FLIGHT SAFETY FOUNDATION
CABIN CREW SAFETY

Vol. 33 No. 2 | *For Everyone Concerned with the Safety of Flight* | March–April 1998

Continuing Study of Nonaccident Evacuations May Help Reduce Passenger Injuries

Several research studies, including a new study by the U.S. National Transportation Safety Board, have used nonaccident aircraft evacuations as a data source with potential to improve cabin safety through better procedures and training.

—

FSF Editorial Staff

Although nonaccident evacuations of air-carrier aircraft have been considered rare and random events among more than 9.8 million annual departures in the U.S.,[1] these evacuations — and related injuries to passengers and crewmembers — have occurred more frequently than evacuations following U.S. air-carrier accidents. Proponents of research on this subject have said that cabin safety could be improved if some evacuations and injuries could be prevented through regular collection and analysis of data about nonaccident evacuations.

[The term "nonaccident evacuation" throughout this article means evacuations by air carriers after occurrences that would not meet the U.S. National Transportation Safety Board's (NTSB) definition of an aircraft accident. This term does not imply that these evacuations are always unnecessary.]

Past and present studies may help prevent some nonaccident evacuations or make them safer. Recent crewmember reports to the Aviation Safety Reporting System (ASRS), a de-identified database of voluntarily submitted narratives administered by the U.S. National Aeronautics and Space Administration (NASA),[2] also provide insights.

At issue are safety factors in incidents such as the following example. The flight crew of a Boeing 767, ready for takeoff from Portland (Oregon, U.S.) International Airport, received a radio transmission from a commuter aircraft to the control tower concerning "fire coming out of [the B-767's] tail section, from the APU [auxiliary power unit]." The radio call triggered events leading to an evacuation of the B-767 and passenger injuries. A flight crewmember later said in an ASRS report that this 1996 evacuation should not have occurred.

The flight crewmember said, "I called the tower to confirm the external indication of a fire. The tower confirmed that they could see a fire [and] smoke. [The tower] rolled the fire equipment for a closer inspection. We were told via radio [that] the fire chief saw a little fire, but [that the fire] seemed to be dissipating. I called operations to let them know [that] we were returning to the gate and made a passenger [announcement] to that effect. The fire marshal then reported smoke coming from the fuselage and ordered us to shut down our engines and evacuate. … The captain fired the APU extinguisher and shut down the engines. An orderly evacuation then terminated the incident."

An ASRS analyst, summarizing a follow-up conversation with the crewmember, said, "The flight crew was intending to taxi back to the gate for further inspection after the fire chief reported [that] the fire was dissipating. However, shortly thereafter, the fire marshal thought smoke was coming from the fuselage and told the flight crew to shut down the engines and evacuate.

"Since the flight crew had no way of confirming what was happening in the tail, they complied with the evacuation instructions. … [After evacuation] the aircraft was towed back to the gate and inspected, with no evidence of fire or damage. … The [crewmember] said [that] it is not too unusual for some fuel to dump when the APU is shut down and [the fuel] can cause a momentary burning in the [tail] pipe, and, in fact, sometimes on certain aircraft, flames will actually shoot out from residual fuel. The [crewmember] questions the qualification of either the tower or the airport fire marshal to direct an evacuation. … This situation was really a nonevent that resulted in passenger injuries and should not have occurred."

Reasons for apparent nonaccident evacuations reported to the ASRS since 1994 have included bomb threats; false or intermittent indications from master fire-warning systems; vapors emitted by batteries; wheel-well, tire, brake and antiskid-system fires; locked brakes; separation of wheels and tire treads; deflated tires; fires contained in engines and tail pipes; APU torching; engine hot-starts; oil leaks into the hot section of an engine; smoke, odors or vapors in the cabin; hydraulic-line damage and hydraulic-fluid leaks; structural failure of landing gear; electrical faults in lavatories; runway overshoots or excursions; fractured bleed-air ducts or manifolds; ruptured fuel-oil heat exchangers; and contained turbine-blade failures.

The following studies consider common factors in nonaccident evacuations:

- In 1997 and 1998, safety consultant Michael K. Hynes completed reports for the U.S. Federal Aviation Administration (FAA) Civil Aeromedical Institute (CAMI) that documented U.S. precautionary evacuations and compiled data on injuries sustained during these evacuations;[3]

- The latest study by the NTSB — begun in December 1997 — covers all types of U.S. air-carrier evacuations and will continue until a specified number of evacuations has been studied; and,

- In 1995, safety consultant Richard L. Gross published results of his study of worldwide air-carrier emergency evacuations from 1987 to 1993.[4]

Based on preliminary data assembled in preparation for its latest study, the NTSB said that air-carrier evacuations of all types occurred at the rate of about one per week in the U.S. during 1994 and 1995.

The study by Hynes estimated that an aircraft evacuation occurred in the United States every five to six days between 1988 and 1996 and that nearly 6,000 people per year were evacuated in nonaccident events from large aircraft operating under U.S. Federal Aviation Regulations (FARs) Part 121 (air carrier) or Part 135 (commuter and on-demand operators).

The study by Gross estimated that more than 3,000 people and 20 aircraft per year were involved in nonaccident air-carrier evacuations between 1987 and 1993. The exact number of accident-related evacuations between 1988 and 1996 has not been determined, the NTSB said, but accidents occurred less frequently than nonaccident evacuations during this period among U.S. air carriers operating under Part 121.[5]

Hynes and Gross used different definitions and methods in their studies. The studies were not intended to be comparable. [Changes in the FARs that required many former Part 135 operators to conduct operations under Part 121 regulations after March 20, 1997, were not a factor in these earlier studies.]

