR-99/68, CD-ROM (Federal Aviation Administration, European Joint Aviation Authorities, Transport Canada Civil Aviation, Japanese Civil Aviation Bureau, 1999).

64. The evacuation slides at Type C exits must be automatically erected in 10 seconds.

65. Flight attendants attempted to deploy 44 slides in these 19 evacuations.

66. The FAA provides guidance on checks of inflation bottles in the Air Transportation Operations Inspection Handbook 8400.10.

67. Safety Recommendation A-74-106 was classified "Closed—Acceptable Action" on January 5, 1978, after the FAA commenced special training for its maintenance inspectors on the maintenance, operation, and inspection of emergency evacuation equipment.

68. The flight attendants and passengers initiated the evacuation in case 29, ARFF personnel initiated the evacuation in case 11, and passengers initiated the evacuation in case 16.

69. "Other" generally included unspecified situations that the captain or first officer judges to be a risk to passenger safety.

70. The Safety Board could not determine the level of planning based upon the information reported to the investigator.

71. In the other air carrier flight crew manuals reviewed, the manuals did not discuss the issue of indicating which exits to use during an evacuation.

72. These evacuations are described in the Safety Board's accident/incident database.

73. A widebody aircraft model was used for the simulation runs because that aircraft type was already available within the airEXODUS model. A smaller aircraft type was not available within the evacuation model and would have had to be designed before using it in simulation runs.

74. Requirements pertaining to slide rate are contained in FAA Technical Standard Order C-69c.

75. "Easy victor" is a code phrase for "evacuate" that allows flight attendants to get to their evacuation positions prior to passengers. "Easy victor left" indicates to use the left exits.

76. National Transportation Safety Board, *Flight Attendant Training and Performance During Emergency Situations,* Special Investigation Report NTSB/SIR-92/02 (Washington, DC: NTSB, 1992).

77. As a result of the FAA's actions, the Safety Board classified A-92-74 "Closed—Unacceptable Action on January 23, 1996, and A-92-77 "Closed—Acceptable Action" on July 15, 1996.

78. Safety Recommendation A-74-113 was classified "Closed—Acceptable Action" on September 27, 1977, based on the FAA's issuance of AC 121-24. However, AC 121-24A, issued by the FAA on May 9, 1989, did not address the intent of Safety Recommendation A-85-101, which was consequently classified "Closed—Unacceptable Action" on August 21, 1991.

79. National Transportation Safety Board, *Airline Passenger Safety Education: A Review of Methods Used to Present Safety Information*, Safety Study NTSB/SS-85/04 (Washington, DC: NTSB, 1985).

80. J.K. Caird, B. Wheat, K.R. McIntosh, and R.E. Dewar, "The Comprehensibility of Airline Safety Card Pictorials," *Proceedings, Human Factors and Ergonomics Society 41st Annual Meeting, September 22–26, 1997, Albuquerque, NM* (Santa Monica, CA: Human Factors and Ergonomics Society, 1997) 801–805.

81. N.C. Silver and C.N. Perlotto, "Comprehension of Aviation Safety Pictograms: Gender and Prior Safety Card Reading Influences," *Proceedings, Human Factors and Ergonomics Society 41st Annual Meeting, September 22–26, 1997, Albuquerque, NM* (Santa Monica, CA: Human Factors and Ergonomics Society, 1997) 806–810.

82. Safety Recommendation A-85-94 was classified "Closed—Acceptable Action" on February 19, 1992.

83. H.C. Muir and A.M. Cobbett, *Influences of Cabin Crew During Emergency Evacuations at Floor Level Exits*, CAA Paper 95006: Part A; FAA No. DOT/FAA/AR-95/52 (London: Civil Aviation Authority, 1996).

84. This evacuation was not one of the study cases; it occurred when analysis of study data was underway.

85. A passenger reported that the slide failed; however, the slide had not been armed.

86. National Transportation Safety Board, *Safety Aspects of Emergency Evacuations from Air Carrier Aircraft*, Special Study NTSB/AAS-74/03 (Washington, DC: NTSB, 1974).

87. Delta Air Lines 727 APU torch in Chicago on January 17, 1992, National Transportation Safety Board accident brief CHI93LA043 (1994).

88. Based on the FAA's action, the Safety Board classified Safety Recommendation A-93-125 "Closed—Acceptable Action" on July 3, 1995.

89. Because the revised AC met the intent of Safety Recommendations A-98-41 and A-98-42, on December 9, 1999, and November 16, 1999, the Safety Board classified these recommendations "Closed—Acceptable Alternate Action" and "Closed—Acceptable Action," respectively.

90. Personal communication on May 8, 2000, with the president of the ARFF working group.

91. Not one of the flight attendants who returned a questionnaire indicated using a megaphone; therefore, the Safety Board did not evaluate the effectiveness of megaphones for this study.

92. National Transportation Safety Board, *Uncontained Engine Failure, Delta Air Lines Flight 1288, McDonnell Douglas MD-88, N927DA, Pensacola, Florida, July 6, 1996*, Aircraft Accident Report NTSB/AAR-98/01 (Washington, DC: NTSB, 1998).

93. This incident was not one of the study cases; it occurred after analysis of the study data was underway.

94. National Transportation Safety Board, *In-flight Fire and Impact With Terrain, ValuJet Airlines Flight 592, DC-9-32, N904VJ, Everglades, Near Miami, Florida, May 11, 1996*, Aircraft Accident Report NTSB/AAR-97/06 (Washington, DC: NTSB, 1997).

95. Evacuations using normal egress means do not have to be reported to the National Transportation Safety Board.

96. There are 272 Saab 340s and 222 CRJs in operation in the United States.

97. The Safety Board is aware through communication with a representative of Walter Kidde, the manufacturer of the smoke detectors on CRJs, that a newly designed smoke detector designed to reduce the occurrence of false smoke indications will be installed on the 400 series of the CRJ. Because this aircraft has not yet completed certification, the effectiveness of this new smoke detector design in the operating environment has not been determined.

Appendix A

Previous Safety Recommendations Relevant to Cabin Safety

The recommendations presented in this appendix appear in sequence by safety recommendation number. They are listed below according to the overall cabin safety issues they address.

Crew Training: A-85-101, A-91-6, A-92-72, A-92-74, A-92-77, A-94-200, A-96-83, A-96-148, A-97-6.

Aircraft Equipment: A-68-31, A-72-84, A-72-133, A-72-141, A-73-42, A-73-53, A-74-105, A-74-106, A 74-107, A-74-108, A-74-111, A-81-21, A-81-129, A-81-130, A-83-79, A-88-37, A-88-107, A-90-95, A-92-78, A-96-82, A-96-84, A-96-138, A-97-1, A-97-84, A-97-103, A-97-104, A-97-105, A-98-22, A-98-23, A-99-10, A-99-100, A-99-101.

Passenger Safety Briefings: A-67-16, A-70-55, A-72-128, A-74-112, A-74-113, A-83-45, A-85-93, A-85-94, A-85-95, A-85-96, A-85-97, A-85-98, A-85-103, A-88-128, A-91-52, A-91-53, A-93-125, A-96-140.

Fire-blocking Materials: A-83-78, A-93-18, A-93-149, A-93-150, A-97-56.

Aircraft Rescue and Firefighting: A-83-84, A-83-87, A-84-32, A-84-34, A-84-35, A-91-32, A-95-77, A-97-107, A-97-108, A-98-41, A-98-42.

Safety Recommendation No.: A-67-16
Date Issued: April 17, 1967
Recommendation:

It is recommended that all passengers be made aware of the procedures required to move the seats out of the way of the window exits. Further, it is recommended that airlines utilizing movable partitions between passenger compartments assure that the overhead signs are properly placed to depict the exact location of the window exits and that the flight attendants be required to indicate where each emergency exit is located during the pre-takeoff briefing.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-68-31
Date Issued: November 4, 1968
Recommendation:

(1) Air carriers be required to have the retainer bar for all door-mounted slides placed in position for slide deployment at the floor-level emergency exits prior to the aircraft's departure from the ramp for flight. (2) FAA inspectors review all printed cards used by the air carriers to supplement the oral briefing to ensure that they include clear instructions showing the direction passengers should take upon leaving the wing whenever over-the-wing exits are used for evacuating the aircraft. (3) All air carriers re-emphasize, through their crew training programs, the basic philosophy of emergency evacuation that all cabin exits that are not jumped, blocked by fire, or otherwise rendered unusable (including ventral stairs) should be used to the extent reasonably possible.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-70-55
Date Issued: October 29, 1970
Recommendation:

Ensure that no flight requiring the briefing of passengers regarding emergency procedures be dispatched without an operable public address system. The system should be functioning so that the flight deck crew can speak to the passengers and a cabin attendant can speak to the passengers from at least one cabin station.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-72-84
Date Issued: July 6, 1972
Recommendation:

Require self-illuminated handles for all Type I and Type A exits.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-72-128
Date Issued: August 28, 1972
Recommendation:

Revise Federal Aviation Regulation 121.571 to state that the appropriate crewmember must physically point out the location of all emergency exits on each aircraft prior to each takeoff. As a general rule, passengers do not listen to the oral announcements. This was testified to during the public hearing relative to this accident. However, passengers will tend to watch a flight attendant who physically points out the area of exits and will retain therefore a general idea of the location of such exits particularly those nearest to them.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-72-133
Date Issued: August 28, 1972
Recommendation:

Present provisions for emergency exit lights for utilization during darkness or smoke conditions be evaluated. During darkness or smoke conditions, it is vitally important to have some form of light available to direct and conduct emergency evacuations as well as to read operating instructions. Surviving passengers indicated that the cabin was dark, and exits were difficult to see.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-72-141
Date Issued: August 31, 1972
Recommendation:

Require all air carrier aircraft to be equipped with an audio and visual evacuation alarm system. This system should be capable of being activated in the cockpit and at each flight attendant's station. The alarm system should be self-powered so that interruption of the aircraft electrical systems will not interfere with use of the evacuation alarm.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-73-42
Date Issued: June 25, 1973
Recommendation:

Amend 14 CFR 25.812 to require exit sign brightness and general illumination levels in the passenger cabin that are consistent with those necessary to provide adequate visibility in conditions of dense smoke.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-73-53
Date Issued: August 10, 1973
Recommendation:

Amend the existing certification and operating rules for air carrier and air taxi aircraft to include provisions requiring tactile guidance and improved visual guidance to emergency exits, as well as more efficient methods of indicating the location of emergency exits in a dark or smoke environment.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-74-105
Date Issued: January 5, 1975
Recommendation:

Require that air carriers report all emergency evacuation slide deployments, failures, and malfunctions to the FAA.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-74-106
Date Issued: January 5, 1975
Recommendation:

Develop a maintenance surveillance program to insure greater reliability of emergency evacuation slide systems.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-74-107
Date Issued: January 5, 1975
Recommendation:

Amend 14 CFR 25.809 to require that the length of the emergency evacuation slides be such that the angle with the ground renders the slide safe and usable after collapse of one leg, or more, of the landing gear, and amend 14 CFR 121.310 to require that these new slides be installed after a reasonable date.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-74-108
Date Issued: January 5, 1975
Recommendation:

Amend 14 CFR 121.310 to require, after a reasonable date, that emergency evacuation slides on all floor-level exits be automatically inflated upon deployment.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-74-111
Date Issued: January 1, 1975
Recommendation:

Amend 14 CFR 121.318 to require after a reasonable date, that public address systems be capable of operating on a power source independent of the main aircraft power supply.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-74-112
Date Issued: January 5, 1975
Recommendation:

Require that air carrier passengers be alerted, during pretakeoff briefings, of the need to familiarize themselves with the procedures involved in the operation of emergency exits.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Alternate Action

Safety Recommendation No.: A-74-113
Date Issued: January 5, 1972
Recommendation:

Issue an advisory circular which would provide standardized guidance to the air transport industry on effective methods and techniques for conveying safety information to passengers.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-81-28
Date Issued: March 20, 1981
Recommendation:

Amend 14 CFR 23.783, 14 CFR 23.807(b)(3), and 14 CFR Part 91 to require external doors and emergency exits of aircraft to be conspicuously marked on the outside with directions for opening the door.

Recipient(s): Federal Aviation Administration
Status: Closed—Superseded

Safety Recommendation No.: A-81-129
Date Issued: September 30, 1981
Recommendation:

Require the installation of an independently powered evacuation alarm system in passenger-carrying aircraft.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-81-130
Date Issued: September 30, 1981
Recommendation:

Promptly adopt the final rule as proposed in FAA's Notice of Proposed Rulemaking No. 81-1—to have the public address system on passenger-carrying aircraft capable of operating from a power source independent of the main electrical generating system without jeopardizing the in-flight emergency electrical power system.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-83-45
Date Issued: July 12, 1983
Recommendation:

Sponsor a government/industry task force open to foreign participants made up of representatives from the airplane manufacturers, air carrier and commuter operators, researchers, flight attendants, and consumers (1) to identify the type of safety information that is most useful and needed by passengers, (2) to identify and develop improved instructional concepts for conveying the safety information, and (3) to recommend appropriate changes to the operating requirements regarding passenger oral briefings and information briefing cards.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-83-78
Date Issued: October 31, 1983
Recommendation:

Expedite the rulemaking action to require at the earliest possible date that passenger seats with fire-blocking materials be installed in transport-category airplanes.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-83-79
Date Issued: October 31, 1983
Recommendation:

Expedite the rulemaking action to require at the earliest possible date that cabin emergency lighting be installed for optimum effectiveness during passenger evacuation from smoke-filled cabins.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-83-84
Date Issued: December 12, 1983
Recommendation:

Require that airport operations manuals (AOM) contain explicit instructions and procedures for the reporting of any known change in the operating status of the airport crash/fire/rescue (CFR) equipment to backup fire departments providing CFR services and that all airport or airport tenant employees who may be required to operate airport CFR equipment be knowledgeable of the instructions and procedures.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-83-87
Date Issued: December 22, 1983
Recommendation:

Issue appropriate notices and instructions to airport inspectors to encourage the operators of Index A and B airports, as well as State airport officials, to provide hands-on fire fighting training to airport tenants.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-84-32
Date Issued: April 16, 1984
Recommendation:

Revise 14 CFR 139.49(h) to require a minimum of two firefighters per vehicle and to specifically define minimum standards for training of crash-fire-rescue personnel.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Alternate Action

Safety Recommendation No.: A-84-34
Date Issued: April 16, 1984
Recommendation:

Amend 14 CFR 139.55 to require a full-scale demonstration of certificated airport emergency plans and procedures at least once every 2 years, and to require an annual validation of notification arrangements and coordination agreements with participating parties.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Alternate Action

Safety Recommendation No.: A-84-35
Date Issued: April 16, 1984
Recommendation:

Incorporate in any 14 CFR Part 139 rulemaking proposal calling for a reduction in crash-fire-rescue capability at Index A and B airports a list of affected airports, a list of types and schedules of air carrier aircraft serving these airports, and a description of the effect of such a reduction on the fire fighting posture of the airports.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-85-93
Date Issued: December 17, 1985
Recommendation:

Develop test methods to improve passenger motivation to listen to safety information.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-85-94
Date Issued: December 17, 1985
Recommendation:

Develop tests and standards which describe the minimum level of acceptable comprehension and performance to measure whether persons who represent typical passengers understand the safety information presented during oral briefings and demonstrations, on safety cards, and in videotaped briefings, and whether these persons actually are able to perform the actions described, such as using supplemental oxygen systems, using life preservers, and opening of exits.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-85-95
Date Issued: December 17, 1985
Recommendation:

Revise, based on the results of testing of passenger comprehension of safety information and performance of emergency procedures, the Advisory Circular entitled "Passenger Safety Information Briefings and Briefing Cards" (AC-121-24, dated June 23, 1977, and AC-135-12, dated October 9, 1984) to include improved guidelines on the content and presentation methods used in oral and videotaped safety briefings, and for pictorial and printed information on safety cards.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-85-96
Date Issued: December 17, 1985
Recommendation:

Revise, based on the results of testing of passenger comprehension of safety information and performance of emergency procedures, Air Carrier Operations Handbooks and Bulletins and air carrier inspection training programs to include instruction to prepare FAA inspectors to provide better guidance to airlines when assisting them in improving the content and presentation of passenger safety information to their passengers.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-85-97
Date Issued: December 17, 1985
Recommendation:

Revise Advisory Circulars 121-24, dated June 23, 1977, and 135-12, dated October 9, 1984, to provide guidelines covering

the following items in briefings and demonstrations: adults donning oxygen masks before placing masks on accompanying children; fastening an adult size life preserver or personal flotation device on a child; and brace positions for children. As an interim measure, issue an Air Carrier Operations Bulletin to assist FAA inspectors in providing better guidance to airlines.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-85-98
Date Issued: December 17, 1985
Recommendation:

Amend 14 CFR 121 to require pre-landing safety announcements to reinforce the pre-takeoff briefings on release of seatbelts, the location of exits, the location and operation of life preservers (in the case of overwater landings), and to urge passengers to refer to safety cards prior to landing.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-85-101
Date Issued: December 17, 1985
Recommendation:

Require that recurrent flight attendant training programs contain instructions on the use of the public address system and techniques for maintaining effective safety briefings and demonstrations which will improve the motivation of passengers to pay attention to the oral briefings and to the demonstrations.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-85-103
Date Issued: December 17, 1985
Recommendation:

Develop a program to test the feasibility, effectiveness, and passenger acceptance of providing safety briefing information in airport terminal gate areas, and of providing printed safety information on or inside ticket envelopes.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-88-37
Date Issued: March 15, 1998
Recommendation:

Coordinate an industry working group to develop a combined puncture/tear test that can be used to establish new strength requirements for evacuation slide materials.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-88-107
Date Issued: September 21, 1988
Recommendation:

Revise Technical Standard Order (TSO)-C69, *Emergency Evacuation Slides, Ramps, and Slide/Raft Combinations*, to require standard text for emergency handle placards, e.g., "PULL TO INFLATE," and to require that the text on the placard be located as close to the appropriate manual handle as possible.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-88-128
Date Issued: October 24, 1988
Recommendation:

Instruct principal operations inspectors to determine if passenger safety cards and flight attendant instructions to passengers for emergency evacuations are consistent with each air carrier's evacuation procedures.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-90-95
Date Issued: June 25, 1990
Recommendation:

Require air carriers to implement procedures requiring that all emergency lighting be illuminated during an evacuation.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-91-6
Date Issued: January 8, 1991
Recommendation:

Require operators of DC-9/MD-80 series airplanes to include in their flightcrew and flight attendant training programs the Safety Board's findings regarding the tailcone manual release system and tailcone familiarization tours and hands-on training on the operation of the release handle in DC-9/MD-80 airplanes using actual airplanes or FAA-approved simulators.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-91-32
Date Issued: July 19, 1991
Recommendation:

Establish and oversee a working group, consisting of at least the Airport Operators Council International, the American Association of Airport Executives, air carrier associations, the Aerospace Industries Association, and the National Fire Protection Association, to conduct an in-depth survey of 14 CFR Part 139 certificated airports to determine the adequacy and timely dissemination of aircraft "crash crew" type publications used by aircraft rescue and fire fighting personnel, and after reviewing the survey information, take action as needed to improve the content of such publications and the methods for disseminating them.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Alternate Action

Safety Recommendation No.: A-91-52
Date Issued: July 19, 1991
Recommendation:

Request member air carriers to depict floor proximity emergency escape path marking systems on passenger safety briefing cards and to include descriptions of the location and operation of the systems during flight attendant oral safety briefings.

Recipient(s): Regional Airlines Association
Status: Closed—Acceptable Action

Safety Recommendation No.: A-91-53
Date Issued: July 19, 1991
Recommendation:

Request member air carriers to depict floor proximity emergency escape path marking systems on passenger safety briefing cards and to include descriptions of the location and operation of the systems during flight attendant oral safety briefings.

Recipient(s): Air Transport Association
Status: Closed—Acceptable Action

Safety Recommendation No.: A-92-72
Date Issued: August 12, 1992
Recommendation:

Ensure that flight attendant training and procedures for each type of airplane include appropriate consideration of the training and procedures used during joint Part 25 and Part 121 certification evacuation demonstrations.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-92-74
Date Issued: August 12, 1992
Recommendation:

Amend 14 CFR Part 121.417 to require an evacuation and/or wet ditching drill group exercise during recurrent training. Ensure that all reasonable attempts are made to conduct joint flightcrew/flight attendant drills, especially for crewmembers operating on airplanes with two-person cockpit crews.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-92-77
Date Issued: August 12, 1992
Recommendation:

Require that flight attendants receive Crew Resource Management training that includes group exercises in order to improve crewmember coordination and communication.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-92-78
Date Issued: August 12, 1992
Recommendation:

Amend the Federal Aviation Regulations to include ergonomic design requirements for cabin safety equipment, including emergency exits.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-93-18
Date Issued: March 8, 1993
Recommendation:

Research the effect of aging upon the self-extinguishing ability of cabin interior furnishings and test furnishings that were certified to 14 CFR 25.853(a)(1) to determine if they comply with the self-extinguishing requirements. Interior furnishings that fail to comply with 14 CFR 25.853(a)(1) should be immediately replaced with materials that comply with 14 CFR 25.853, Appendix F.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-93-125
Date Issued: October 14, 1993
Recommendation:

Issue an Air Carrier Operations Bulletin to require that Boeing 727 cockpit crewmembers make a public address

announcement about auxiliary power unit (APU) starts immediately prior to starting the APU.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-93-149
Date Issued: November 10, 1993
Recommendation:

Amend 14 CFR 25.853 to include a requirement to test the fire-retardant properties of fire blocking materials after they have been subjected to in-service wear.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-93-150
Date Issued: November 10, 1993
Recommendation:

Conduct research upon the effects of actual in-service wear on the continued airworthiness of fire-blocking materials. Based on the findings, require periodic actual in-service tests of fire-blocking materials to verify compliance with the requirements of 14 CFR 25.853.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-94-200
Date Issued: November 30, 1994
Recommendation:

Revise the Federal Aviation Regulations to require all fight attendants to participate, during recurrent training, in emergency drills that allow them the opportunity to use emergency equipment and to practice procedures under simulated emergency conditions.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-95-77
Date Issued: July 17, 1995
Recommendation:

Require that all 14 CFR 139 certificated airports identify gates that aircraft rescue and fire fighting personnel and their equipment might need to access while responding to emergencies, and make the necessary changes to ensure that emergency personnel and their equipment can pass through these gates without hesitation or delay. Additionally, the gates that are identified and the procedures required to access them should be included in the Airport Emergency Plan.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-96-82
Date Issued: September 9, 1996
Recommendation:

Require that all transport-category aircraft manufactured before November 27, 1990, be retrofitted with a public address system capable of operating on an independent power source.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-96-83
Date Issued: September 9, 1996
Recommendation:

Emphasize to principal operations inspectors the importance of thoroughly reviewing flight attendant training programs before approving them and flight attendant manuals before accepting them.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-96-84
Date Issued: September 9, 1996
Recommendation:

Provide guidance on how to implement the requirement that occupants who are more than 24 months old are restrained during takeoffs, landings, and during turbulence.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-96-138
Date Issued: December 3, 1996
Recommendation:

Require all operators to inspect immediately all MD-80 and DC-9 floor level exits to ensure that evacuation slides have been properly rigged.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-96-140
Date Issued: December 3, 1996
Recommendation:

Develop a uniform policy on shoe removal during evacuations, and require that all operators train their flight attendants to

issue commands during an emergency evacuation consistent with that policy.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-96-148
Date Issued: December 20, 1996
Recommendation:

Amend Advisory Circular 120-51B (crew resource management training) to include guidance regarding the communication of time management information among flight and cabin crewmembers during an emergency.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-97-1
Date Issued: January 3, 1997
Recommendation:

Immediately issue a telegraphic airworthiness directive directing all Beechcraft 1900 operators to (1) conspicuously identify the external air stair exit door button with highly visible markings, (2) indicate that the button must be depressed while the handle is rotated, and (3) include an arrow to show the direction that the handle must be moved to open the door.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-97-6
Date Issued: February 18, 1997
Recommendation:

Require all principal operations inspectors of 14 CFR Part 121 carriers to ensure that crew resource management programs provide pilots with training in recognizing the need for, and practice in presenting, clear and unambiguous communications of flight-related concerns.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-97-56
Date Issued: September 9, 1997
Recommendation:

Expedite final rulemaking to require smoke detection and fire suppression systems for all class D cargo compartments.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-97-84
Date Issued: August 29, 1997
Recommendation:

Identify Part 139 airports that have irregular runway light spacing, evaluate the potential hazards of such irregular spacing, and determine if standardizing runway light spacing is warranted.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-97-95
Date Issued: August 29, 1997
Recommendation:

Require all 14 CFR Part 121 and 135 operators to review their flight attendant training programs and emphasize the need for flight attendants to aggressively initiate their evacuation procedures when an evacuation order has been given.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-97-103
Date Issued: September 12, 1997
Recommendation:

Evaluate the propensity of Beech 1900C door/frame system to jam when it sustains minimal permanent door deformation and, based on the results of that evaluation, require appropriate design changes.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-97-104
Date Issued: September 12, 1997
Recommendation:

Establish clear and specific methods for showing compliance with the freedom from jamming certification requirements.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-97-105
Date Issued: September 12, 1997
Recommendation:

Consider the circumstances of the November 19, 1996, Quincy, Illinois, accident when developing methods for showing compliance with freedom from jamming requirements, and determine whether it is feasible to require that doors be shown to be free from jamming after an impact of similar severity.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-97-107
Date Issued: September 12, 1997
Recommendation:

Develop ways to fund airports that are served by scheduled passenger operations on aircraft having 10 or more passenger seats, and require these airports to ensure that aircraft rescue and fire fighting units with trained personnel are available during commuter flight operations and are capable of timely response.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-97-108
Date Issued: September 12, 1997
Recommendation:

Add to the Safety Information Section of the FAA's Internet Home Page a list of airports that have scheduled air service but do not have aircraft rescue and fire fighting capabilities.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-97-125
Date Issued: January 9, 1998
Recommendation:

Modify the service difficulty reporting system so that it contains more complete and accurate information about component failures; for example, (a) revise the various Service Difficulty Report (SDR) forms and database to include cycles and times since last inspection for failed components; (b) relate to the operators who submit SDRs the need for complete and accurate information when they report component failures; and (c) remind Federal Aviation Administration inspectors assigned to Part 121 and Part 135 operators of their need to review the component failure reports for accuracy and completeness.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-98-22
Date Issued: March 4, 1998
Recommendation:

Require that all newly manufactured passenger-carrying airplanes operated under 14 *Code of Federal Regulations* Part 121 be equipped with independently powered evacuation alarm systems operable from each crewmember station, and establish procedures and provide training to flight and cabin crews regarding the use of such systems.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-98-23
Date Issued: March 4, 1998
Recommendation:

Require that all newly manufactured airplanes be equipped with cockpit indicators showing open exits, including overwing exit hatches, and that these cockpit indicators be connected to emergency power circuits.

Recipient(s): Federal Aviation Administration
Status: Closed—Unacceptable Action

Safety Recommendation No.: A-98-41
Date Issued: June 25, 1998
Recommendation:

Establish a designated radio frequency at all airports certified under Title 14 CFR Part 139 that allows direct communication between airport rescue and firefighting (ARFF) personnel and flightcrew members in the event of an emergency and take appropriate measures to ensure that air traffic control personnel, ARFF personnel, and pilots are aware of its designation.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Alternate Action

Safety Recommendation No.: A-98-42
Date Issued: June 25, 1998
Recommendation:

Develop a universal set of hand signals for use between airport rescue and fire fighting personnel and flight crews and flight attendants for situations in which radio communication is lost.

Recipient(s): Federal Aviation Administration
Status: Closed—Acceptable Action

Safety Recommendation No.: A-99-10
Date Issued: February 19, 1999
Recommendation:

Identify all airplanes operated under Title 14 *Code of Federal Regulations* Part 121 with liferaft ceiling stowage compartments or compartments that formerly stored liferafts that open downward and issue an airworthiness directive to limit the distance that those compartments can open.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response

Safety Recommendation No.: A-99-100
Date Issued: December 9, 1999
Recommendation:

For a 12-month period, require that all operators of transport-category aircraft demonstrate the on-airplane operation of all emergency evacuation systems (including door opening assist mechanisms and slide or slide/raft deployment) on 10 percent of each type of airplane (minimum of one airplane per type) in their fleets. These demonstrations should be conducted on an airplane in a controlled environment so that the entire evacuation system can be properly evaluated by qualified personnel. The results of the demonstrations (including an explanation of the reasons for any failures) should be documented for each component of the system and should be reported to the FAA.

Recipient(s): Federal Aviation Administration
Status: Open—Unacceptable Response

Safety Recommendation No.: A-99-101
Date Issued: December 9, 1999
Recommendation:

Revise the requirements for evacuation system operational demonstrations and maintenance procedures in air carrier maintenance programs to improve the reliability of evacuation systems on the basis of an analysis of the demonstrations recommended in A-99-100. Participants in the analysis should include representatives from aircraft and slide manufacturers, airplane operators, and crewmember and maintenance associations.

Recipient(s): Federal Aviation Administration
Status: Open—Acceptable Response♦

Appendix B

Summary of the Evacuation Cases Investigated for the Study

Case No. 1

Date of Evacuation: September 24, 1997
Location: Salt Lake City, Utah
Air Carrier: Frontier Airlines
Aircraft Type: Boeing 737
Number of Passengers: 66
Description:

After takeoff from Salt Lake City, the captain advised the other crewmembers that there was a system failure and they should "be prepared for anything." The airplane turned back to Salt Lake City. The flight attendants reported that the landing appeared fast and that the airplane took a long time to slow down. After landing, the airplane took a sharp turn to the right, began bumping, tilted right, and then stopped. When the airplane came to a stop, the captain announced over the public address system, "Flight attendants evacuate." The flight attendants unbuckled their seat belts and then opened floor level exit doors (L1, R1, R2). The escape slides immediately inflated. The flight attendants reported that most passengers wanted to take carry-on baggage including guitars, crutches, and cases. The flight attendants confiscated the passenger baggage. Many passengers argued with the flight attendants and became forceful. No fire or smoke was apparent. One flight attendant sustained a minor injury using a slide.

Case No. 2

Date of Evacuation: November 4, 1997
Location: Sterling, Virginia
Air Carrier: Atlantic Coast Airlines
Aircraft Type: British Aerospace Jetstream 3100
Number of Passengers: 2
Description:

After the flight crew noticed in flight a "glow" and an electrical burning smell emanating from the communication control station panel, the captain decided to return to Dulles International Airport. After landing, the airplane taxied off the runway, and the passengers and crew evacuated using an airplane door. ARFF personnel found no evidence of fire. There were no injuries reported to the Safety Board.

Case No. 3

Date of Evacuation: November 7, 1997
Location: Charlotte, North Carolina
Air Carrier: US Airways
Aircraft Type: Fokker 100
Number of Passengers: 99
Description:

The airplane landed normally, but then experienced a failure and separation of its right main landing gear. The first officer called the tower controller to report that the airplane had stopped on the runway and asked if there was any fire on the airplane. The tower responded, "No." Because of lack of fire, the captain ordered an evacuation through the R1 exit only. A flight attendant opened the door and inflated the slide. A passenger opened the overwing window exit at seat 12F prior to the evacuation notice but went forward after hearing the evacuation announcement. At the exit, the flight attendant was commanding, "Sit and slide." After 10–15 passengers evacuated, the first officer at the bottom of the slide noticed fire on the left main gear and ordered the right window exits to be used also. A passenger opened the overwing window exit at seat 11F. The flight attendants reported that many passengers attempted to take their belongings. There were no reported injuries. The only reported equipment problem was condensation that covered the viewer for assessing conditions outside the R1 door.

Case No. 4

Date of Evacuation: December 19, 1997
Location: San Francisco, California
Air Carrier: Alaska Airlines
Aircraft Type: McDonnell Douglas MD-80
Number of Passengers: 69
Description:

The airplane was taxiing to the gate when fumes and mist began to enter the cabin. The smoke quickly filled the cabin, reducing visibility and causing respiratory distress for passengers and the crew. The captain stopped the airplane on a taxiway and ordered an evacuation using the public address system. All exits were opened and slides were deployed. No problems were reported but all flight attendants commented on having to divest passengers of carry-on baggage. The flight attendants indicated a concern that baggage could block the path to the exit. Flight attendants also commented on how useful their flashlights were during the evacuation. There were eight minor injuries reported to the Safety Board.

Case No. 5

Date of Evacuation: December 25, 1997
Location: Eugene, Oregon
Air Carrier: United Airlines

Aircraft Type: Boeing 737
Number of Passengers: 100
Description:

While the airplane was standing at the gate, passengers were in the process of deplaning when ground personnel signaled the captain that there was a fire in the No. 2 engine. The captain ordered an evacuation. The flight crew then performed the checklist procedures. About 20 passengers exited the R2 exit via the slide. About 20 passengers more exited via the left and right overwing exits. The slide at exit L2 had already been disarmed, and the slide did not operate. During the evacuation, the captain noticed that the fuel lever was in the idle position and when he retarded it to "off," the smoke stopped coming from the engine. The captain then stopped the evacuation. No injuries were reported to the Safety Board.

Case No. 6

Date of Evacuation: January 21, 1998
Location: Windsor Locks, Connecticut
Air Carrier: Continental Express
Aircraft Type: Avions de Transport Regional ATR-42
Number of Passengers: 36
Description:

During the landing roll, the flight crew heard a loud bang and saw an orange glow from the right side of the airplane. After the airplane had stopped, the flight crew attempted to extinguish the fire from the cockpit. The fire was not extinguished so the captain ordered an evacuation of the airplane using only the left exits. The flight attendant opened the main cabin door and the first officer opened the overwing exit. Passengers attempted to take carry-on baggage. One minor injury was reported to the Safety Board.

Case No. 7

Date of Evacuation: January 22, 1998
Location: Peoria, Illinois
Air Carrier: Trans States Airlines
Aircraft Type: Avions de Transport Regional ATR-72
Number of Passengers: 10
Description:

While in flight, the flight crew received an indication of a fire on the right engine. The captain used the fire bottle, but the indication stayed on. After landing, the captain used the second fire bottle and the indication went out. The captain initiated an evacuation on the left side of the airplane. The evacuation was conducted via the main cabin door. No injuries were reported to the Safety Board.

Case No. 8

Date of Evacuation: February 9, 1998
Location: Honolulu, Hawaii
Air Carrier: Hawaiian Airlines
Aircraft Type: McDonnell Douglas DC-9
Number of Passengers: 139
Description:

During the takeoff roll, the flight crew felt and heard loud vibrations. The captain aborted the takeoff. The tower then reported a fire on the right side, and the flight crew ordered an evacuation using the forward exits. During the evacuation, the R1 slide did not deploy. The investigation revealed that the inflation bottle was not charged. The airline reported confusion over who had responsibility for performing the daily checks of the inflation bottle. The airstairs were deployed for the L1 exit after the flight attendant heard there was no fire. Passengers and crew deplaned without incident. No injuries were reported to the Safety Board.

Case No. 9

Date of Evacuation: February 9, 1998
Location: Chicago, Illinois
Air Carrier: American Airlines
Aircraft Type: Boeing 727
Number of Passengers: 115
Description:

The airplane landed short of the runway threshold while attempting a landing in fog. The captain reported issuing the "easy victor" command, but the flight attendants did not hear this command because the public address system and radios were damaged in the impact. A liferaft storage bin door that opened upon impact blocked the L1 exit. Further, oxygen masks deployed, and two passengers reported seeing other passengers putting on masks. One flight attendant reported having to rock the R2 door to get the slide out. Another flight attendant reported a passenger helped her open the L2 exit by kicking the door. While the passengers was evacuating, one airplane landed on the runway and another airplane performed a "touch and go" after seeing debris on the runway. Twenty-three minor injuries were reported to the Safety Board.