Both studies said that passenger and crewmember injuries occurred during many nonaccident evacuations, and that the present data for nonaccident-evacuation studies are inadequate. Both studies recommended that operators be required to file a standard form that would provide data about all evacuations to the FAA and the NTSB.

Study by Hynes documents nonaccident evacuations. Although the FAA and NTSB have investigated emergency evacuations of aircraft following accidents, the agency and the board have not investigated every aircraft evacuation in the past. The study of nonaccident evacuations has been difficult because analysis requires compilation of data from various sources. Data for 60 percent of known nonaccident evacuations were not contained in FAA or NTSB databases, according to the 1997 CAMI study by Hynes.

Hynes identified 519 nonaccident evacuations by U.S. air carriers between 1988 and 1996. In many cases, notification of the NTSB was not required because emergency egress systems (slides) were not used. In cases where slides were used, the NTSB often did not request a written report after the airline complied with the NTSB's incident-notification requirements. Hynes augmented the FAA and NTSB data with mail surveys and follow-up contacts with managers of 136 U.S. airports that represented approximately 90 percent of the reported U.S. passenger enplanements (1995 data).

A database of nonaccident evacuations was formed from data definitions developed for Hynes's study. A nonaccident evacuation — which he called a "precautionary emergency-evacuation event" — was defined as "an event in which passengers and crewmembers were required to conduct an unscheduled deplanement at other than normal gate locations under noncrash-related circumstances." Evacuations were *included* in the database if emergency-egress systems were not deployed, but passengers and crewmembers conducted an unscheduled deplanement away from a gate. Unscheduled deplanements through cabin doors were *excluded* from the database if they occurred at a gate, regardless of whether an emergency occurred.

"One of the [research] motivations for me was to give cabin-safety people information they could take to [airline]

Research Prompts Recommendations about Nonaccident Aircraft Evacuations

Aircraft evacuations associated with accidents usually are considered necessary, but a review of 519 U.S.-carrier nonaccident evacuations suggested that some were not necessary. Pilots, flight attendants, aircraft rescue and fire-fighting (ARFF) professionals, airline safety managers, passenger advocates and aviation regulators have found it difficult to reach a consensus about how to distinguish appropriate from inappropriate evacuations of aircraft in some circumstances.

Flight-crew descriptions of nonaccident evacuations in the Aviation Safety Reporting System (ASRS) of the U.S. National Aeronautics and Space Administration (NASA), airport and ARFF records, background interviews and other research sources showed that some nonaccident evacuations are characterized as "false alarms" or "preventable." One of the problems inherent in discussing nonaccident evacuations, however, has been a lack of comprehensive data.

The data in the author's 1997 study were compiled from several sources, each of which had significant limitations, covering operations by U.S. carriers from 1988 to 1996 under U.S. Federal Aviation Regulations (FARs) Part 121 and Part 135.

Most evacuations involved a human-factors issue. For example, some aircraft evacuations were conducted in response to bomb threats several hours after the threats were made. Flat tires, low-oil-pressure warnings, false engine-fire warnings and common engine-start phenomena prompted some of the nonaccident evacuations. Passenger injuries or crewmember injuries occurred in many of these evacuations.

Although the type of aircraft was identified in most reports, no conclusion could be made about the potential for evacuation injuries in any specific make or model. Nevertheless, the data show that passenger injuries were involved in every evacuation of a wide-body aircraft and in most evacuations using an aircraft's emergency-egress systems (slides).

Information should be shared. There is a need for adequate information about all transport-aircraft evacuations, not just accidents and incidents for which the U.S. National Transportation Safety Board (NTSB) and/or the U.S. Federal Aviation Administration (FAA) *must be notified* to comply with federal regulations. Immediate notification must be provided to the NTSB when emergency-egress systems are used in a nonaccident situation, and a written report *may be required* at the discretion of the NTSB.

Human-factors engineers and aviation-safety specialists could benefit from more information about evacuations to improve air-carrier safety. The FAA, the NTSB and aviation-safety specialists could use a standardized form to collect consistent information about all evacuations from airline and airport personnel. The current form for accident reports could be used for nonaccident evacuations.

Evacuation data collected by the FAA and the NTSB in recent years have been incomplete. Examples of information needed are age and sex of passengers and crewmembers, causes and types of injuries, and medical assistance provided. The *FAA Inspector's Handbook* would require modification to guide inspectors and air-carrier personnel in complying with evacuation-reporting requirements. An FAA advisory circular could support compliance and explain the value of the data collected.

Mandatory evacuation reporting would be valuable. Current U.S. regulations require notification of the NTSB and/or the FAA about aircraft evacuations in some circumstances, and written reports occasionally are required. A program of mandatory and uniform reporting of all evacuations would provide a valuable source of cabin-safety data. This reporting program would be enhanced by the following:

- FARs 121.557 and 121.703, and NTSB Part 830 should be amended to include ground operations (in addition to flight operations) and to capture information about "false alarms" that have resulted in the use of emergency-egress systems or evacuations; and,
- FARs 121.703 (b), specifically the definition of when a flight begins and ends, should be amended in the same manner.

Emergency-exit differences need review. The requirements of FARs 25.807 (d) regarding passenger emergency exits should be reviewed. The data available for the author's study showed that injuries occurred in every evacuation of a wide-body aircraft. Further research should attempt to explain this observation, such as by considering design features that exist on or are missing from wide-body aircraft and any correlation to the potential for passenger or crewmember injuries.