Case No. 10

Date of Evacuation: February 12, 1998
Location: Arlington, Virginia
Air Carrier: Delta Air Lines
Aircraft Type: McDonnell Douglas MD-88
Number of Passengers: 49
Description:

While taxiing, the flight crew received a report from another airplane that flames were coming from the No. 2 engine.

Thirteen passengers evacuated via the L1 slide before the flight crew halted the evacuation. The 13 passengers were reboarded and the airplane was towed to the gate. No injuries were reported to the Safety Board.

Case No. 11

Date of Evacuation: February 22, 1998
Location: Lawton–Fort Sill, Oklahoma
Air Carrier: American Eagle
Aircraft Type: Saab 340
Number of Passengers: 3
Description:

In flight, the flight crew smelled an odor of electrical burning and noticed the gear control circuit breaker had popped. The flight crew lowered the gear and received an unsafe gear indication for the main gear. After three flybys of the tower could not determine the status of the gear, the flight crew told the flight attendant the problem but did not brief the passengers. ARFF units were waiting along the runway for the airplane. Upon landing, the left main gear collapsed and the airplane left the runway. ARFF crewmembers opened the left overwing exit and passengers evacuated. No injuries were reported to the Safety Board.

Case No. 12

Date of Evacuation: March 27, 1998
Location: Chicago, Illinois
Air Carrier: Air Canada
Aircraft Type: McDonnell Douglas DC-9
Number of Passengers: 27
Description:

During taxi prior to takeoff, the flight crew smelled smoke in the cockpit and called for the lead flight attendant to enter the cockpit to verify the smoke. Flames and smoke were observed to be coming from the overhead console. The flight crew then issued the evacuation command directly to the flight attendant in the cockpit. The flight attendant called for passengers to evacuate using the forward two exits. He opened both doors and the slides deployed. The flight attendant commanded passengers to "sit and slide." The flight attendant decided to evacuate forward to minimize injury from overwing exits. No injuries were reported to the Safety Board.

Case No. 13

Date of Evacuation: March 30, 1998
Location: Ft. Lauderdale, Florida
Air Carrier: Royal Airlines
Aircraft Type: Boeing 727
Number of Passengers: 188
Description:

During the takeoff roll, the captain stated he felt a thud and observed the engine fail and engine fire lights illuminate for the No. 2 engine. He rejected the takeoff and brought the airplane to a stop on the runway where he ordered an evacuation. The flight attendants were able to open all four doors, and all slides deployed normally. The passengers opened all four overwing exits. The first officer left the airplane via the cockpit window and noticed many passengers standing on the wing heading toward the wingtip. The first officer then directed passengers to the back of the wing and assisted them off the wing. There were 14 minor injuries reported, and 3 passengers sustained serious injuries getting off the wing.

Case No. 14

Date of Evacuation: April 15, 1998
Location: Indianapolis, Indiana
Air Carrier: Chautauqua Airlines
Aircraft Type: British Aerospace Jetstream 3100
Number of Passengers: 6
Description:

The flight crew was advancing the propeller levers to take off when they received a fire warning indication for the left engine. They aborted the takeoff and declared an emergency with air traffic control (who contacted ARFF). The airplane proceeded to a taxiway. The first officer went to the cabin and opened the right overwing exit. All passengers and crew used this exit. No injuries were reported to the Safety Board.

Case No. 15

Date of Evacuation: April 18, 1998
Location: Worcester, Massachusetts
Air Carrier: United Express
Aircraft Type: British Aerospace Jetstream 4100
Number of Passengers: 29
Description:

After departure, the belly (POD) baggage compartment fire warning light illuminated. The airplane returned to the airport and landed. The crew and the passengers evacuated onto the taxiway via the entry stairs. The ARFF inspection revealed no fire. No injuries were reported to the Safety Board.

Case No. 16

Date of Evacuation: April 20, 1998
Location: Chicago, Illinois
Air Carrier: American Airlines
Aircraft Type: Boeing 727
Number of Passengers: 149
Description:

While the airplane was at the gate, the auxiliary power unit (APU) torched during start. Passengers saw the flame and proceeded to begin an uncommanded evacuation. The left

overwing exits were opened by passengers. The aft flight attendant reported passengers moving toward the aft portion of the airplane. She tried to stop the passengers but could not. She also reported attempting to contact the flight crew. She opened the rear airstairs "to avoid the stampede." The flight attendants in the front of the airplane were unaware of why the passengers were evacuating through the jetway and told the flight crew that a problem existed. In the rear of the airplane, two passengers opened the unarmed L2 door and lowered a passenger out of the exit. The flight crew was able to stop the evacuation and ordered passengers to deplane using the aft airstairs. Passengers on the wing who were unwilling to jump to the ground reentered the cabin and deplaned via the aft airstairs. Two minor injuries were reported, and one passenger sustained a serious injury as a result of jumping off the wing.

Case No. 17

Date of Evacuation: April 23, 1998
Location: Atlantic City, New Jersey
Air Carrier: US Airways Express
Aircraft Type: de Havilland DHC-8 ("Dash" 8)
Number of Passengers: 19
Description:

The flight was en route when a smoke indication light illuminated for the aft baggage compartment. The flight was diverted and landed safely. The passengers were evacuated from the airplane via the main door. There was no evidence of smoke or fire. No injuries were reported to the Safety Board.

Case No. 18

Date of Evacuation: April 25, 1998
Location: Detroit, Michigan
Air Carrier: Trans World Airlines
Aircraft Type: McDonnell Douglas DC-9
Number of Passengers: 26
Description:

The flight crew aborted takeoff after a failure of the right engine. The airplane was stopped on the runway, and the captain ordered an evacuation through the forward exits. The flight crew indicated that ARFF personnel were unable to indicate the extent of the engine fire. The R1 and L1 exits were opened. Only a few passengers used the R1 exit because the flight attendant was not directing people to it. One minor injury was reported to the Safety Board.

Case No. 19

Date of Evacuation: May 26, 1998
Location: Indianapolis, Indiana
Air Carrier: Northwest Airlines
Aircraft Type: McDonnell Douglas DC-9
Number of Passengers: 101
Description:

The flight crew was in the process of starting the engines just after pushback when a ground crewmember in front of the airplane called the flight crew to report a left engine fire. A flight crewmember proceeded to use the fire bottle for the left engine, which was not on fire. (Each crewmember had a different vantage of the engine.) The flight crew commanded an evacuation using only the forward exits. Passengers in the exit row opened their overwing exits. Both Type III exit hatches were found inside the airplane blocking the exit rows. Ground personnel noticed passengers hesitant to leave the wing and brought a baggage loader belt to the wings to assist passengers off the wings. Passengers insisted on taking carry-on baggage. This created congestion in the front of the airplane so flight attendants began tossing luggage out of the door. One captain, not on the flight, received a minor injury while assisting at the bottom of a slide.

Case No. 20

Date of Evacuation: June 4, 1998
Location: Huntsville, Alabama
Air Carrier: Northwest Airlink
Airplane Type: Saab 340
Number of Passengers: 16
Description:

The baggage compartment smoke indication activated during the climb to cruise altitude. The flight returned to the airport and landed. The airplane was stopped on the runway, and passengers exited using the main cabin door. ARFF personnel found no evidence of a fire. No injuries were reported to the Safety Board.

Case No. 21

Date of Evacuation: June 6, 1998
Location: Evansville, Indiana
Air Carrier: Trans States Airlines
Airplane Type: British Aerospace Jetstream 4100
Number of Passengers: 20
Description:

The airplane took off from Evansville at 9:35 a.m. The captain saw an indication of a cargo fire and declared an emergency and returned to Evansville. The captain taxied the airplane off the runway and commanded "easy victor left" on the taxiway. The flight attendant determined that the forward left exit was unsafe because of a rotating propeller. The flight attendant directed passengers out of the right rear exit. ARFF personnel found no evidence of a fire. One passenger sustained bruised ribs jumping from the exit.

Case No. 22

Date of Evacuation: June 28, 1998
Location: Newark, New Jersey

Air Carrier: Continental Express
Aircraft Type: Avions de Transport Regional ATR-42
Number of Passengers: 45
Description:

The airplane taxied almost directly downwind for departure. The high ambient temperature and a strong surface wind caused hot exhaust gases to become trapped in the nacelle area. Eventually, this condition activated the engine fire warning system. The crew secured both engines and ordered a precautionary passenger evacuation. The main cabin entrance door was the only exit used during this evacuation. One minor injury was reported to the Safety Board.

Case No. 23

Date of Evacuation: July 8, 1998
Location: Rochester, New York
Air Carrier: Blue Ridge/Atlantic Coast
Aircraft Type: British Aerospace Jetstream 4100
Number of Passengers: 10
Description:

In flight, the flight crew received an indication of a right engine fire. The flight crew discharged the engine halon and landed the airplane. The evacuation proceeded out the main cabin door. Thirteen passengers and crew evacuated without injury.

Case No. 24

Date of Evacuation: July 9, 1998
Location: San Juan, Puerto Rico
Air Carrier: American Airlines
Aircraft Type: Airbus Industrie A300
Number of Passengers: 234
Description:

Shortly after takeoff, the flight crew received an indication of a fire in the No. 1 engine. The flight crew immediately declared an emergency and returned to the departure airport. After landing, the flight crew stopped the airplane on the runway and ordered an evacuation using the public address system stating, "Do not use the left overwing exits." The power assist for doors L1 and R1 did not function. The R2 and R4 exit doors opened as intended, but the R3 door never opened fully during the evacuation. The R4 slide was blown by the wind, making it temporarily unavailable for passenger use. Twenty-eight minor injuries were reported to the Safety Board.

Case No. 25

Date of Evacuation: July 29, 1998
Location: Newark, New Jersey
Air Carrier: Continental Airlines
Aircraft Type: Boeing 737
Number of Passengers: 109
Description:

While waiting for departure, the flight crew received a report from ground control that heavy smoke had been seen coming out of the engine. The flight crew requested ARFF support. Once on scene, ARFF personnel reported that they suspected an internal fire. The flight crew, using the ARFF information, decided to evacuate from the right side of the airplane. When all passengers had exited the airplane, the flight attendants evacuated down the slides. Once on the ground, the flight attendants noticed all passengers that evacuated to the wing were still on the wing. The flight attendants assisted the passengers off the wings. Eleven minor injuries were reported.

Case No. 26

Date of Evacuation: August 13, 1998
Location: Knoxville, Tennessee
Air Carrier: Comair
Aircraft Type: Canadair Regional Jet
Number of Passengers: 46
Description:

While en route, the flight crew had a smoke cargo warning message, triple chimes, and a smoke aural. The flight crew completed the required checklist and declared an emergency with air traffic control. The flight attendant, briefed by the flight crew on the problem, prepared the passengers for an emergency landing. The airplane landed and was stopped on a high-speed taxiway at which time the captain ordered an evacuation. After the airplane was evacuated, ARFF inspected the cargo bay. No evidence of fire was found. No injuries were reported to the Safety Board.

Case No. 27

Date of Evacuation: August 27, 1998
Location: Phoenix, Arizona
Air Carrier: American Airlines
Aircraft Type: McDonnell Douglas MD-82
Number of Passengers: 75
Description:

ARFF advised the flight crew that fuel was coming out of the airplane's left engine. The flight crew ordered an evacuation and indicated that the L2 and left overwing exits were not to be used. No injuries were reported to the Safety Board.

Case No. 28

Date of Evacuation: September 10, 1998
Location: Newburg, New York
Air Carrier: Atlantic Southeast Airlines

Aircraft Type: Canadair Regional Jet
Number of Passengers: 30
Description:

As the plane neared the airport, the cargo compartment fire indication light illuminated intermittently. The flight crew discharged halon into the compartment and continued their flight. After the airplane landed, the warning light illuminated once again and the captain decided to evacuate the airplane on the taxiway. The L1 door was used. There was no evidence of fire found by ARFF, and no injuries were reported to the Safety Board.

Case No. 29

Date of Evacuation: September 13, 1998
Location: Raleigh–Durham, North Carolina
Air Carrier: US Airways Express
Aircraft Type: Canadair Regional Jet
Number of Passengers: 40
Description:

The flight crew received an in-flight indication of smoke in the cargo compartment and declared an emergency. During the airplane's descent, the flight attendant prepared the passengers for an evacuation. After the airplane, and passengers exited via the forward left exit onto the taxiway. ARFF personnel did not find any evidence of smoke or fire in the cargo compartment. No injuries were reported to the Safety Board.

Case No. 30

Date of Evacuation: October 24, 1998
Location: San Juan, Puerto Rico
Air Carrier: American Eagle
Aircraft Type: Avions de Transport Regional ATR-42
Number of Passengers: 23
Description:

The airplane collided with a ground power unit after engine start, causing fuel to leak from the No. 2 engine and ignite. After completing the checklist for engine fire on the ground, the captain opened the left forward emergency exit. The flight attendant attempted to contact the cockpit but received no response. On her own initiative, she opened the main cabin door to evacuate passengers. Three passengers sustained minor injuries.

Case No. 31

Date of Evacuation: October 30, 1998
Location: Shreveport, Louisiana
Air Carrier: American Eagle
Aircraft Type: Saab 340
Number of Passengers: 27
Description:

In flight, the flight crew detected smoke in the cockpit and cabin. They declared an emergency and landed. The flight crew stopped the airplane on a taxiway and ordered an evacuation. The passengers exited the airplane via the left forward exit. The smoke was from an engine malfunction. No injuries were reported to the Safety Board.

Case No. 32

Date of Evacuation: November 1, 1998
Location: Atlanta, Georgia
Air Carrier: Air Trans Airlines
Aircraft Type: Boeing 737
Number of Passengers: 100
Description:

In flight, the flight crew received an indication of a loss of their airplane's "A" hydraulic system. Upon landing, the airplane lost its "B" hydraulic system, causing the airplane to veer off the runway and collide with an embankment. The flight crew ordered an evacuation. One flight attendant reported difficulty opening the R1 exit because of the incline of the airplane. Another flight attendant reported a failure of a slide to inflate automatically. Although the placard indicated the slide was automatic, it was a manually inflating slide. Eleven minor injuries were reported to the Safety Board.

Case No. 33

Date of Evacuation: November 3, 1998
Location: Miami, Florida
Air Carrier: Gulfstream
Aircraft Type: Beech 1900
Number of Passengers: 19
Description:

The captain reported that shortly after takeoff, while climbing through 2,800 feet, the first officer noted smoke in the cockpit. The smoke was reported to have an acrid smell and was light gray in color. An emergency was declared to air traffic control and both pilots donned their oxygen masks. Oxygen was also provided to the passengers. The captain completed the landing checklist then notified the passengers of the intent to evacuate the airplane after landing. The airplane landed uneventfully and all passengers were evacuated using the overwing exits. There were no reported injuries.

Case No. 34

Date of Evacuation: November 12, 1998
Location: Boston, Massachusetts
Air Carrier: Allegheny Airlines

Aircraft Type: de Havilland DHC-8 ("Dash" 8)
Number of Passengers: 18
Description:

While the airplane was at the gate preparing for departure, the captain noticed smoke and sparks coming from the No. 1 engine cowling. The captain ordered an evacuation through the right floor level exit. The flight attendant opened the exit and placed the exit door inside the airplane to avoid hurting ramp personnel. There were no reported injuries.

Case No. 35

Date of Evacuation: December 26, 1998
Location: Dallas–Fort Worth, Texas
Air Carrier: Delta Airlines
Aircraft Type: McDonnell Douglas MD-88
Number of Passengers: 44
Description:

The airplane was taxiing for departure when crewmembers in other airplanes observed a fire on the No. 2 engine of the taxiing airplane. The airport tower called for ARFF support. The captain decided to evacuate the airplane using the left (opposite fire) side exits. The evacuation was assisted by four commuting flight attendants and two commuting pilots. One passenger broke an ankle at the bottom of a slide.

Case No. 36

Date of Evacuation: December 28, 1998
Location: Phoenix, Arizona
Air Carrier: United Airlines
Aircraft Type: Airbus Industrie A320
Number of Passengers: 145
Description:

The flight crew declared an emergency en route after a suspicious package was found. The pilot radioed for two portable stairs to be brought to the airplane to assist in removing passengers. After the airplane landed, it was taken to a secure area where passengers evacuated through the L1 exit down the portable stairs following a discussion between ground personnel and flight crew. No injuries were reported to the Safety Board.

Case No. 37

Date of Evacuation: December 29, 1998
Location: White Plains, New York
Air Carrier: Business Express
Aircraft Type: Saab 340
Number of Passengers: 4
Description:

When the airplane arrived at the gate, the flight attendant observed smoke in the vicinity of the left engine and notified the captain. The captain commanded an evacuation on the right side. When the flight attendant opened the right door, the propellers were still spinning. The flight crew reassessed the situation and commanded an evacuation out the left main cabin. No injuries were reported to the Safety Board.

Case No. 38

Date of Evacuation: January 7, 1999
Location: San Diego, California
Air Carrier: AeroMexico
Aircraft Type: McDonnell Douglas MD-80
Number of Passengers: 36
Description:

A report of a bomb threat was transmitted to the flight crew when they were 1 hour away from landing. The flight crew notified the flight attendants. Upon landing, the captain ordered an evacuation. The flight attendants gave instructions to the passengers in Spanish only. Everyone evacuated via emergency slides except the tailcone slide, which failed to inflate. The air carrier reported that the lanyard for deploying the slide was installed incorrectly. One minor injury was reported to the Safety Board.