Extra assistants should be added. The requirements of FARs 121, Subpart G, Manual Requirements, section 121.135 (b) (2) should be reviewed. The appropriateness of assigning a second "able-bodied assistant" (designated passenger) as a backup at each door-exit position should be evaluated. The review should consider procedures in the cabin and on the ground when the aircraft's emergency-egress system is utilized.

Emergency checklists should support decision making. FARs 121.135 (b) (11) should require airline emergency-checklist items that support the captain's evacuation-decision process. Airline policies and FAA-required operations and training manuals also should address directly the issue of decision making in nonaccident evacuations.

Engine-starting procedures help prevent panic. FARs 121.135 (b) (16) should include procedures to inspect and adjust engine-fuel controllers to decrease the possibility of flashes, flames and/or fires during auxiliary power unit (APU) and engine starts. This change would help prevent inappropriate reactions and evacuations prompted by misinterpretation of signs of fire by passengers, controllers, crews of other aircraft and ARFF personnel.

Airlines can clarify nonaccident evacuation practices. Airline policies regarding nonaccident evacuations should clarify the rationale for nonaccident evacuations, notification procedures and where nonaccident evacuations should take place under various conditions. The following actions also should be taken:

- Update policies and procedures for crew resource management (CRM) and training in aeronautical decision making for evacuation events, emphasizing cabin-crewmember assertiveness to stop an unwarranted passenger-initiated evacuation or to manage a nonaccident evacuation;

- Conduct regular joint evacuation training including CRM training (flight crews and cabin crews);

- Update preflight briefings and flight-crew checklists covering nonemergency but abnormal events based on research findings. Discuss passenger reactions to cabin-pressurization-system or air-conditioning-system vapors or odors, smoke, flashes of light or flames from starting APUs or engines;

- Include in passenger briefings and safety literature (briefing cards) information about nonhazardous vapors or odors, smoke, flashes of light or flames from starting APUs or engines, or other false indications of fires, especially at night;

- Advise passengers not to respond to a fellow passenger's direction to evacuate an aircraft unless crewmembers obviously are unable to order the evacuation during an emergency; and,

- Provide current airline policies regarding when, where and how nonaccident evacuations ideally should be conducted to airport station managers and staff, airport management, and ARFF personnel to improve coordination of their respective activities and communication.

Airport response policies may need updating. Airport policies covering how airport staff should respond to nonaccident evacuations should be updated. The policies should ensure clear airport-notification requirements for airlines. Airport administrators also should consider the following actions:

- Identify airport locations where evacuations ideally would occur under various conditions;

- Make research-based revisions to policies, drills and training to improve the ARFF response to nonaccident evacuations (such as provision of portable stairs and other equipment);

- Make available airport policy information about evacuations to airline management and operations personnel;

- Standardize radio-communication procedures for nonaccident evacuations. This would include communications before an evacuation with all members of the flight and cabin crews; airline station managers; airline operations, dispatch or maintenance personnel; airport management and ARFF personnel; air traffic control personnel; and passengers; and,

- Establish a common radio frequency for external radio communications during evacuations for ARFF crews, other ground personnel and the aircraft crew.

Human-factors questions require attention. Although ongoing research addresses emergency-egress-systems design and procedures — including computer simulation of human behavior in emergency evacuations of aircraft — additional studies are needed on the human-factors aspects of nonaccident evacuations.

Based on these research efforts, there will be opportunities to:

- Improve decision making by flight crews as they evaluate the risks and benefits of a nonaccident-evacuation order;

- Decrease the potential for passenger injuries during evacuations; and,

- Reduce passenger-initiated evacuations in reaction to false perceptions of fires or inappropriate direction from fellow passengers.♦

— Michael K. Hynes

Michael K. Hynes, Ed.D., is an aviation consultant and director of aviation research at Western Oklahoma State College, Altus, Oklahoma, U.S. He has studied emergency-evacuation events involving air carriers operating under U.S. Federal Aviation Regulations (FARs) Part 121 and Part 135. Two studies — "Emergency Egress System Use and Emergency Evacuation Events by Part 121 and 135 Air Carriers from 1988 to 1996" and "Demographic and Injury Data on Persons Injured During Part 121 Air Carrier Precautionary Emergency Evacuation Events" — were completed in 1997 and 1998, respectively, under contract to the Civil Aeromedical Institute (CAMI) of the U.S. Federal Aviation Administration (FAA). Hynes' aviation background includes certification as an airline transport pilot rated in airplanes and helicopters/autogyros, designated pilot examiner, airframe and powerplant technician/inspector, and FAA accident-prevention counselor. His pilot experience includes 16,100 flight hours.

management, to give the crews ammunition for discussing these issues with management," Hynes said. "My main concern is … airline-management direction on evacuations." Ideally, Hynes said, the study of nonaccident evacuations would allow immediate debriefing of participants while their memories are clear, and timely collection of related data.

Hynes said that he believes the central issue in making nonaccident evacuations safer is not crew judgment but adequate procedural direction, training and checklists for emergencies.

"If you don't discuss [nonaccident-evacuation decisions] in training, the flight crew may feel uncomfortable deciding not to evacuate," Hynes said. "In a flight simulator, the captain always orders the evacuation. If flight crews and cabin crews were better informed, we might see more decisions not to evacuate, thereby diminishing the number of events and the chance of injury."

Hynes's data showed that 42,811 passengers and crewmembers participated in nonaccident evacuations during the study period. To account for missing data, he used statistical interpolation to estimate that 47,520 people actually had participated in these evacuations. The data also showed that 1,228 people were injured or claimed injuries. By interpolation, he estimated that the actual number injured was 1,363.

The study analyzed injuries in more detail for a three-year sample period (1991–1993) to make allowance for delays in the filing and processing of insurance claims related to nonaccident-evacuation injuries. In the sample period, 193 nonaccident evacuations occurred and 250 injuries were reported. Based on the availability of data for 185 injury claims related to the 250 injuries, the study said that 44 percent of injuries involved males with an average age of 41, and 56 percent of injuries involved females with an average age of 48.

Hynes's 1998 CAMI report described injuries during a sample of 109 nonaccident evacuations at 24 airports. (This sample was a subset of the 519 evacuations at 136 airports described in his 1997 CAMI report.) The 24 airports selected for the study of injuries had approximately 70 percent of all reported nonaccident evacuations that occurred during a 34-month study period from February 1994 through November 1996. The study obtained information about 193 people (190 passengers and three crewmembers) injured during these 109 evacuations. The 193 injuries occurred during 19 of the 109 evacuations.

For this sample, the study said that:

- 71 of 190 injured passengers were males ranging in age from three years to 82 years;

- 102 of 190 injured passengers were females ranging in age from two years to 80 years;

- 26 of 193 people who were reported as injured refused medical assistance;

- Injury details were available for 135 of 193 injured people; and,

- Eleven people reported broken bones; 15 reported lacerations; 53 reported back or neck injuries; eight reported sprains; 10 reported abdominal or chest pains; 12 reported abrasions; 27 reported leg/foot injuries; and 19 reported unspecified minor injuries.

Hynes's 1998 CAMI study also said that reported injuries included fractures of the ankle, foot or spine; chest pain; pain in the lower back, coccyx, neck, ribs, shoulders or abdomen; strains, sprains or stiffness of the ankle, wrist, neck, spine or shoulder; abrasions; nervousness; lacerations; jaw soreness; shortness of breath; friction burns to skin; contusions; muscle soreness; bleeding from the mouth; motion sickness; back-muscle spasms; hypertension; thermal burns; puncture wounds; smoke inhalation; and unspecified minor injuries.

The study estimated that in the early 1990s, 17 percent of the injured passengers were age 60 or older, but by the late 1990s, 30 percent of the injured passengers were age 60 or older.

Hynes also used these data, insurance-industry valuations of serious aviation injuries and other sources to estimate that the total economic cost to consumers, air travelers and airlines of nonaccident evacuations was US$16 million per year during the study period. Factors counted were passenger claims, administrative costs, and emergency-egress-system maintenance and lost-revenue costs for aircraft. The value of the average nonaccident-evacuation injury claim for which data were reported was $551,507, the study said.

Jeffrey H. Marcus, manager of CAMI's Protection and Survival Laboratory, said that these data are consistent with information about evacuations reviewed by the FAA, but the study's limitations also have been recognized.

"I am reasonably confident that Hynes's data are reliable," said Marcus. "The biggest problem is relying on airport data because the quality of data goes down as you get further away in time. But overall, the story that it tells makes sense to me."

A common reason for nonaccident evacuations identified in recent ASRS reports was smoke and/or flames inside, or emerging from, engines or APUs. Usually the smoke and/or flames were reported by flight crews of other aircraft, control-tower personnel, aircraft rescue and fire-fighting (ARFF) crewmembers or maintenance technicians.

Occasionally during aircraft-engine and APU starting procedures, torching occurs when excess fuel in the exhaust pipe ignites and expels a visible flash or flame, typically lasting from a fraction of a second to about 15 seconds. Flight crews

ASRS Reports Provide Examples of Evacuation Issues

The following excerpts from reports filed with the Aviation Safety Reporting System (ASRS) of the U.S. National Aeronautics and Space Administration (NASA) provide examples of issues that are considered in nonaccident evacuation research:

"The tragedy of this incident is that there was no fire, just a prolonged tail pipe fire. … The [aircraft rescue and fire-fighting] people were in the process of plugging in the interphone system to tell the flight crew that there was only a tail pipe fire when the order was given to evacuate. One passenger sprained an ankle and others complained of 'rug burns' [deceleration-strip friction burns] from the slide. A flight attendant broke her [coccyx] when she fell backwards while trying to get off the slide. She [was] required, by [airline] procedure, to carry a megaphone, medical kit, and fire extinguisher. No one was at the bottom of the slide to help her off with her load."

— NASA ASRS report by flight crew, 1995
Medium-large transport aircraft
Minneapolis-St.Paul (Minnesota, U.S.)
International Airport

"No smoke was ever seen and the source of the fumes could not be determined. … The possibility of aircraft evacuation was briefly considered, but odds [of fire] appeared low since the fumes had been steadily decreasing and no source of smoke, fire, heat, etc. could be determined. … I was able to make a brief [public address system announcement] to reassure passengers, who were essentially unworried (the [strong burning] smell was confined to mid- and aft-cabin, with no secondary indications such as smoke, fire, sounds, etc. to cause anxiety)."

— NASA ASRS report by flight crew, 1995
McDonnell Douglas MD-88
Kansas City (Missouri, U.S.) International Airport

"Madison tower informed us that we had flames in the rear of the engine. The second [engine-]start attempt was terminated. The tower then informed us that flames were visible in an engine inlet. The [ground] engine fire checklist [procedures were] performed … and one fire [extinguishing agent] bottle was used. At no time was there a cockpit indication of a fire warning. Fire equipment was called … they examined the left engine and stated no fire [was] visible. … No emergency [was] declared and the aircraft was not evacuated. Next time, more consideration should be given to a tailwind when clearing an engine after [a] start [is] aborted. Also, controllers should be more aware of what they see related to some common start problems."