Case No. 39

Date of Evacuation: January 8, 1999
Location: Covington, Kentucky
Air Carrier: Comair
Aircraft Type: Canadair Regional Jet
Number of Passengers: 5
Description:

While holding for takeoff, the captain noticed a cargo smoke warning indicator illuminate. The captain taxied to the airport fire station 1,000 feet away. When the airplane reached the fire station, passengers evacuated via the main cabin door. No evidence of fire was found by ARFF personnel, and there were no injuries reported to the Safety Board.

Case No. 40

Date of Evacuation: January 19, 1999
Location: St. Louis, Missouri
Air Carrier: Trans States Airlines
Aircraft Type: Avions de Transport Regional ATR-72
Number of Passengers: 17
Description:

On short final approach at an altitude of less than 400 feet above ground level, the flight crew received a fire warning for engine No. 2. The landing was continued. After landing, the airplane was taxied clear of the runway. ARFF personnel responded; however, the fire was reportedly extinguished prior to their arrival. Passengers evacuated through the main cabin door. No injuries were reported to the Safety Board.

Case No. 41

Date of Evacuation: January 24, 1999
Location: Charlotte, North Carolina
Air Carrier: American Airlines
Aircraft Type: Fokker 100
Number of Passengers: 70
Description:

While taxiing, the flight crew received an indication of smoke coming from the right main landing gear. The airplane entered a taxiway, and the flight crew ordered an evacuation using the forward exits and the left overwing exits. The flight attendant had to rock the L1 door to get it to open. One flight attendant incurred a sprained knee. Further, a flight attendant reported that the window to assess conditions outside the L1 door was covered in condensation and difficult to use. One minor injury was reported to the Safety Board.

Case No. 42

Date of Evacuation: January 24, 1999
Location: Newark, New Jersey
Air Carrier: Continental Express
Aircraft Type: Embraer EMB-145
Number of Passengers: 48
Description:

After landing and during taxi to the gate, the flight crew started the auxiliary power unit (APU). Shortly thereafter the crew received a lavatory smoke warning. The flight crew called the flight attendant on the intercom and asked if any smoke was visible in the lavatory or the cabin. The flight attendant reported that smoke/fire was not visible in the lavatory or the cabin and the lavatory was not occupied. However, the flight attendant informed the flight crew that an odor of something burning was present in the cabin. The flight crew elected to stop the airplane and ordered an evacuation. The airplane was inspected and there was no evidence of smoke or fire. No injuries were reported to the Safety Board.

Case No. 43

Date of Evacuation: February 17, 1999
Location: Columbus, Ohio
Air Carrier: American West
Aircraft Type: Airbus Industrie A320
Number of Passengers: 26
Description:

Upon approach, the flight crew received indications of a gear problem. The crew conducted a tower flyby and determined the nosegear was sideways. The flight attendants were informed of an impending emergency landing. The flight attendants reseated the passengers and briefed the passengers for the emergency landing. The evacuation was carried out through the four overwing exits. There were no injuries reported to the Safety Board.

Case No. 44

Date of Evacuation: May 8, 1999
Location: Jamaica, New York
Air Carrier: American Eagle
Aircraft Type: Saab 340
Number of Passengers: 27
Description:

Upon landing in rain with visibility of less than 1/4 mile, the flight crew landed the airplane 7,000 feet down an 8,400-foot runway. The airplane proceeded off the end of the runway and into an "engineered materials arresting system" (EMAS). The airplane sank 30 inches into the EMAS at its stopping point 214 feet across the 600-foot system. The crew ordered an evacuation. The flight attendant decided not to lower the main cabin door airstairs because the gear was sunken in the EMAS. One passenger broke an ankle jumping from an exit.

Case No. 45

Date of Evacuation: June 1, 1999
Location: Little Rock, Arkansas
Air Carrier: American Airlines
Aircraft Type: McDonnell Douglas MD-82
Number of Passengers: 139
Description:

The airplane crashed after landing. Thunderstorms and heavy rain were in the area at the time of the accident. The airplane departed the end of runway, went down an embankment, and impacted approach-light structures. Eleven persons were killed in the accident, and 45 sustained serious injuries. Two of the 11 fatalities involved smoke inhalation and thermal injuries sustained during the evacuation.

Case No. 46

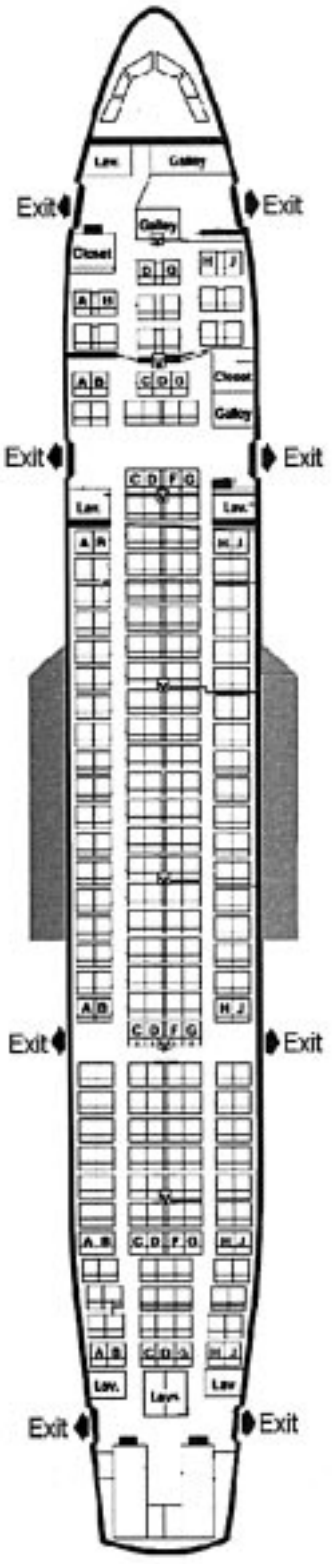
Date of Evacuation: June 22, 1999
Location: Scottsbluff, Nebraska
Air Carrier: United Airlines
Aircraft Type: Boeing 737
Number of Passengers: 63
Description:

While in flight, flight attendants observed smoke in the cabin and informed the flight crew. The smoke was suspected to be from a light ballast. The flight crew declared an emergency and proceeded toward an alternate airport. The flight crew had requested portable airstairs for getting passengers off the airplane. The airplane landed uneventfully; however, no portable airstairs were available at the airport. Passengers left the airplane using either a ladder from the L1 exit or stepping onto a deicing stand after exiting onto the wing. There were no injuries reported to the Safety Board.♦

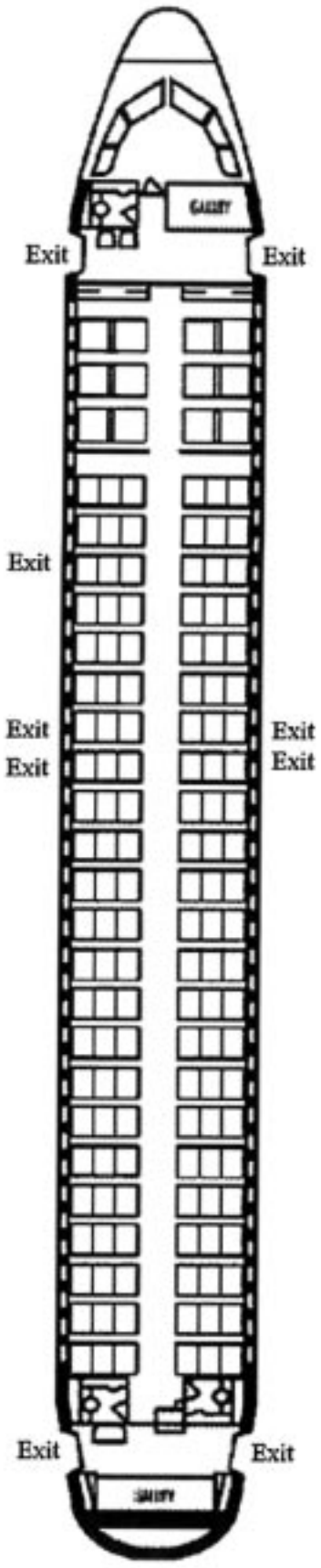
Appendix C

Configurations of the Aircraft Types Represented in the Study

The diagrams in this appendix are not to scale.



Airbus Industrie A300



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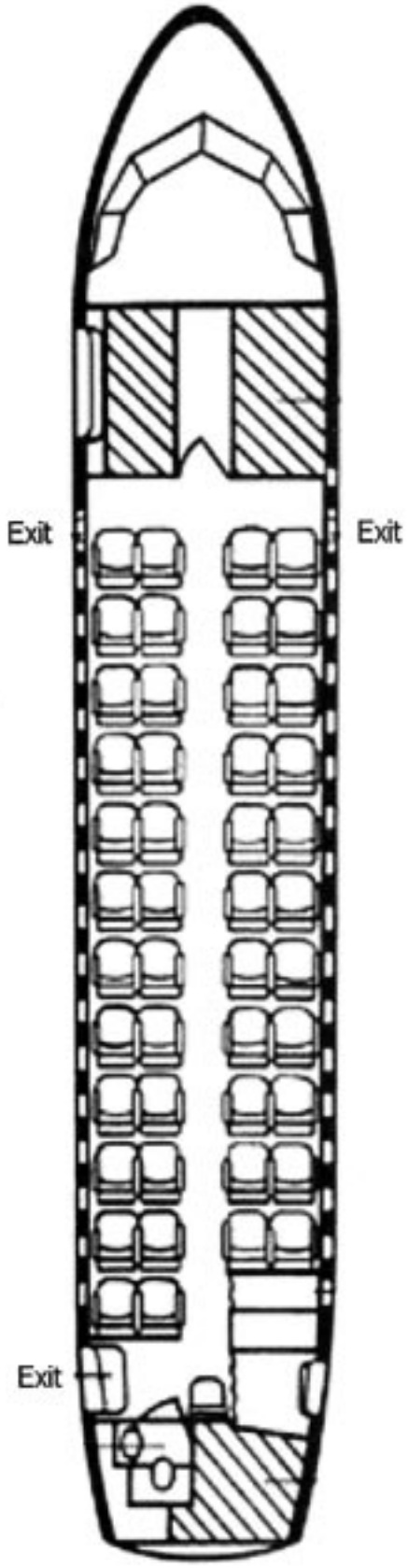
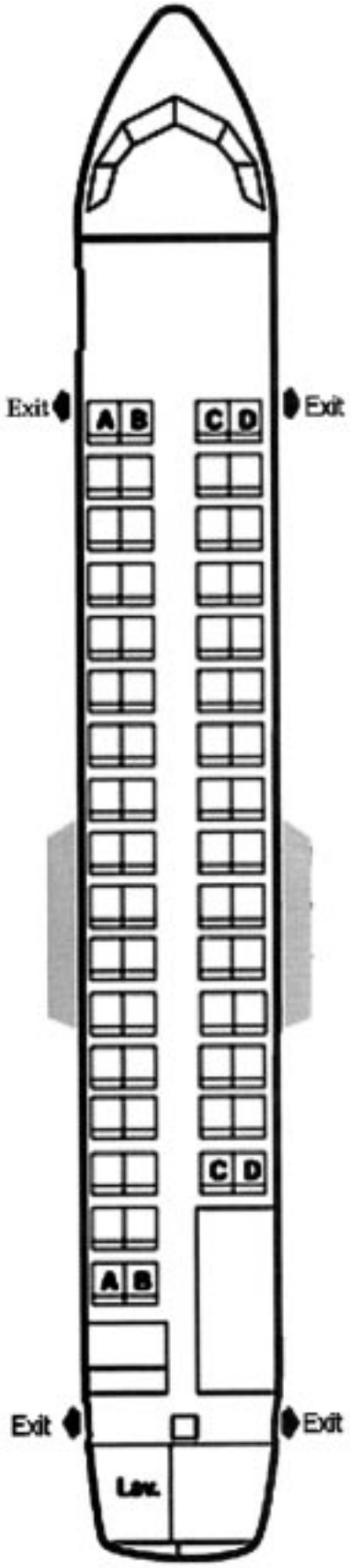
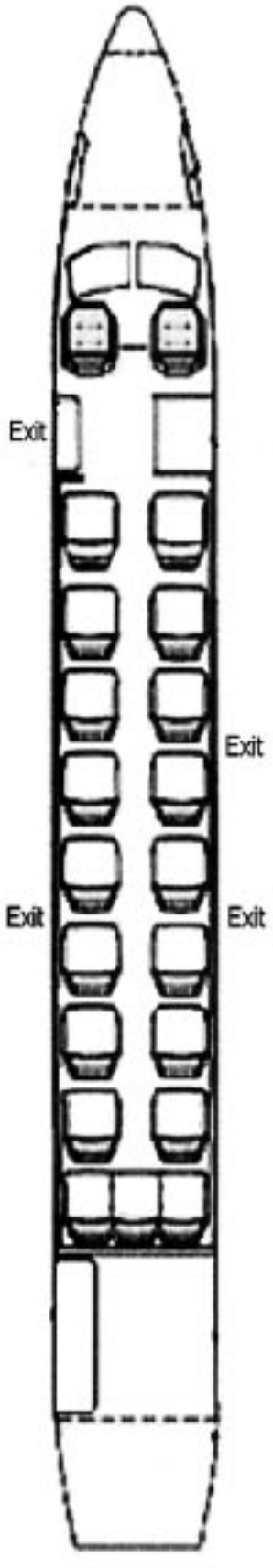


Avions de Transport Regional ATR-42



Avions de Transport Regional ATR-72



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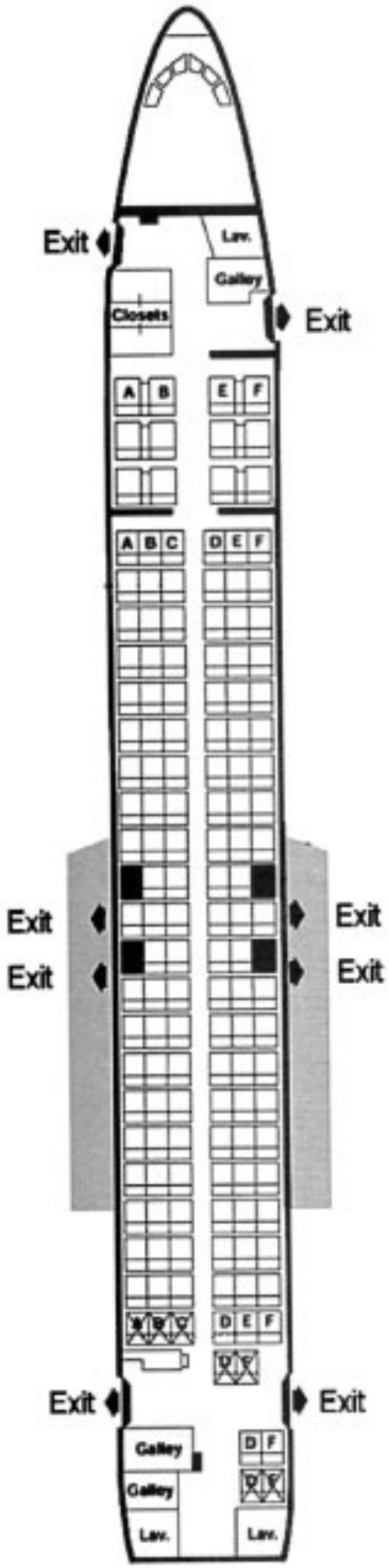
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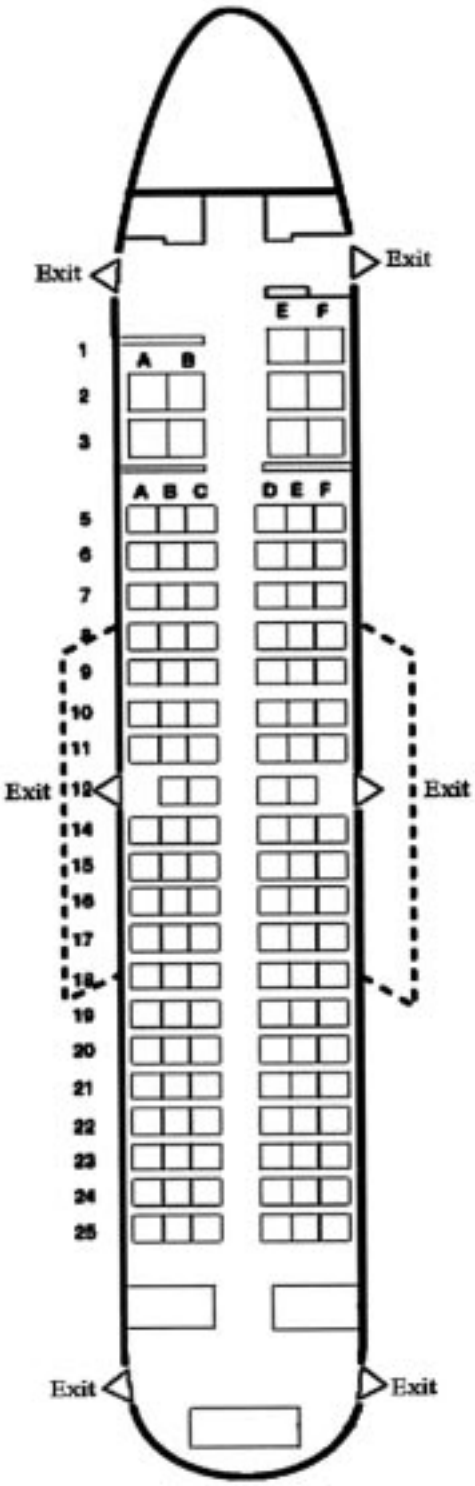
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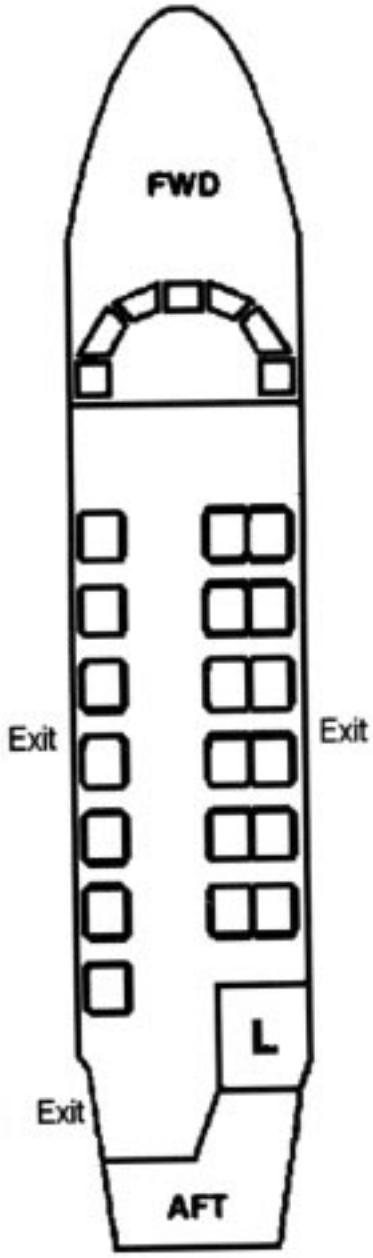