— NASA ASRS report by flight crew, 1995
McDonnell Douglas DC-9
Dane County (Madison, Wisconsin, U.S.)
Regional Airport

"As captain, the thought of conducting a passenger evacuation came to mind immediately. Using all resources available to me and the excellent feedback I got from very professional and capable people, I realized [that] an evacuation was not only *not* necessary, it would have been a very poor choice indeed. … [A cockpit] fire warning did not occur because the fire had no way to get to the fire-warning loops. The fire [was caused by] compressor stalls as the number-one engine came out of reverse. Apparently the fuel controller was supplying excess fuel to the stalled engine and the fire was coming from the exhaust. … As a result of the coordination of everyone — the tower, the flight attendants, and the ground crew — the experience was a nonevent and no one was hurt."

— NASA ASRS report by flight crew, 1995
Wide-body transport aircraft
San Francisco (California, U.S.) International Airport

"... The flight crew was unsure of the extent of the aircraft damage and/or if they had a fire in the left brake. Smelling burning rubber and hot brakes in the cabin, they were uncertain [whether] there either was, or would be, a brake fire. Being concerned that the passengers [might] initiate an evacuation on their own, the flight crew elected to evacuate the aircraft."

— NASA ASRS report by flight crew, 1997
Boeing 737-200
Denver (Colorado, U.S.) International Airport♦

who filed ASRS reports sometimes said that they did not consider APU torching or engine-tailpipe torching an emergency. The torching usually stops when the excess fuel is consumed and the turbine speed increases to the normal engine-operating range.

It was standard operating procedure in the ASRS reports for the captain to obtain all available information in an emergency, evaluate the risks and benefits of an emergency evacuation, and order an aircraft evacuation when appropriate. Flight crewmembers and cabin crewmembers typically assisted in evaluating the situation at the captain's direction and took assigned actions based on evacuation commands, preflight briefings and training.

ASRS narratives indicated that decisions to evacuate considered factors such as immediate interior and exterior hazards, condition of the aircraft and available exits, location of ARFF equipment, passenger load, distance to an airport gate, weather, and terrain, according to the reports. When the captain ordered an evacuation, checklist procedures covered items such as crew signals, commanding the evacuation and the brace position, reporting the time available, disarming the spoilers, and setting the flaps.

Captains sometimes had several options, including controlled evacuation through the main cabin door onto the jetway at a gate; controlled evacuation using aft airstairs or mobile stairs such as a stair-truck, ramp stand or mobile-lounge (people-mover) vehicle; emergency evacuation using emergency-egress systems (slides); and/or emergency evacuation through overwing hatches. Flight-crew ASRS reports sometimes said that the risk of injury was greater when people exited an aircraft using slides or overwing hatches.

Passenger-initiated evacuations were rare. Hynes's data show that among 519 nonaccident evacuations, 14 passenger-initiated evacuations occurred. In 10 of the passenger-initiated evacuations, smoke from an APU or momentary APU flashes or flames caused by excess fuel (torching) were the reasons. Reasons cited for the other four passenger-initiated evacuations were smoke and flames in unspecified aircraft locations, and engine hot-starts. Hynes also said that there were three cabin-crew-initiated evacuations; these were not addressed in his study.

Hynes said that the passenger-initiated evacuations apparently occurred when passengers interpreted unfamiliar flashes of light, flames and/or smoke in an engine or APU as a signal that the aircraft was on fire. Panic behavior resulted, and passengers either opened exits themselves or persuaded other passengers to open exits without waiting for direction from cabin crewmembers.

Flight crews and cabin crews said in recent ASRS reports that public-address-system briefings concerning unusual sights, sounds, odors, vibrations and aircraft motions were valuable in maintaining calm and cooperative behavior among passengers. Update briefings of passengers about actions being taken to evaluate and to resolve these occurrences — including the possibility of an evacuation ordered by the captain and clear direction not to evacuate the aircraft unless directed by the cockpit crew or flight attendants — were noted in ASRS reports of successful evacuations. Passenger-initiated evacuations increase the risk of injury in nonaccident occurrences because the crew needs to perform vital checklist procedures before anyone exits the aircraft.

"In my opinion, the number of passenger-initiated evacuations is decreasing," Hynes said. "Because of changing technology and aircraft designs, the APU and exhaust stack are more typically out of sight of the passengers. APU fuel-controller adjustments have reduced the chance of APU torching. On newer aircraft, passengers don't even see the engines — hot-starts are more likely to occur beneath large aircraft wings."

An informal review of 77 ASRS evacuation reports filed from January 1994 to June 1998 found only one occurrence in which passengers apparently initiated a nonaccident evacuation. In 1997, the flight crew of a Boeing 737-500 — parked at a gate at Eugene (Oregon, U.S.) Airport — inadvertently moved a fuel-start lever from the CUTOFF position to the IDLE position, causing fuel to enter hot engines. Some passengers apparently believed that they were seeing smoke from an engine fire and initiated an evacuation.

A flight crewmember said, "I did, inadvertently and without realizing it, reintroduce fuel to the engines [after shutting down both engines]. This caused fuel to flow into the hot engine, and with a temperature outside of 32 degrees Fahrenheit [0 degrees Celsius], created a big white cloud of fuel steam/ smoke. This was thought to be a fire by ground personnel, who advised me of a fire in the number-two engine. Partially through passenger deplaning, I ordered an evacuation. I then began the evacuation checklist and noticed the fuel levers at IDLE, not CUTOFF. I moved [the levers] quickly to CUTOFF and the smoke immediately stopped and the evacuation was canceled. Passengers had already opened both overwing exits and were on the wings … a flight attendant had [deployed] a slide at door 2R and passengers were evacuating down [the slide]. No one was hurt and no damage was caused; only one slide was used."

The small number of nonaccident evacuations initiated by cabin crewmembers in Hynes's data was not analyzed. No reasons for these evacuations were published. In recent ASRS reports, however, aircraft crews credited preflight and pre-evacuation briefings, recurrent training including crew resource management training, and effective communication during emergencies for preventing premature actions by crewmembers and panic among passengers.

One narrative described a nonaccident evacuation in which a flight attendant — who was stationed in an aft cabin filling with hydraulic-fluid vapor and who was temporarily unable to communicate with the flight crew — opened an overwing hatch. In this 1995 occurrence, the flight crew of a McDonnell Douglas MD-80 made a normal landing at San Francisco (California, U.S) International Airport and then noticed an abnormal sound and the left-side hydraulic-fluid quantity indicator showing zero. The forward flight attendant asked the flight crew to open the cockpit door to assess smoke emerging from the rear of the cabin.

The ASRS report said, "I ordered [the] forward flight attendant to evacuate through the forward airstair as [there were] only 59 passengers and [the] smoke was light. … I entered the cabin and saw that [the] flight attendant was gone. Passengers were getting bags and moving slowly. I yelled at [the] passengers to leave [their] luggage and deplane. Passengers began to move much quicker. … I saw passengers on [a] wing going back into [the] cabin through [an] overwing exit. I re-entered [the] aircraft through [the] forward airstair and ran down [the] aisle and yelled at passengers to get back out on [the] wing. [Firefighters] used [a] ladder to remove passengers from [the] wing. No injuries to passengers were incurred in [the] evacuation process."

An ASRS analyst, summarizing a follow-up conversation with the captain who filed the report, said, "The hot APU vaporized the nonflammable … hydraulic fluid and sent the vapor into the cabin through the air-conditioning system. As [the vapor] is toxic to humans and unpleasant to breathe, the aft flight attendant attempted to call the cockpit by using the chime system. … [On this aircraft] rapid ringing of the chime system will cancel itself out so that no chime is heard in the cockpit. The forward flight attendant [went] to the cockpit and said something like, 'Do you want us to use the slides or the forward door?' This [was] the first indication that the cockpit [crew] had that there was a serious problem. The reporting captain ordered the airstairs to be used. The aft flight attendant opened an overwing exit, letting people out onto the wing. … When the forward flight attendant saw people on the wing, she went outside to keep people from jumping off the wing. This [meant that neither flight attendant was] in the cabin to direct or expedite the evacuation. The [captain] directed the remaining passengers out the forward door. … The [air carrier] has changed its procedures regarding evacuation — flight attendants now have the autonomy to start an evacuation when they deem it necessary."

U.S. regulations require operators to notify the NTSB immediately after any evacuations in which emergency-egress systems are used. A *written* report from the aircraft operator is required, however, *only if requested* by the NTSB, according to NTSB Part 830.5 and Part 830.15.

Despite controversy in interpreting some research findings, there is a consensus among some government and airline-industry evacuation specialists that additional data and routine analysis could reduce injuries and help ensure that evacuations occur only under appropriate circumstances.

The FAA seeks better injury data. David Palmerton, industrial engineer in CAMI's Protection and Survival Laboratory, said, "We are not comfortable with the idea of an 'unwarranted' evacuation. If the pilot initiates the evacuation, it is not unwarranted. We want it clear that the captain is in charge. Pilots don't order aircraft evacuations unless there is a real threat of injury. If there is a fire, people could die if the crew does not evacuate." However, passenger-initiated evacuations based on false perceptions of an emergency might be viewed as unwarranted, said Palmerton.

The FAA and the NTSB have been interested in nonaccident evacuations for a long time, said CAMI's Marcus.

"People are not aware of the extent of the problem. There are more nonaccident evacuations than accident evacuations. Recent research has made us more familiar with them," said Marcus. He said that the emphasis at CAMI has been on obtaining reliable data to determine whether nonaccident evacuations warrant significant research attention. His first step was to document how often these evacuations had occurred and the severity of injuries associated with them.

"I'd like to find out the nature of the injuries that occur," Marcus said. "I want to know how many fractured ankles occurred when passengers mounted a slide. I want to look at equipment design and procedures to reduce the prevalence of injuries. But the injury data I have wanted most has been hardest to get. Hynes's 1998 CAMI study found a decided statistical bias based on passenger age among nonaccident-evacuation injuries. That is not at all surprising based on our impact testing. There is a very strong bias based on age because as people get older, tolerance for any type of trauma goes down markedly."

Marcus said that FAA safety specialists have been cautious about retrospectively judging the necessity of any evacuation.

"All you need is one case where you did not evacuate [and fatalities occurred]," he said. "No one can second-guess the crew on the scene with information available later. I personally would not want to be in the position of criticizing a crew for ordering an evacuation … you want to err on the side of safety; you don't want to take a chance with fire [as one example of a reason for evacuation]. If there is any delay and [the occurrence] does turn out to be a fire, [passengers and crew] must get off the aircraft and as far away as possible. Otherwise you put a lot of people at risk."