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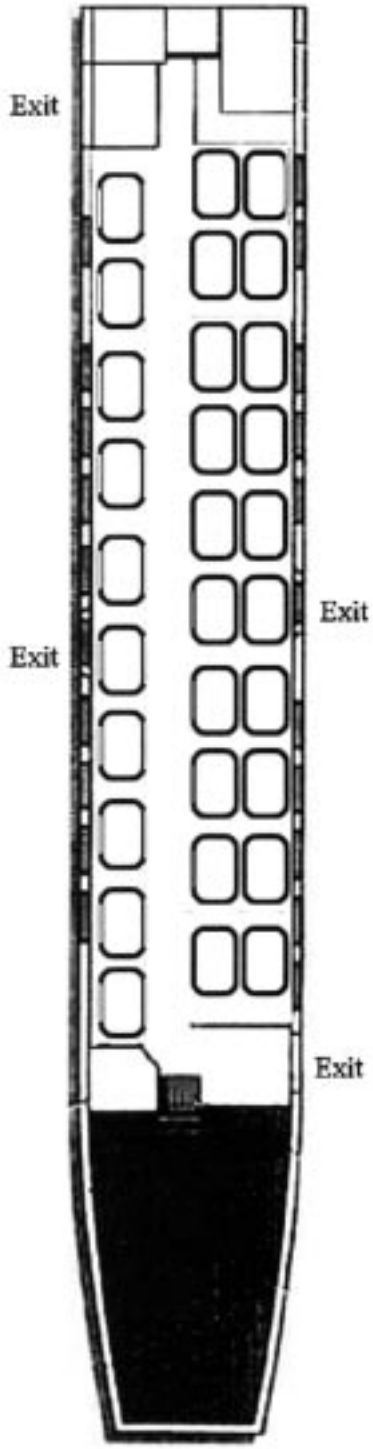

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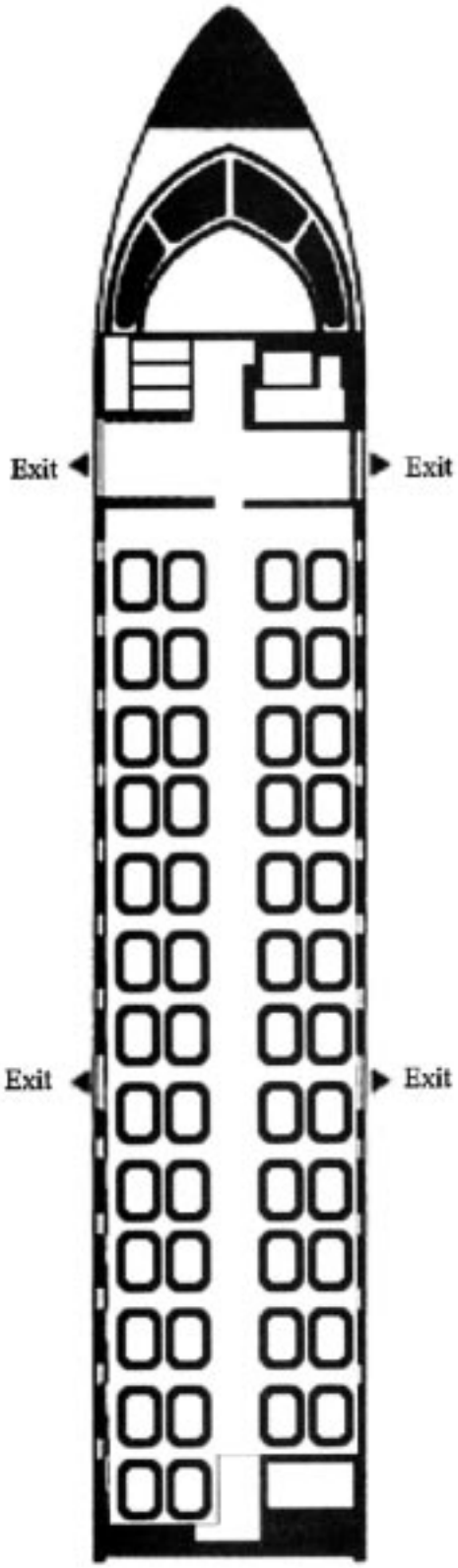

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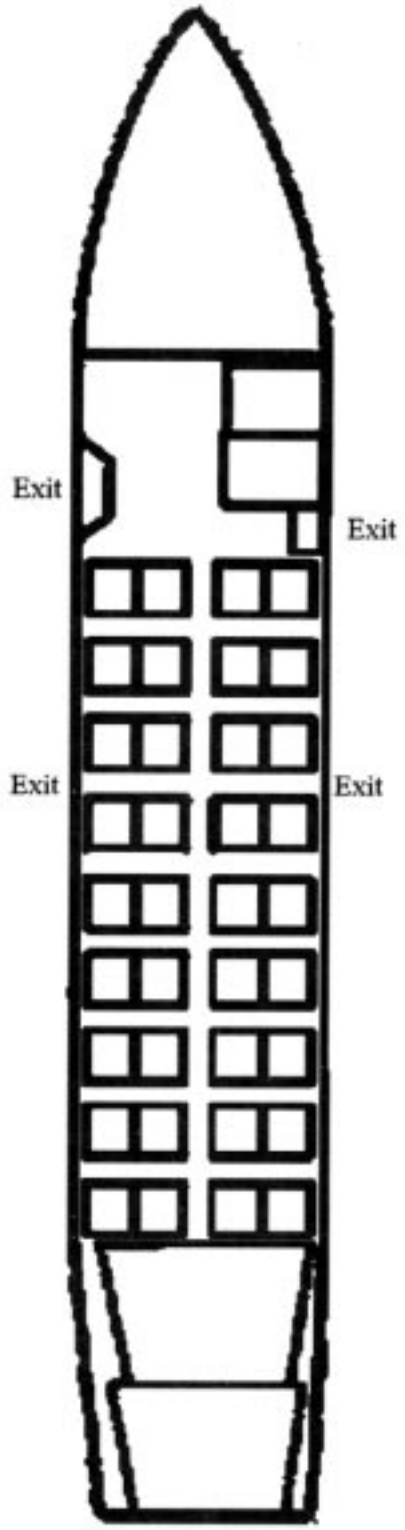

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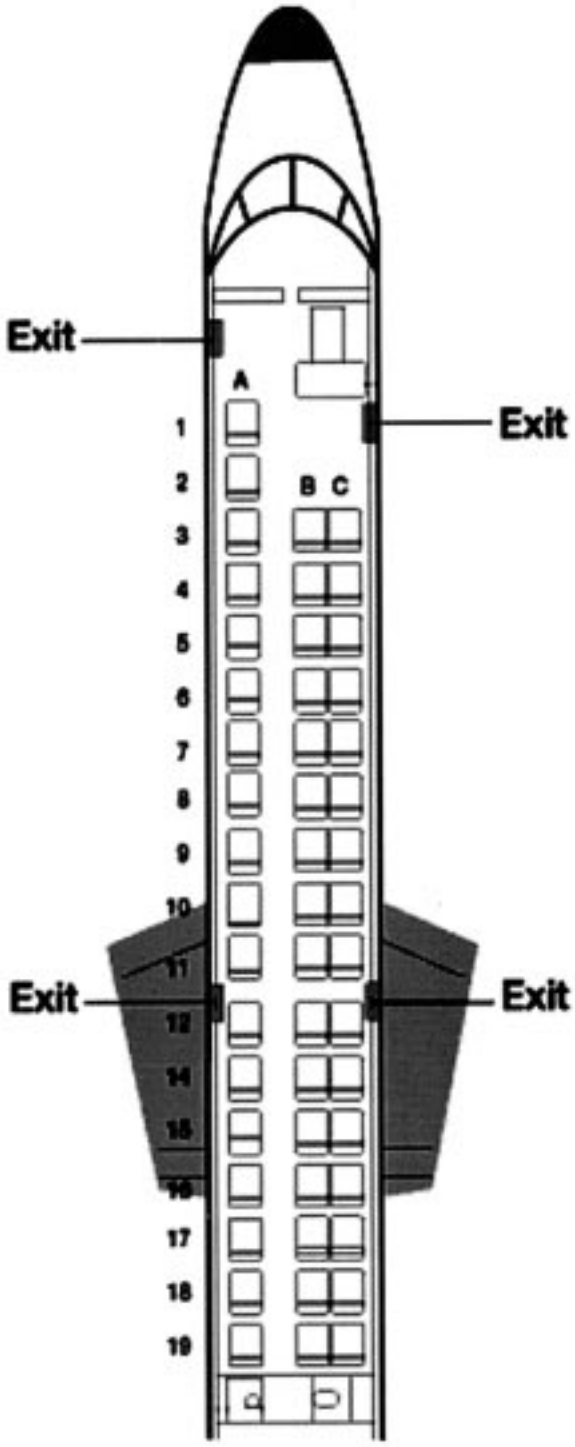

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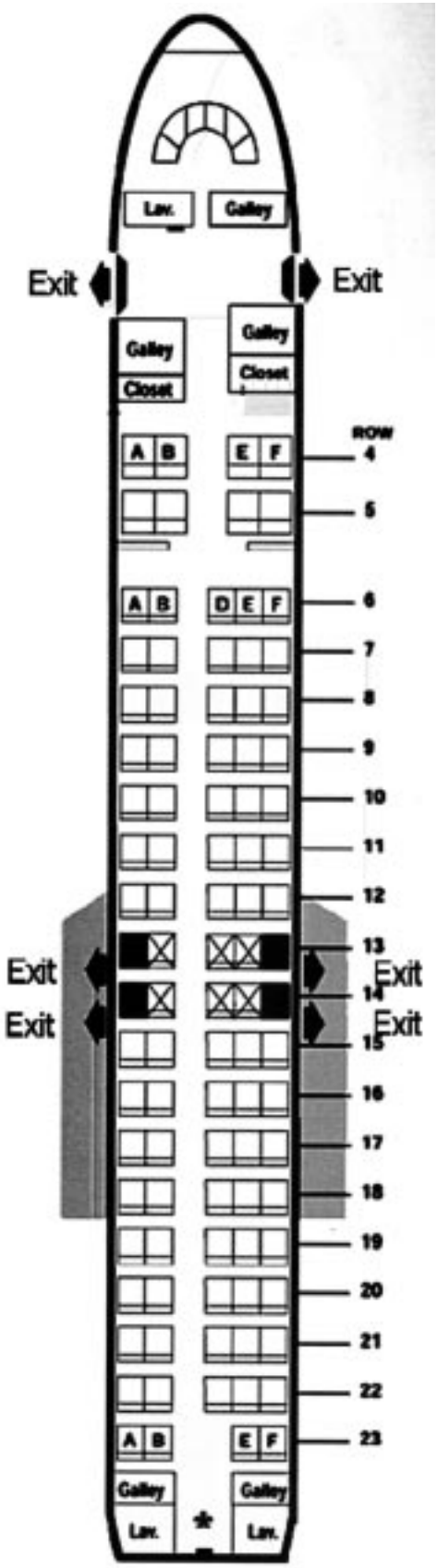
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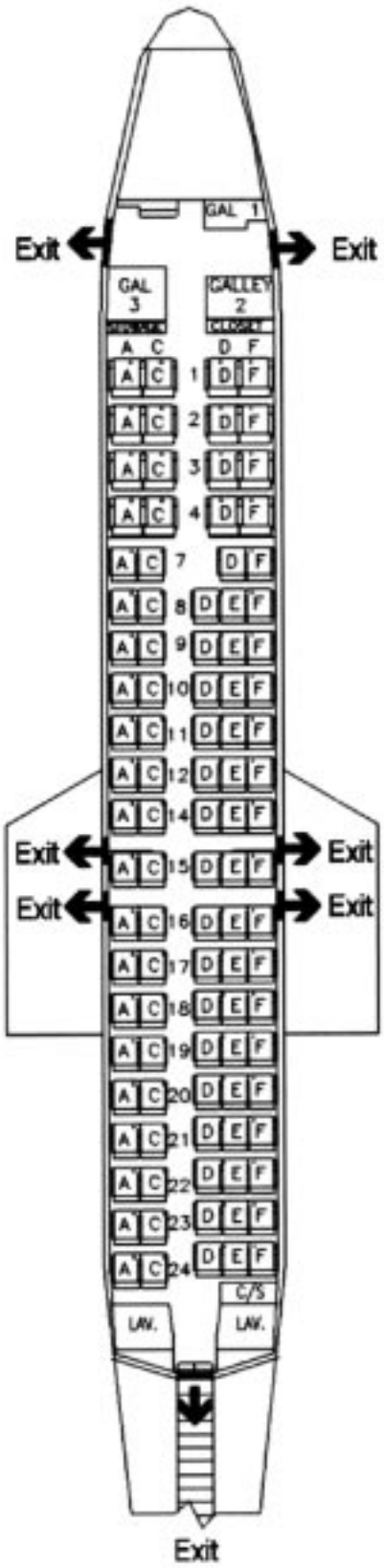

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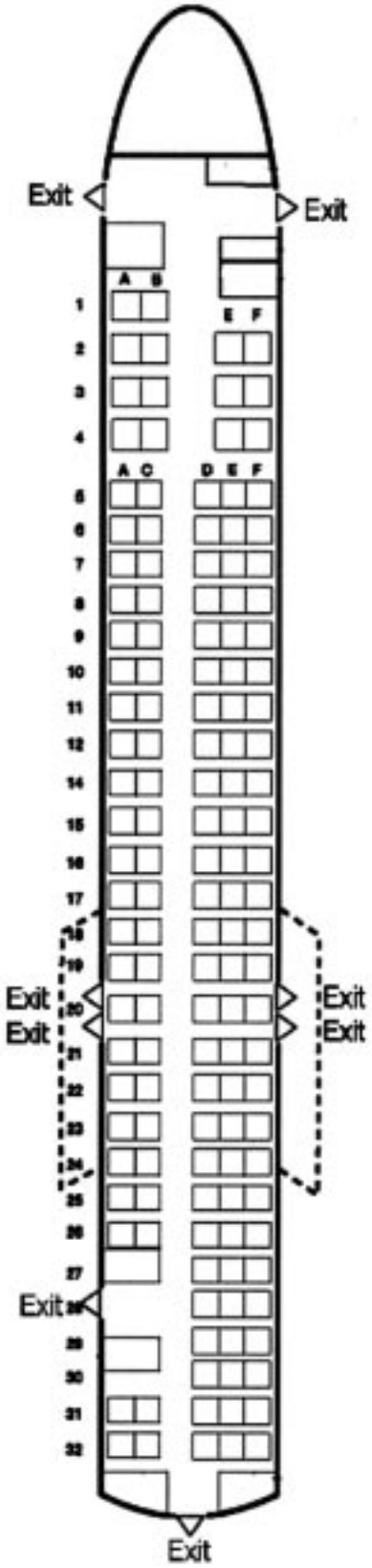

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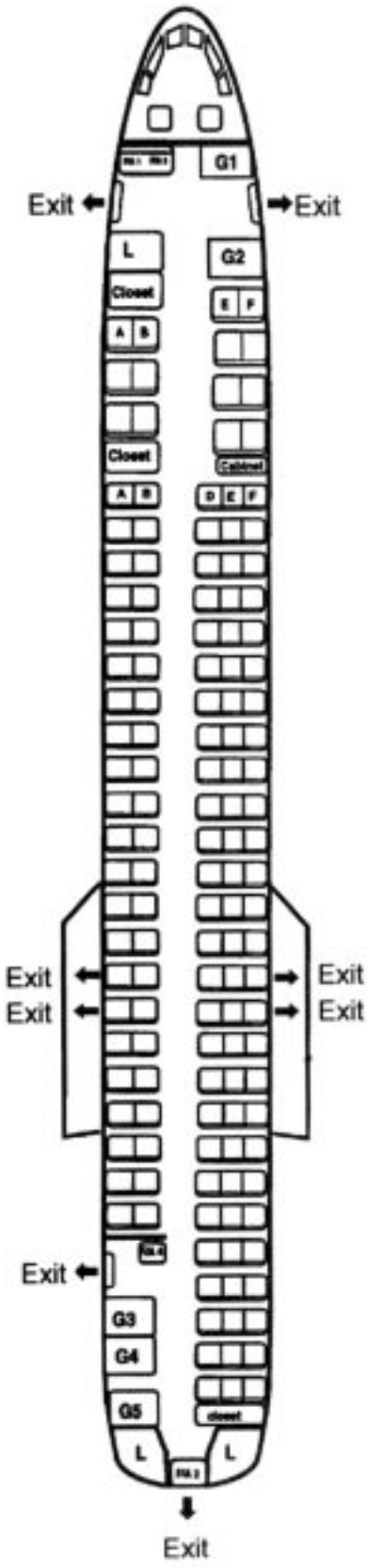