Marcus said that the FAA requires U.S. airlines to have a training syllabus on evacuation procedures. The FAA reviews the syllabus to be sure it is adequate, but the FAA does not provide the training or direct airlines on how to train flight crews or cabin crews.

Airlines recognize the risks and benefits of evacuations. Ron Welding, director of operations standards for the Air Transport Association of America (ATA), said, "Nonaccident evacuations are rare events, especially when you consider that there are more than 25,000 departures every day by our member airlines. We don't want anyone to get hurt. Evacuation-training programs are designed to get people off the airplane as quickly and safely as possible. The procedures are standardized to a great extent among airlines but you will have differences based on the aircraft you are operating. We welcome the NTSB study and hope that we can learn from this research. We are always striving to improve our operations and improve our safety record."

Flight attendants expect clear guidelines. A recent discussion of policies at four U.S. airlines showed that they generally provide flight attendants the authority to initiate the evacuation of an aircraft when the flight attendants perceive a threat to the lives of passengers or emergency conditions that jeopardize their own safety, said Candace Kolander, coordinator of air safety and health at the Association of Flight Attendants (AFA).

Improved Communications Sought for Aircraft Emergencies at Airports

Eight major airports in the United States have designated a radio frequency for emergency use by flight crews and aircraft rescue and fire-fighting (ARFF) personnel, said the U.S. National Transportation Safety Board (NTSB).* At each airport, the designated radio frequency enables flight crews and ARFF personnel to communicate accurate information about an emergency in progress, including any factors that could affect flight-crew decisions to evacuate or not to evacuate an aircraft.

Citing one incident, one accident and one event in which an aircraft-engine fire was extinguished without evacuating the passengers, the NTSB recommended on June 25, 1998, that the U.S. Federal Aviation Administration (FAA):

- "Establish a designated radio frequency at all airports certified under [U.S. Federal Aviation Regulations (FARs)] Part 139 that allows direct communication between [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); [and,]
- "Develop a universal set of hand signals for use between [aircraft] rescue and fire-fighting personnel, flight crews and flight attendants for situations in which radio communication is lost. (A-98-42)"

The NTSB said that the recommendation of hand signals grew from a concern that ARFF personnel may not be able to communicate with a flight crew if electrical power is unavailable or if the flight crew evacuates the aircraft. Following rejected takeoffs (RTOs) and emergency landings, flight crews may turn off the airplane's electrical power and prevent two-way radio communication, said the NTSB.

The NTSB cited three situations involving communication among ARFF personnel, flight crews and flight attendants:

"On April 28, 1997, at 1222 [hours local time], American Airlines Flight 230, a McDonnell Douglas MD-82, sustained a left-engine turbine-section fire and a tail pipe fire shortly after takeoff from the Tucson (Arizona, U.S.) International Airport. The flight was operating in [visual meteorological] conditions under [FARs] Part 121 as a scheduled domestic passenger flight from Tucson to Dallas-Fort Worth (Texas, U.S.). The five crewmembers and 118 passengers sustained no injuries.

"The captain [said] that he heard a loud bang as the aircraft was climbing through 1,800 feet, and the left engine "spooled down." A left-engine fire-extinguisher bottle was activated to control the fire, and the engine was secured. The flight returned and landed on Runway 29R. As [ARFF] personnel extinguished a fire in the left-engine tail pipe, the flight crew attempted to contact them on the ground-control frequency. By the time radio contact was made, approximately 16 passengers had exited the aircraft via the forward left-door slide, and several other passengers had climbed onto the right wing to evacuate. The flight attendant [said] that she saw fire trucks and [firefighters] outside the cabin door and one [firefighter] "gave me the thumbs up, then I proceeded to open the door." The firefighter [said] that he gave the "thumbs up" hand signal to [signal that all was well and to] stop the evacuation. The ARFF personnel stopped the passengers from evacuating the aircraft and directed them back inside the airplane. The remaining passengers eventually deplaned using portable stairs.

"During a debriefing session [regarding] the incident, ARFF personnel determined that the evacuation of this aircraft was not necessary and that the aircraft could have been safely towed to a gate. The passengers could have safely deplaned at that point. During the discussions, ARFF personnel [said] that if they had a direct means of communicating with the flight crew, unnecessary evacuations such as this one could be avoided.

"On July 8, 1996, about 0741 [hours local time], Southwest Airlines Flight 363, a Boeing 737-200, received minor damage during a rejected takeoff (RTO) from Runway 20C at the Nashville (Tennessee, U.S.) Metropolitan Airport. The airplane was operated as a regularly scheduled domestic passenger flight under the provisions of [FARs] Part 121. The airplane stopped approximately 750 feet [229 meters] off the departure end of Runway 20C, about 100 feet [31 meters] east of the extended center line. The five crewmembers and 122 passengers evacuated using the emergency slides. One passenger received serious injuries, and four passengers received minor injuries during the emergency evacuation.

"After completing the emergency checklist and announcing over the public-address system that the passengers should remain seated, the captain saw that the fire department equipment had arrived. The captain and the ARFF on-scene supervisor established voice communications through the captain's open cockpit window. The ARFF supervisor reported to the captain that the tires were smoking and deflating. The right main landing gear ignited and [the fire] was immediately extinguished with foam. After hearing a fire warning and without determining the location or severity of the fire, the flight attendants initiated an aircraft evacuation. During the evacuation, the left main landing gear ignited and [the fire] was immediately extinguished. Although the flight crew was able to communicate with the ARFF personnel through the open cockpit window, the Nashville Metropolitan Airport Authority determined that a designated radio frequency might have allowed the ARFF personnel to advise the flight crew about the situation in a more timely manner. Therefore, the flight crew might have been able to coordinate with the flight attendants and prevent an evacuation. As a result of this accident, a designated frequency was assigned for use during accidents and incidents at the Nashville airport.