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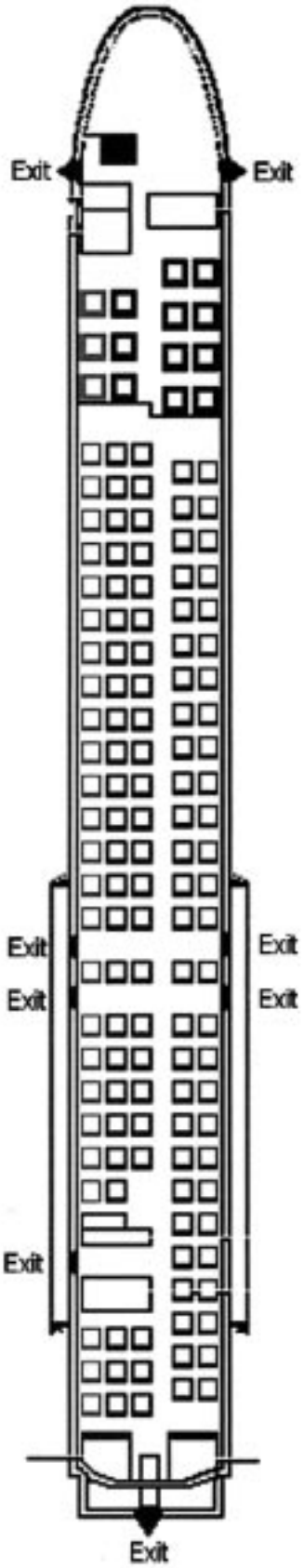

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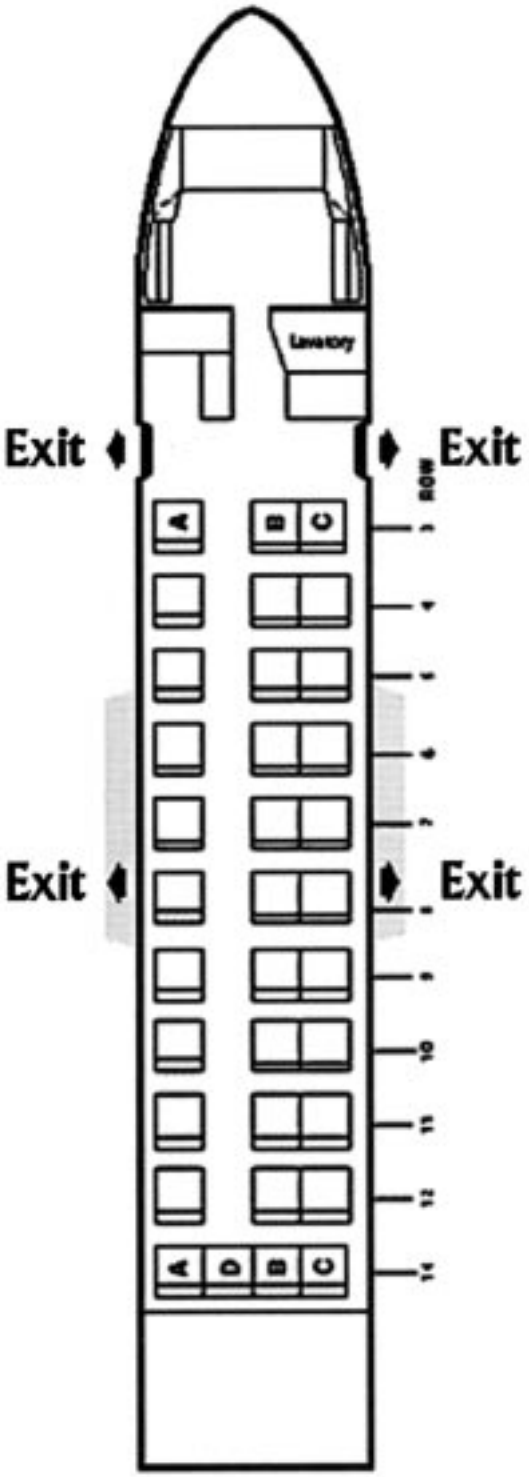

Saab 340

Appendix D

Excerpts From the Federal Regulations Pertaining to Evacuations

§ 25.803 Emergency evacuation.

(a) Each crew and passenger area must have emergency means to allow rapid evacuation in crash landings, with the landing gear extended as well as with the landing gear retracted, considering the possibility of the airplane being on fire.

(b) [Reserved]

(c) For airplanes having a seating capacity of more than 44 passengers, it must be shown that the maximum seating capacity, including the number of crewmembers required by the operating rules for which certification is requested, can be evacuated from the airplane to the ground under simulated emergency conditions within 90 seconds. Compliance with this requirement must be shown by actual demonstration using the test criteria outlined in appendix J of this part unless the Administrator finds that a combination of analysis and testing will provide data equivalent to that which would be obtained by actual demonstration.

(d)-(e) [Reserved]

[Doc. No. 24344, 55 FR 29781, July 20, 1990]

§ 25.807 Emergency exits.

(a) *Type.* For the purpose of this part, the types of exits are defined as fo lows:

(1) *Type I.* This type is a floor lev exit with a rectangular opening of n less than 24 inches wide by 48 inch high, with corner radii not great than one-third the width of the exit.

(2) *Type II.* This type is a rectangul opening of not less than 20 inches wi by 44 inches high, with corner radii n

greater than one-third the width of the exit. Type II exits must be floor level exits unless located over the wing, in which case they may not have a step-up inside the airplane of more than 10 inches nor a step-down outside the airplane of more than 17 inches.

(3) *Type III.* This type is a rectangular opening of not less than 20 inches wide by 36 inches high, with corner radii not greater than one-third the width of the exit, and with a step-up inside the airplane of not more than 20 inches. If the exit is located over the wing, the step-down outside the airplane may not exceed 27 inches.

(4) *Type IV.* This type is a rectangular opening of not less than 19 inches wide by 26 inches high, with corner radii not greater than one-third the width of the exit, located over the wing, with a step-up inside the airplane of not more than 29 inches and a step-down outside the airplane of not more than 36 inches.

(5) *Ventral.* This type is an exit from the passenger compartment through the pressure shell and the bottom fuselage skin. The dimensions and physical configuration of this type of exit must allow at least the same rate of egress as a Type I exit with the airplane in the normal ground attitude, with landing gear extended.

(6) *Tail cone.* This type is an aft exit from the passenger compartment through the pressure shell and through an openable cone of the fuselage aft of the pressure shell. The means of opening the tailcone must be simple and obvious and must employ a single operation.

(7) *Type A.* This type is a floor level exit with a rectangular opening of not less than 42 inches wide by 72 inches high with corner radii not greater than one-sixth of the width of the exit.

(b) *Step down distance.* Step down distance, as used in this section, means the actual distance between the bottom of the required opening and a usable foot hold, extending out from the fuselage, that is large enough to be effective without searching by sight or feel.

(c) *Over-sized exits.* Openings larger than those specified in this section, whether or not of rectangular shape, may be used if the specified rectangular opening can be inscribed within the opening and the base of the inscribed rectangular opening meets the specified step-up and step-down heights.

(d) *Passenger emergency exits.* Except as provided in paragraphs (d)(3) through (7) of this section, the minimum number and type of passenger emergency exits is as follows:

(1) For passenger seating configurations of 1 through 299 seats:

Passenger seating configuration (crewmember seats not included)	Emergency exits for each side of the fuselage			
	Type I	Type II	Type III	Type IV
1 through 9	.....	.....	.....	1
10 through 19	.....	.....	1	.....
20 through 39	.....	1	1	.....
40 through 79	1	.....	1	.....
80 through 109	1	.....	2	.....
110 through 139	2	.....	1	.....
140 through 179	2	.....	2	.....

Additional exits are required for passenger seating configurations greater than 179 seats in accordance with the following table:

Additional emergency exits (each side of fuselage)	Increase in passenger seating configuration allowed
Type A	110
Type I	45
Type II	40
Type III	35

(2) For passenger seating configurations greater than 299 seats, each emergency exit in the side of the fuselage must be either a Type A or Type I. A passenger seating configuration of 110 seats is allowed for each pair of Type A exits and a passenger seating configuration of 45 seats is allowed for each pair of Type I exits.

(3) If a passenger ventral or tail cone exit is installed and that exit provides at least the same rate of egress as a Type III exit with the airplane in the most adverse exit opening condition that would result from the collapse of one or more legs of the landing gear, an increase in the passenger seating configuration beyond the limits specified in paragraph (d)(1) or (2) of this section may be allowed as follows:

(i) For a ventral exit, 12 additional passenger seats.

(ii) For a tail cone exit incorporating a floor level opening of not less than 20 inches wide by 60 inches high, with cor-

ner radii not greater than one-third the width of the exit, in the pressure shell and incorporating an approved assist means in accordance with §25.809(h), 25 additional passenger seats.

(iii) For a tail cone exit incorporating an opening in the pressure shell which is at least equivalent to a Type III emergency exit with respect to dimensions, step-up and step-down distance, and with the top of the opening not less than 56 inches from the passenger compartment floor, 15 additional passenger seats.

(4) For airplanes on which the vertical location of the wing does not allow the installation of overwing exits, an exit of at least the dimensions of a Type III exit must be installed instead of each Type IV exit required by subparagraph (1) of this paragraph.

(5) An alternate emergency exit configuration may be approved in lieu of that specified in paragraph (d)(1) or (2) of this section provided the overall evacuation capability is shown to be equal to or greater than that of the specified emergency exit configuration.

(6) The following must also meet the applicable emergency exit requirements of §§25.809 through 25.813:

(i) Each emergency exit in the passenger compartment in excess of the minimum number of required emergency exits.

(ii) Any other floor level door or exit that is accessible from the passenger compartment and is as large or larger than a Type II exit, but less than 46 inches wide.

(iii) Any other passenger ventral or tail cone exit.

(7) For an airplane that is required to have more than one passenger emergency exit for each side of the fuselage, no passenger emergency exit shall be more than 60 feet from any adjacent passenger emergency exit on the same side of the same deck of the fuselage, as measured parallel to the airplane's longitudinal axis between the nearest exit edges.

(e) *Ditching emergency exits for passengers.* Ditching emergency exits must be provided in accordance with the following requirements whether or not certification with ditching provisions is requested:

(1) For airplanes that have a passenger seating configuration of nine seats or less, excluding pilots seats, one exit above the waterline in each side of the airplane, meeting at least the dimensions of a Type IV exit.

(2) For airplanes that have a passenger seating configuration of 10 seats or more, excluding pilots seats, one exit above the waterline in a side of the airplane, meeting at least the dimensions of a Type III exit for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, with one on each side of the airplane. The passenger seat/exit ratio may be increased through the use of larger exits, or other means, provided it is shown that the evacuation capability during ditching has been improved accordingly.

(3) If it is impractical to locate side exits above the waterline, the side exits must be replaced by an equal number of readily accessible overhead hatches of not less than the dimensions of a Type III exit, except that for airplanes with a passenger configuration of 35 seats or less, excluding pilots seats, the two required Type III side exits need be replaced by only one overhead hatch.

(f) *Flightcrew emergency exits.* For airplanes in which the proximity of passenger emergency exits to the flightcrew area does not offer a convenient and readily accessible means of evacuation of the flightcrew, and for all airplanes having a passenger seating capacity greater than 20, flightcrew exits shall be located in the flightcrew area. Such exits shall be of sufficient size and so located as to permit rapid evacuation by the crew. One exit shall be provided on each side of the airplane; or, alternatively, a top hatch shall be provided. Each exit must encompass an unobstructed rectangular opening of at least 19 by 20 inches unless satisfactory exit utility can be demonstrated by a typical crewmember.

[Amdt. 25-72, 55 FR 29781, July 20, 1990]

§25.813 Emergency exit access.

Each required emergency exit must be accessible to the passengers and located where it will afford an effective means of evacuation. Emergency exit distribution must be as uniform as practical, taking passenger distribution into account; however, the size and location of exits on both sides of the cabin need not be symmetrical. If only one floor level exit per side is prescribed, and the airplane does not have a tail cone or ventral emergency exit, the floor level exit must be in the rearward part of the passenger compartment, unless another location affords a more effective means of passenger evacuation. Where more than one floor level exit per side is prescribed, at least one floor level exit per side must be located near each end of the cabin, except that this provision does not apply to combination cargo/passenger configurations. In addition—

(a) There must be a passageway leading from the nearest main aisle to each Type I, Type II, or Type A emergency exit and between individual passenger areas. Each passageway leading to a Type A exit must be unobstructed and at least 36 inches wide. Passageways between individual passenger areas and those leading to Type I and Type II emergency exits must be unobstructed and at least 20 inches wide. Unless there are two or more main aisles, each Type A exit must be located so that there is passenger flow along the main aisle to that exit from both the forward and aft directions. If two or more main aisles are provided, there must be unobstructed cross-aisles at least 20 inches wide between main aisles. There must be—

(1) A cross-aisle which leads directly to each passageway between the nearest main aisle and a Type A exit; and

(2) A cross-aisle which leads to the immediate vicinity of each passageway between the nearest main aisle and a Type 1, Type II, or Type III exit; except that when two Type III exits are located within three passenger rows of each other, a single cross-aisle may be used if it leads to the vicinity between the passageways from the nearest main aisle to each exit.

(b) Adequate space to allow crewmember(s) to assist in the evacuation of passengers must be provided as follows:

(1) The assist space must not reduce the unobstructed width of the passageway below that required for the exit.

(2) For each Type A exit, assist space must be provided at each side of the exit regardless of whether the exit is covered by §25.810(a).

(3) For any other type exit that is covered by §25.810(a), space must at least be provided at one side of the passageway.

(c) The following must be provided for each Type III or Type IV exit—(1) There must be access from the nearest aisle to each exit. In addition, for each Type III exit in an airplane that has a passenger seating configuration of 60 or more—

(i) Except as provided in paragraph (c)(1)(ii), the access must be provided by an unobstructed passageway that is at least 10 inches in width for interior arrangements in which the adjacent seat rows on the exit side of the aisle contain no more than two seats, or 20 inches in width for interior arrangements in which those rows contain three seats. The width of the passageway must be measured with adjacent seats adjusted to their most adverse position. The centerline of the required passageway width must not be displaced more than 5 inches horizontally from that of the exit.

(ii) In lieu of one 10- or 20-inch passageway, there may be two passageways, between seat rows only, that

must be at least 6 inches in width and lead to an unobstructed space adjacent to each exit. (Adjacent exits must not share a common passageway.) The width of the passageways must be measured with adjacent seats adjusted to their most adverse position. The unobstructed space adjacent to the exit must extend vertically from the floor to the ceiling (or bottom of sidewall stowage bins), inboard from the exit for a distance not less than the width of the narrowest passenger seat installed on the airplane, and from the forward edge of the forward passageway to the aft edge of the aft passageway. The exit opening must be totally within the fore and aft bounds of the unobstructed space.

(2) In addition to the access—

(i) For airplanes that have a passenger seating configuration of 20 or more, the projected opening of the exit provided must not be obstructed and there must be no interference in opening the exit by seats, berths, or other protrusions (including any seatback in the most adverse position) for a distance from that exit not less than the width of the narrowest passenger seat installed on the airplane.

(ii) For airplanes that have a passenger seating configuration of 19 or fewer, there may be minor obstructions in this region, if there are compensating factors to maintain the effectiveness of the exit.

(3) For each Type III exit, regardless of the passenger capacity of the airplane in which it is installed, there must be placards that—

(i) Are readable by all persons seated adjacent to and facing a passageway to the exit;

(ii) Accurately state or illustrate the proper method of opening the exit, including the use of handholds; and

(iii) If the exit is a removable hatch, state the weight of the hatch and indicate an appropriate location to place the hatch after removal.

(d) If it is necessary to pass through a passageway between passenger compartments to reach any required emergency exit from any seat in the passenger cabin, the passageway must be unobstructed. However, curtains may be used if they allow free entry through the passageway.

(e) No door may be installed in any partition between passenger compartments.

(f) If it is necessary to pass through a doorway separating the passenger cabin from other areas to reach any required emergency exit from any passenger seat, the door must have a means to latch it in open position. The latching means must be able to withstand the loads imposed upon it when the door is subjected to the ultimate inertia forces, relative to the surrounding structure, listed in § 25.561(b).

[Amdt. 25–1, 30 FR 3204, Mar. 9, 1965, as amended by Amdt. 25–15, 32 FR 13265, Sept. 20, 1967; Amdt. 25–32, 37 FR 3971, Feb. 24, 1972; Amdt. 25–46, 43 FR 50597, Oct. 30, 1978; Amdt. 25–72, 55 FR 29783, July 20, 1990; Amdt. 25–76, 57 FR 19244, May 4, 1992; Amdt. 25–76, 57 FR 29120, June 30, 1992]

APPENDIX J TO PART 25—EMERGENCY EVACUATION

The following test criteria and procedures must be used for showing compliance with §25.803:

(a) The emergency evacuation must be conducted either during the dark of the night or during daylight with the dark of night simulated. If the demonstration is conducted indoors during daylight hours, it must be conducted with each window covered and each door closed to minimize the daylight effect. Illumination on the floor or ground may be used, but it must be kept low and shielded against shining into the airplane's windows or doors.

(b) The airplane must be in a normal attitude with landing gear extended.

(c) Unless the airplane is equipped with an off-wing descent means, stands or ramps may be used for descent from the wing to the ground. Safety equipment such as mats or inverted life rafts may be placed on the floor or ground to protect participants. No other equipment that is not part of the emergency evacuation equipment of the airplane may be used to aid the participants in reaching the ground.

(d) Except as provided in paragraph (a) of this Appendix, only the airplane's emergency lighting system may provide illumination.

(e) All emergency equipment required for the planned operation of the airplane must be installed.

(f) Each external door and exit, and each internal door or curtain, must be in the takeoff configuration.

(g) Each crewmember must be seated in the normally assigned seat for takeoff and must remain in the seat until receiving the signal for commencement of the demonstration. Each crewmember must be a person having knowledge of the operation of exits and emergency equipment and, if compliance with §121.291 is also being demonstrated, each flight attendant must be a member of a regularly scheduled line crew.

(h) A representative passenger load of persons in normal health must be used as follows:

(1) At least 40 percent of the passenger load must be female.

(2) At least 35 percent of the passenger load must be over 50 years of age.

(3) At least 15 percent of the passenger load must be female and over 50 years of age.

(4) Three life-size dolls, not included as part of the total passenger load, must be carried by passengers to simulate live infants 2 years old or younger.

(5) Crewmembers, mechanics, and training personnel, who maintain or operate the airplane in the normal course of their duties, may not be used as passengers.

(i) No passenger may be assigned a specific seat except as the Administrator may require. Except as required by subparagraph (g) of this paragraph, no employee of the applicant may be seated next to an emergency exit.

(j) Seat belts and shoulder harnesses (as required) must be fastened.

(k) Before the start of the demonstration, approximately one-half of the total average amount of carry-on baggage, blankets, pillows, and other similar articles must be distributed at several locations in aisles and emergency exit access ways to create minor obstructions.

(l) No prior indication may be given to any crewmember or passenger of the particular exits to be used in the demonstration.

(m) The applicant may not practice, rehearse, or describe the demonstration for the participants nor may any participant have taken part in this type of demonstration within the preceding 6 months.

(n) The pretakeoff passenger briefing required by §121.571 may be given. The passengers may also be advised to follow directions of crewmembers but not be instructed on the procedures to be followed in the demonstration.

(o) If safety equipment as allowed by paragraph (c) of this appendix is provided, either all passenger and cockpit windows must be blacked out or all of the emergency exits must have safety equipment in order to prevent disclosure of the available emergency exits.

(p) Not more than 50 percent of the emergency exits in the sides of the fuselage of an airplane that meets all of the requirements applicable to the required emergency exits for that airplane may be used for the demonstration. Exits that are not to be used in the demonstration must have the exit handle deactivated or must be indicated by red lights, red tape, or other acceptable means placed outside the exits to indicate fire or other reason why they are unusable. The exits to be used must be representative of all of the emergency exits on the airplane and must be designated by the applicant, subject to approval by the Administrator. At least one floor level exit must be used.

(q) Except as provided in paragraph (c) of this section, all evacuees must leave the airplane by a means provided as part of the airplane's equipment.

(r) The applicant's approved procedures must be fully utilized, except the flightcrew must take no active role in assisting others inside the cabin during the demonstration.

(s) The evacuation time period is completed when the last occupant has evacuated the airplane and is on the ground. Provided that the acceptance rate of the stand or ramp is no greater than the acceptance rate of the means available on the airplane for descent from the wing during an actual crash situation, evacuees using stands or ramps allowed by paragraph (c) of this Appendix are considered to be on the ground when they are on the stand or ramp.

[Amdt. 25-72, 55 FR 29788, July 20, 1990, as amended by Amdt. 25-79, Aug. 26, 1993]

Australia Records Three Nonfatal Accidents Among High-capacity Air Transport Aircraft In 2000

Preliminary data also show that three accidents, including one fatal accident, occurred among low-capacity air transport aircraft.

FSF Editorial Staff

Six accidents, including one fatal accident, occurred among air transport category aircraft in Australia in 2000, the Australian Transport Safety Bureau (ATSB) said.

Preliminary statistics compiled by ATSB (formerly known as the Bureau of Air Safety Investigation) showed that there were three accidents — none of them fatal — involving high-capacity air transport aircraft (Table 1).[1] Two accidents occurred outside Australia.

Three accidents occurred involving low-capacity air transport aircraft, including one fatal accident.[2]

The statistics also showed that charter aircraft were involved in 27 accidents, including three fatal accidents, in 2000 and that helicopters were involved in 46 accidents, including three fatal accidents (Table 2).[3]

The preliminary statistics did not include accident rates or total hours flown.

Statistics for 1990–1999 show that there were eight accidents involving high-capacity air transport aircraft in 1999, the highest single-year total for the 10-year period (Table 3); none of the accidents was fatal (Table 4, page 94). Low-capacity air transport aircraft were involved in three accidents in 1999, the largest number since 1995; none of the accidents was fatal. Twenty-one accidents — including three fatal accidents in which a total of 10 people were killed (Table 5, page 94) — involved charter aircraft; the 21-accident total was about half the number of charter aircraft accidents recorded during each of the two previous years.

High-capacity air transport aircraft were flown 685,000 hours in 1999, compared with 714,800 hours in 1998 (Table 6, page 94). Low-capacity air transport aircraft were flown 277,300 hours in 1999, compared with 273,200 hours in 1998, and charter aircraft were flown 507,500 hours in 1999, compared with 497,500 hours in 1998.

Accident rates per 100,000 flight hours in 1999 were 1.16 for high-capacity air transport aircraft, 1.08 for low-capacity air transport aircraft and 4.13 for charter aircraft (Table 7, page 95). Fatal accident rates were zero for both categories of air transport aircraft in 1999 and 0.59 per 100,000 flight hours for charter aircraft (Table 8, page 95).♦

Notes

1. The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).
2. CASA defines a *low-capacity air transport aircraft* as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less.
3. CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Table 1
Australian Civil Aircraft Accidents, 2000

	Total Accidents	Fatal Accidents
High-capacity air transport[1]	3	0
Low-capacity air transport[2]	3	1
Charter[3]	27	3
Agricultural	20	3
Flying training	36	0
Other aerial work	27	2
Private	80	9
Business	3	0
Total	**199**	**18**

Note: Preliminary information as of Nov. 23, 2000, subject to revision. This table includes both fixed-wing and helicopter accidents, but excludes sport aviation.

[1]The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).

[2]CASA defines a *low-capacity air transport aircraft* as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Table 2
Australian Helicopter Accidents, 2000

	Total Accidents	Fatal Accidents
High-capacity air transport[1]	0	0
Low-capacity air transport[2]	0	0
Charter[3]	4	0
Agricultural	5	0
Flying training	8	0
Other aerial work	19	2
Private	10	1
Business	0	0
Total	**46**	**3**

Note: Preliminary information as of Nov. 23, 2000, subject to revision.

[1]The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).

[2]CASA defines a *low-capacity air transport aircraft* as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Table 3
Australian Civil Aircraft Accidents, 1990–1999

Aircraft Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
High-capacity air transport[1]	2	2	2	1	2	1	1	0	1	8
Low-capacity air transport[2]		4	6	5	4	4	2	0	1	3
Supplementary airline/commuter[2]	7									
Charter[3]	39	32	37	44	49	42	34	49	41	21
Agricultural	38	25	28	24	16	29	33	34	35	24
Flying training	33	30	25	36	28	36	26	38	24	32
Other aerial work	43	35	32	35	27	19	27	34	17	18
Private/business	116	137	111	117	86	90	83	74	91	71
Total general aviation	**276**	**259**	**233**	**256**	**206**	**216**	**203**	**229**	**208**	**166**

[1]The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).

[2]In 1991, the term *low-capacity air transport aircraft* (which CASA defines as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less) replaced the terms *supplementary airline* and *commuter*. Statistics prepared before 1991 treated such operations as sectors of general aviation, which does not include air transport operations.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Table 4
Australian Civil Aircraft Fatal Accidents, 1990–1999

Aircraft Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
High-capacity air transport[1]	0	0	0	0	0	0	0	0	0	0
Low-capacity air transport[2]		0	0	1	0	1	0	0	0	0
Supplementary airline/commuter[2]	0									
Charter[3]	5	2	2	4	6	3	6	4	2	3
Agricultural	2	1	3	1	4	2	4	5	2	0
Flying training	4	3	1	0	2	1	0	0	1	1
Other aerial work	9	1	1	3	4	4	4	1	2	1
Private/business	10	14	18	14	9	12	9	7	16	16
Total general aviation	**30**	**21**	**25**	**22**	**25**	**22**	**23**	**17**	**23**	**21**

[1]The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).

[2]In 1991, the term *low-capacity air transport aircraft* (which CASA defines as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less) replaced the terms *supplementary airline* and *commuter*. Statistics prepared before 1991 treated such operations as sectors of general aviation, which does not include air transport operations.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Table 5
Australian Civil Aircraft Fatalities, 1990–1999

Aircraft Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
High-capacity air transport[1]	0	0	0	0	0	0	0	0	0	0
Low-capacity air transport[2]		0	0	7	0	2	0	0	0	0
Supplementary airline/commuter[2]	0									
Charter[3]	18	3	2	8	22	8	13	8	7	10
Agricultural	2	2	3	1	4	2	4	5	2	0
Flying training	6	4	2	0	4	1	0	0	1	2
Other aerial work	14	1	1	4	5	6	5	3	3	2
Private/business	24	35	41	33	16	20	21	12	33	26
Total general aviation	**64**	**45**	**49**	**46**	**51**	**37**	**43**	**28**	**46**	**40**

[1]The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).

[2]In 1991, the term *low-capacity air transport aircraft* (which CASA defines as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less) replaced the terms *supplementary airline* and *commuter*. Statistics prepared before 1991 treated such operations as sectors of general aviation, which does not include air transport operations.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Table 6
Australian Civil Aircraft Hours Flown (in Thousands), 1990–1999

Aircraft Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
High-capacity air transport[1]	412.9	483.5	526.8	561.7	613.2	667.0	711.1	729.2	714.8	685.0
Low-capacity air transport[2]		212.8	223.4	227.7	238.3	243.1	246.2	272.4	273.2	277.3
Supplementary airline/commuter[2]	204.3									
Charter[3]	402.7	387.5	407.0	396.5	427.2	468.8	483.3	486.7	497.5	507.5
Agricultural	161.1	110.2	89.6	97.9	86.9	103.2	125.6	136.9	147.5	134.5
Flying training	486.4	458.4	427.5	442.7	424.9	436.5	450.4	455.3	484.1	454.4
Other aerial work	302.2	290.0	264.0	286.1	308.4	309.7	292.5	314.6	319.3	313.6
Private/business	576.7	502.9	462.7	480.7	458.2	443.2	447.3	445.7	429.7	432.1
Total general aviation	**2,133.4**	**1,749.0**	**1,650.8**	**1,703.9**	**1,705.6**	**1,761.4**	**1,799.1**	**1,839.2**	**1,878.1**	**1,842.2**

[1]The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).

[2]In 1991, the term *low-capacity air transport aircraft* (which CASA defines as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less) replaced the terms *supplementary airline* and *commuter*. Statistics prepared before 1991 treated such operations as sectors of general aviation, which does not include air transport operations.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Table 7
Australian Civil Aircraft Accident Rate per 100,000 Hours, 1990–1999

Aircraft Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
High-capacity air transport[1]	0.48	0.41	0.38	0.18	0.33	0.15	0.14	0.00	0.14	1.16
Low-capacity air transport[2]		1.88	2.69	2.20	1.68	1.65	0.81	0.00	0.37	1.08
Supplementary airline/commuter[2]	3.43									
Charter[3]	9.68	8.26	9.09	11.10	11.47	8.96	7.03	10.07	8.24	4.13
Agricultural	23.59	22.69	31.24	24.50	18.41	28.10	26.28	24.83	23.73	17.83
Flying training	6.78	6.54	5.85	8.13	6.32	8.25	5.77	8.35	4.96	7.04
Other aerial work	14.23	12.07	12.12	12.23	8.75	6.13	9.23	10.80	5.32	5.74
Private/business	20.11	27.24	24.01	24.34	18.77	20.31	18.56	16.60	21.18	16.43
Total general aviation	**12.93**	**14.81**	**14.11**	**15.02**	**12.07**	**12.26**	**11.28**	**12.45**	**11.08**	**9.01**

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[2]In 1991, the term *low-capacity air transport aircraft* (which CASA defines as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less) replaced the terms *supplementary airline* and *commuter*. Statistics prepared before 1991 treated such operations as sectors of general aviation, which does not include air transport operations.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Table 8
Australian Civil Aircraft Fatal Accident Rate per 100,000 Hours, 1990–1999

Aircraft Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
High-capacity air transport[1]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Low-capacity air transport[2]		0.00	0.00	0.44	0.00	0.41	0.00	0.00	0.00	0.00
Supplementary airline/commuter[2]	0.00									
Charter[3]	1.24	0.52	0.49	1.01	1.40	0.64	1.24	0.82	0.40	0.59
Agricultural	1.24	0.91	3.36	1.02	4.60	1.94	3.19	3.65	1.36	0.00
Flying training	0.82	0.65	0.23	0.00	0.47	0.23	0.00	0.00	0.21	0.22
Other aerial work	2.98	0.34	0.38	1.05	1.30	1.29	1.37	0.32	0.63	0.31
Private/business	1.73	2.78	3.89	2.91	1.96	2.71	2.01	1.57	3.72	3.70
Total general aviation	**1.41**	**1.20**	**1.51**	**1.29**	**1.47**	**1.25**	**1.28**	**0.92**	**1.22**	**1.13**

[1]The Australian Civil Aviation Safety Authority (CASA) defines a *high-capacity air transport aircraft* as an aircraft that is certified as having a maximum seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,259 pounds).

[2]In 1991, the term *low-capacity air transport aircraft* (which CASA defines as an aircraft with 38 seats or fewer and a maximum payload of 4,200 kilograms or less) replaced the terms *supplementary airline* and *commuter*. Statistics prepared before 1991 treated such operations as sectors of general aviation, which does not include air transport operations.

[3]CASA defines a *charter aircraft* as one used for the carriage of passengers or cargo for hire or reward other than airline operations.

Source: Australian Transport Safety Bureau

Publications Received at FSF Jerry Lederer Aviation Safety Library

FAA Issues New Guidelines on Portable Electronic Devices

Devices may be used when the operator determines that they will not interfere with the safe operation of the aircraft.

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FSF Editorial Staff

Advisory Circulars

Use of Portable Electronic Devices Aboard Aircraft. U.S. Federal Aviation Administration Advisory Circular (AC) 91.21-1A. Oct. 10, 2000. 4 pp. Available through GPO.*

This AC provides aircraft operators with guidance about complying with U.S. Federal Aviation Regulations Part 91.21, "Portable Electronic Devices," which was established because some portable electronic devices (PEDs) can interfere with aircraft communication equipment and navigation equipment. PEDs include devices such as cellular telephones, remote control devices, citizens band radios and medical monitoring equipment. This AC permits the use of specified PEDs and similar devices that the operator determines will not interfere with safe operation of the aircraft. This AC cancels AC 91.21-1, *Use of Portable Electronic Devices Aboard Aircraft*, dated Aug. 20, 1993.

Change #2 to Design of Aircraft Deicing Facilities. U.S. Federal Aviation Administration Advisory Circular (AC) 150/5300-14, Change #2. Aug. 31, 2000. 7 pp. Figures, tables. Available through GPO.*

This AC addresses two significant changes. Chapter 5, "Water Quality Mitigation," includes new methods for lessening the effects of deicing and anti-icing products in storm water runoff. Appendix 1, "Design of Infrared Deicing Facilities," provides standards and recommendations for constructing facilities where gas-powered, computer-controlled infrared energy unit systems will be used. The AC says that such facilities are intended only for deicing operations.

Reports

Abnormal Glucose Levels Found in Transportation Accidents. Canfield, Dennis V.; Chaturvedi, Arvind K.; Boren, Henry K.; Véronneau, Stephen J.H.; White, Vicky L. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine (OAM). DOT/FAA/AM-00/22. June 2000. 11 pp. Tables. Available through NTIS.**

FAA OAM is responsible for the medical certification of pilots with diabetic conditions. Therefore, OAM monitors pilots involved in fatal accidents to check for abnormal glucose levels that might have caused their incapacitation or the impairment of their performance. In this study, OAM evaluated the practice of examining postmortem glucose levels in vitreous humor (fluids in the eye) and/or the urine in 192 fatal accident victims. Researchers concluded that the existence of hyperglycemia (abnormally increased content of glucose in the blood) can be established from vitreous humor and urine glucose levels. Hypoglycemia (abnormally decreased concentration of glucose in the blood) cannot be established in this manner because of the rapid postmortem drop in vitreous humor glucose levels.

Impact of Aviation Highway-in-the-Sky Displays on Pilot Situation Awareness. Williams, Kevin W. Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AM-

00/31. October 2000. 9 pp. Figures, tables. Available through NTIS.**

Highway-in-the-sky (HITS) displays provide course guidance to pilots by giving a perspective view of a path through the air. As a result of technological advances and lower production costs, HITS displays could replace displays used in general aviation. Discussions within the industry focus on the purpose, appropriate use, effectiveness and safety of the displays. This study was conducted with 36 private pilots to determine the effect that an HITS display would have on pilot situational awareness. The report presents pilots' experiences in three types of situational awareness: position of intended flight path relative to current aircraft position, ability to locate other aircraft and knowledge of secondary information available on the HITS display.

The Relationship Between Aviators' Home-Based Stress To Work Stress and Self-Perceived Performance. Fiedler, Edna R.; Della Rocco, Pam S.; Schroeder, David J.; Nguyen, Kiet T. Federal Aviation Administration Office of Aviation Medicine. DOT/FAA/AM-00/32. October 2000. 7 pp. Tables. Available through NTIS.**

Nineteen U.S. Coast Guard helicopter pilots completed questionnaires designed to assess sources of stress (home and job) and coping strategies. The pilots also evaluated their own flying performance relative to the influences of stress. Results of the study indicate that the effects of domestic stress directly influenced work stress and indirectly influenced pilots' perceptions of their flying performance. The positive influences of home life and family support were important factors in mediating stress.

Aviation and the Environment, Airport Operations and Future Growth Present Environmental Challenges. U.S. General Accounting Office (GAO). Report GAO/RCED-00-153. August 2000. 100 pp. Figures, appendixes. Available through GAO.***

U.S. airports are under increasing pressure to expand operations to accommodate the growing demand for domestic air travel. The U.S. Federal Aviation Administration (FAA) forecasts a 3.6 percent annual growth rate in domestic air travel through 2011. The GAO, which conducts research for the U.S. Congress, reviewed key environmental issues associated with current airport operations and future growth. The review included surveying airports and examining actions being taken by FAA and other federal government agencies to address these environmental concerns.

Aviation and the Environment, Results From a Survey of the Nation's 50 Busiest Commercial Service Airports. U.S. General Accounting Office (GAO). Report GAO/RCED-00-222. August 2000. 73 pp. Figures, appendixes. Available through GAO.***

This report accompanies *Aviation and the Environment: Airport Operations and Future Growth Present Environmental Challenges* and provides detailed question-by-question analysis of responses to the survey of the 50 busiest commercial service airports in the United States by the GAO, which conducts research for the U.S. Congress. Noise, water and air quality issues are the primary environmental concerns facing airports today and in the future.

Books

Patterns in Safety Thinking: A Literature Guide to Air Transportation Safety. McIntyre, Geoffrey R. Burlington, Aldershot, Hants, England: Ashgate Publishing, 2000. 137 pp.

This book is a bibliographic essay, a critical work that identifies and evaluates core literature of a subdiscipline or field of study, providing guidance to students, researchers and others. The author examines major air transportation safety books and transportation safety journals. The author's intent is to provide students and practitioners with an educational supplement to safety literature and aviation safety management training courses.

Airport Planning & Management. Wells, Alexander T. Hightstown, New Jersey, U.S.: McGraw Hill, Fourth Edition, 2000. 553 pp.

This introductory textbook is written for students of aviation programs and practitioners in airport management and operations. The fourth edition provides new or expanded text on the following topics: funding sources, privatization, revenue diversion, passenger facility charges, terminal design updates, airport-airway system developments, airside and landside technology improvements, noise and environmental regulations, U.S. Federal Aviation Administration requirements, capacity and management issues, and military base conversions.♦

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*** U.S. General Accounting Office (GAO)
P.O. Box 37050
Washington, DC 20013 U.S.
Internet: http://www.gao.gov

Broken Fan Blade Prompts Shutdown of Engine on Boeing 767

The incident, which occurred during departure from an airport in Australia, led to safety recommendations from the engine manufacturer and the aircraft operator.

FSF Editorial Staff

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

Fatigue Crack Began at Site of Foreign-object Damage

Boeing 767. Minor damage. No injuries.

The airplane was being flown to Flight Level 310 (31,000 feet) after an evening departure from an airport in Australia when the flight crew heard a bang from the right engine and observed that the right-engine instruments indicated a decrease in engine pressure ratio and an increase in exhaust gas temperature (EGT). Cabin crew and passengers saw a flash and sparks from the rear of the engine. A "moderate vibration" was felt throughout the airplane.

The EGT continued to increase, and the right engine was shut down. The flight crew declared a "Pan Pan" urgency condition and reported the engine shutdown to air traffic control. The crew requested clearance to return to the departure airport. The crew reduced speed to 240 knots in an attempt to reduce the vibration, but the vibration continued until the airplane was on final approach. The airplane was landed without further incident.

A subsequent inspection of the engine revealed that "about one-quarter of the no. 28 fan blade had broken away, resulting in substantial damage to the inside of the nose [cowling] and to the majority of the fan blades. Abnormal displacement of fan blades (shingling) was evident on the mid-span shrouds of a number of blades surrounding the fractured blade."

The fan-blade-attrition lining also was damaged, the forward fan case was distorted, the nose-cowling outer skin was punctured, and the nose cowling had moved forward.

The operator's maintenance records said that the right-engine fan blades were inspected for leading-edge cracks 93 operational hours (and 54 cycles) before the incident, and no leading-edge cracks were found. In the nine months preceding the accident, 13 right-engine fan blades were repaired because of foreign-object damage (FOD). The fractured fan blade was not among them. The operator also said that fan-blade leading-edge restoration was performed at 5,000-cycle intervals. The fan blades were overhauled 6,689 hours (or 3,889 cycles) before the incident.

Inspection revealed that the fan blade had fractured inboard of the mid-span shroud as a result of a fatigue crack. The failure originated at a site that had incurred previous FOD, and the crack probably grew during about 35 cycles, the report said.

The engine manufacturer said that only one other fracture of this type of fan blade had been reported, also because of a fatigue crack that began at an FOD impact site.

As a result of the fan-blade fracture, the engine manufacturer recommended that specific areas of the fan blade shroud be lubricated during every "A" check. The operator added the lubrication procedure to its maintenance manual.

The manufacturer recommended that:

- Proper leading-edge contours be maintained on fan blades and that leading-edge restoration be performed every 2,000 cycles to 3,000 cycles; and,
- Operators inspect fan blades for FOD in accordance with the maintenance manual.

Corrosion Blamed for Aileron Control Problem

Boeing 737. No damage. No injuries.

The airplane was descending through 500 feet on final approach to an airport in Ireland when the pilot flying observed that an input of five units to six units of right aileron was needed to maintain a wings-level attitude. The right-aileron input was necessary until the landing was completed.

A subsequent inspection revealed that the actuator on the outboard spoiler on the left wing was not connected to the control surface of the spoiler. The problem was attributed to severe corrosion on the actuator shaft and on the eye end of the actuator. The corrosion had separated the eye end from the shaft.

The actuator had been in place since the airplane was delivered to the operator 10 years before the incident.

Engine Failure During Descent Prompts Priority Handling for Landing

BAE SYSTEMS 146. Substantial damage. No injuries.

Instrument meteorological conditions prevailed, and an instrument flight rules flight plan had been filed for the predawn maintenance ferry flight in Colombia. As the flight crew retarded the thrust levers for the descent from Flight Level 250 (25,000 feet) to the destination airport, they heard a bang, felt severe vibrations and observed a loss of engine indications for the no. 4 engine. The airplane yawed to the right, and the crew disengaged the autopilot to hand-fly the airplane. After the crew completed the engine-failure checklist, the captain walked to the rear of the airplane to look out the window and observed that the no. 4 engine was seriously damaged and that the engine cowling was torn in the turbine area.

The crew requested priority handling and landed the airplane without further incident. An inspection revealed that an uncontained engine failure had occurred in the AlliedSignal Textron Lycoming LF507-1F engine, the engine cowling had ruptured, the fourth turbine wheel had been dislodged and the no. 4 and no. 5 bearing assemblies were missing.

"The bearing chamber was completely clean and dry of oil, the combustion chamber torn, the exhaust vein assembly melted, and several bolts that hold the engine together sheared," the accident report said. "The engine mount was also damaged, but there were no signs of fire. There was also damage to the flap, as a result of the turbine wheel impact as it became dislodged from the engine, as well as damage to the leading and trailing edge of the wing, and the wing's underside."

The operator said that maintenance had been performed four months earlier to replace engine vibration pickup sensors. The work required removal of the fourth turbine wheel. The engine had been in operation for 600 hours after the maintenance work.

Tail Cone Separates From Airplane During Landing Roll

McDonnell Douglas DC-9. Minor damage. No injuries.

During the landing roll at an airport in Canada, the airplane's tail cone fell onto the runway. The flight crew taxied to the gate without further incident. They were unaware that the tail cone had separated from the airplane until air traffic controllers told them.

About 54 hours before the incident, maintenance personnel had installed a second internal-release handle for the tail cone. While performing the work, maintenance personnel had disconnected the release cable from the original internal-release handle and removed a pipe through which the cable was routed. When the cable was re-installed, it was not re-routed through the pipe.

"As a result," the accident report said, "there was no tension on the tail cone latching levers, and as a consequence, they eventually unlocked, allowing the tail cone to detach from the aircraft."

Cleaner's Wiping Rag Renders Nosewheel Steering Inoperative

Boeing 747. No damage. No injuries.

After the airplane was landed in Taiwan, the nosewheel-steering system did not function. The airplane was towed to the ramp, and passengers deplaned normally.

A maintenance inspection revealed that a wiping rag had jammed a pulley in the nosewheel-steering system. The system had been cleaned before departure from Canada. The operator subsequently published instructions for cleaning crews to account for all wiping rags after completing their work.

Lightning Strike on Final Approach Disables Airplane Instruments

Saab SF 340. Minor damage. No injuries.

Darkness prevailed for the domestic flight in Sweden, and the airplane had been flown through moderate turbulence. Pilots of other aircraft in the area had reported lightning, but the crew saw no indication of storms on their weather radar.

The airplane was established on the localizer for an instrument landing system approach. About nine nautical miles (16.7 kilometers) from the runway, at 2,700 feet, the airplane was struck by lightning, which disabled all instruments (except standby instruments), emergency lighting and communication with air traffic control (ATC).

The crew continued the approach using standby instruments. They failed in attempts to restart the generators but succeeded in re-establishing communication with ATC and then requested radar vectors during the approach. The landing gear was extended using the emergency landing-gear-extension procedure.

The flight crew declared an emergency, and the cabin crew-member briefed passengers. After an uneventful landing, the crew reset both engine-driven generators, and all instruments began to function normally except the electronic flight instrument system screens, on which colors appeared faded.

A subsequent inspection revealed a crack between 40 centimeters (15.8 inches) and 50 centimeters (19.7 inches) long in the upper portion of the nose radome.

Distractions During Approach Result in Gear-up Landing

Piper Navajo. Substantial damage. No injuries.

The pilot flew the airplane out of clouds at 5,000 feet while on a mid-morning nondirectional radio beacon-distance-measuring equipment (NDB-DME) approach to an airport in New Zealand.

The pilot decided to continue the instrument approach rather than fly a visual approach because he believed that would give parachutists on another airplane time to complete their jumps to the runway. The pilot also delayed extending the landing gear "until he was sure that the parachutists were clear of the runway," the accident report said. "He said that he wanted to avoid having the drag of the undercarriage in the event that he had to maneuver the aircraft to give the parachutists time to clear the end of the runway."

On short final approach, the pilot continued to observe the locations of the parachutists. As the airplane crossed the runway threshold and the pilot reduced power, a warning horn sounded. The pilot initially believed that he was hearing the stall warning horn, then realized that the sound was from the landing-gear warning horn. As he initiated a go-around, the propellers struck the runway, and the cargo pod beneath the aircraft's undercarriage settled onto the runway. The airplane slid along the runway, then onto the grass.

The accident report said, "During his landing approach, the pilot became preoccupied with the parachutists, and his attention was diverted from the need to complete the outstanding [short-final] checklist action and to positively confirm that the undercarriage was down before landing."

Failed Engine Bearing Prompts Unscheduled Landing

De Havilland Canada DHC-8-202. Minor damage. No injuries.

During cruise at Flight Level 220 (22,000 feet) on a domestic flight in Australia, the flight crew heard a muffled sound and observed an increase in the left engine's interturbine temperature. The crew reduced engine power and landed the airplane at an airport.

An inspection of the engine revealed that the no. 5 bearing had failed and that the bearing cage was open and contained two cracks. Some of the roller pockets in the bearing cage were enlarged and were distorted, and the rollers were rotating in the plane of the cage; other rollers were immobilized. Half of the 12 rollers had smaller diameters than the others, and their surfaces were abraded and were smeared — conditions consistent with heavy contact loads. The engine manufacturer had issued Service Bulletin 21472R2 on Feb. 25, 1999, recommending installation of improved no. 5 bearings in Pratt & Whitney PW100 engines with serial numbers prior to that of the failed engine when the engines were disassembled. (The improved bearings were installed in engines with serial numbers subsequent to that of the failed engine.) The improved bearing had not been installed in this engine.

Navigation Light Broken as Wing Tip Strikes Wall

Cessna 750 Citation X. Minor damage. No injuries.

The crew was being directed to a parking space in a business-jet parking area at an airport in England. A 230-degree right turn was being conducted in stages, and, during the last 140 degrees of the turn, the left wing tip was near a blast wall.

When the airplane approached the required turning point, the marshaller positioned himself near the blast wall, but he moved away after he was satisfied that there was sufficient clearance. The airplane's left wing tip then contacted the vanes of the blast wall, damaging the left navigation light. The captain felt the wing tip contact the wall, stopped the airplane and shut down the engines.

The flight manual says that, for turns using nosewheel steering, the airplane is pivoted around either the left main wheels or the right main wheels. For a 180-degree turn, the wing tip describes a semicircle with a diameter of 24.64 meters (80 feet 10 inches), which is 5.25 meters (17 feet 3 inches) more than the wing span.

Smoke in Cockpit Prompts Emergency Landing

Cessna 550 Citation. Minor damage. No injuries.

During an evening departure from an airport in Canada, the crew observed smoke in the cockpit. They donned oxygen masks, declared an emergency and returned to the departure airport.

An investigation determined that the smoke had been generated by an overhead fan in the rear pressurization bulkhead.

The accident report said, "The overhead fan was found with one of the two screws holding the armature together unscrewed and backing off. The screw eventually jammed the fan rotor. This condition caused the motor to overheat and smoke."

The investigation also determined that a main electrical wire bundle was chafing against the overhead fan's motor body, that there was "significant heat transfer" to the protective sleeve and that material in the protective sleeve had melted.

Tow Plane Damaged During Landing With Banner on Tailwheel

Piper PA-25-235 Pawnee. Substantial damage. No injuries.

During a banner-towing pick-up at an airport in Canada, the banner caught on the airplane's tailwheel. Air traffic controllers in the airport control tower advised the pilot that the banner pick-up "looked good," and the pilot proceeded with the flight.

Later, the pilot was unable to release the banner. The pilot then tried unsuccessfully to dislodge the banner by changing the airplane's yaw and pitch, and eventually decided to land with the banner attached. When the pilot advanced the throttle to level the airplane after a descent, the engine stopped and could not be restarted. The pilot attempted to land in a field, but the airplane struck trees.

"Company maintenance attended the scene and discovered that there was very little fuel in the bottom of the tank," the accident report said. "Fuel was removed from the carburetor and found to be clean and free of contaminants. A replacement propeller was installed, fuel was put in the tank, and the engine started and ran without difficulty."

Airplane Ditched in Ocean After Loss of Engine Power

Cessna 172N. Airplane destroyed. No injuries.

Day visual meteorological conditions prevailed over the Atlantic Ocean as the pilot began an initial descent from 6,500 feet for landing at an airport about 35 miles (56 kilometers) away in the United States.

When the pilot leveled the airplane at 3,500 feet and advanced the throttle, the engine remained at idle. The pilot ditched the airplane near a commercial boat, and the airplane sank in water about 1,000 feet (305 meters) deep; all four occupants of the airplane were rescued.

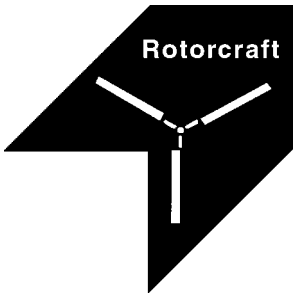
The accident report said that the airplane was not recovered and the engine was not examined but that weather conditions were conducive to formation of carburetor ice. Carburetor heat was not used during the descent.

Airplane Collides With Truck During Landing Roll

Piper PA-32-300. Substantial damage. Two serious injuries; two minor injuries.

Day visual meteorological conditions prevailed for landing at an airport in the Caribbean.

The pilot described the landing as uneventful until a pickup truck was driven onto the runway in front of the airplane. The pilot steered left in an unsuccessful attempt to avoid striking the truck. The airplane and the truck received substantial damage. The pilot and his sole passenger received minor injuries; both occupants of the truck received serious injuries.



Low-flying Helicopter Strikes Electric Wires

Aerospatiale AS 350B Ecureuil. Minor damage. No injuries.

The pilot was on a photographic mission above a river in Wales and had obtained permission to fly the helicopter at low altitudes — about 50 feet to 60 feet above the water and level with treetops on the riverbanks.

The pilot observed two wires in front of the helicopter and tried to avoid them by initiating a climb. The helicopter's windscreen struck the wires, which broke the outside air temperature probe. Sparks were observed, but the helicopter appeared to handle normally. The pilot made a precautionary landing in a nearby field. An inspection revealed scratches on the windscreen, the cabin roof and the main gearbox cowling.

The pilot said that he had chosen the location because of the width of the river and the apparent absence of obstructions. The electric wires and the supporting poles were obscured by trees.

Tail Boom Separates During Flight

Hughes 369D. Substantial damage. No injuries.

Visual meteorological conditions prevailed for the midday flight. The pilot said that the helicopter was in level flight at 500 feet when he felt a high-frequency vibration through the anti-torque pedals. The vibration increased, and the pilot heard a bang. The helicopter yawed violently to the right and pitched nose-down. The anti-torque pedals were ineffective.

The pilot conducted an emergency autorotational landing in a clearing in a wooded area. Subsequent examination of the helicopter revealed that the stabilizer and an 18-inch (46-centimeter) section of the tail boom had separated from the helicopter and that the 90-degree gearbox had separated partially and was attached by one bolt.

Helicopter Strikes Terrain During Instructional Flight

Robinson R22 Beta. Helicopter destroyed. One serious injury; one minor injury.

The helicopter was being flown on an instructional flight in Australia. After prolonged hovering on a warm day, the instructor took control and transitioned the helicopter into forward flight with the intention of cooling the cockpit. An earlier rain shower had left an accumulation of raindrops on the canopy.

The instructor flew the helicopter at about 35 knots to about 50 feet above ground level, then began a left turn to resume the hover.

The accident report said, "The instructor reported that while he was looking out to his left at the area where he intended arriving, he realized that the helicopter was too low to the ground. The helicopter's left skid hit the ground, then the helicopter rolled right, and the main-rotor blades hit the ground."

The helicopter cartwheeled, skidded and stopped on its right side. The fuel tanks ruptured, and the helicopter began to burn. Both pilots escaped through the shattered canopy just before the helicopter exploded.

The pilots said that the helicopter had operated normally before striking the ground. Investigators could not determine whether the raindrops on the canopy had interfered with the instructor's visual perception.♦

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