"On June 19, 1996, Delta Air Lines Flight 229, a Boeing 767-332, returned to the Salt Lake City (Utah, U.S.) Airport after the flight crew detected a fire in the right engine; although the fire was still burning, ARFF personnel and the flight crew decided not to evacuate the airplane while ARFF members extinguished the fire. Although before this incident the Salt Lake City Airport did not have a designated frequency, the ground controller provided the flight crew and ARFF personnel a discrete frequency on which to communicate that resulted in improved emergency response. The flight crew was able to taxi the aircraft to a gate under the airplane's own power. The passengers and crew sustained no injuries."♦

* The airports are located in Covington/Cincinnati, Ohio (KCVG); Honolulu, Hawaii (PHNL); Seattle, Wash. (KSEA); Nashville, Tenn. (KBNA); Los Angeles, Calif. (KLAX); Fort Lauderdale, Fla. (KFLL); Philadelphia, Pa. (KPHL); and Boston, Mass. (KBOS).

"These carriers said that before initiating an evacuation, flight attendants would be expected to attempt to contact the flight deck," Kolander said. "The primary goal is to get as many people off the airplane as safely and as quickly as possible."

Cabin-crew training varies among airlines, she said, but tends to focus on immediate evacuation-decision factors such as uncontrollable fire in the cabin, dense smoke in the cabin and major structural damage. In one carrier's training, factors that typically do not call for a flight attendant to initiate an aircraft evacuation include engine-fire indications, an aborted takeoff or indications of fire from the landing gear. Ideally, every flight attendant should have the same baseline knowledge of emergency situations and expected scenarios, and the same level of training and competence, Kolander said.

"My evacuation training should not be better because I work for one carrier. If I move from carrier A to carrier B, my emergency voice commands to passengers shouldn't change — whether assertive or nonassertive commands, positive or negative commands, or whether I will say 'unfasten' or 'release' seat belts. If there is an incident or accident … we will be reviewing it during recurrent training."

The NTSB begins an evacuation study. The NTSB typically has studied aircraft evacuations either while investigating an aircraft accident or when one or more accidents involved a recurring evacuation issue. In 1974, for example, an NTSB special study examined 10 U.S. air-carrier accidents in which an evacuation occurred.[6]

For the current study, the NTSB began collecting data for a basic review of both accident evacuations and nonaccident evacuations. The NTSB also is performing more detailed investigations of certain occurrences, said Nora Marshall, senior investigator in the board's Survival Factors Division.

The NTSB will gather information from airports and airlines following *all* evacuations until investigators examine 25 evacuations in which emergency-egress systems (slides) were used or there was an actual or suspected fire.

"It's the first time we have looked at a specific period of time," said Robert Molloy, Marshall's coinvestigator for the study. "We want to learn from the successes of [nonaccident] evacuations, not just those that fit the accident category."

In spring 1998, Marshall and Molloy conducted the first of several briefings about the study for representatives of airlines, pilots, flight attendants, the FAA and ARFF departments.

"The NTSB did a preliminary study in 1996 to see how many evacuations of all types were occurring before we presented our proposed study plan," said Molloy. "We came up with about one evacuation per week for 1994 and 1995."

Previous NTSB studies looked at the safety aspects of evacuations from air-carrier aircraft involved in accidents (1974), air-carrier over-water emergency equipment and procedures (1985), airline-passenger safety education (1985) and flight-attendant training and performance during emergency situations (1992).[7]

Marshall said that the latest NTSB study has three basic purposes:

- To answer questions asked by the U.S. Congress and the public concerning all types of aircraft evacuations;
- To examine what works and what does not work during all types of evacuations, such as the effectiveness of evacuation equipment, different cabin configurations, cabin and exterior environment, evacuation procedures and communication, and demographic and behavioral factors; and,
- To compile a database of general statistics about all these evacuations.

The basic data comprises:

- A general description of the evacuation;
- Location (such as airport identifier);
- Specific point where the evacuation occurred;
- Whether the evacuation was stopped prior to completion;

- The number of exits available and used;
- The exits used;
- Problems with evacuation equipment;
- The reason for the evacuation;
- Evacuation planning;
- The initiator of the evacuation;
- Number of persons evacuated;
- Number of persons injured;
- Description of injuries sustained; and,
- ARFF response.

The detailed data will be assembled in two categories, preliminary and primary. Preliminary data are crew contact and address information; passenger manifest and addresses; ARFF contact and address; weather information; and, photos of the aircraft interior and exterior.

Primary data are derived from flight-crewmember questionnaires; cabin-crewmember questionnaires; passenger questionnaires; ARFF questionnaires; follow-up interviews as needed; a cabin diagram; safety-briefing cards; certification-test information; cockpit voice recordings; flight-crew and cabin-crew procedures (manuals and training information); and, injury documentation.

"This study was something the Safety Studies Division proposed after we realized that the last time we had done a study of evacuations was 1974," Marshall said. "The Safety Studies Division chooses subjects once a year. We're hoping to get a more detailed, complete picture because we're collecting data on events that we normally wouldn't study. We were used to looking at an event when things weren't so successful."

Marshall said that once the NTSB reviews the finished study and makes its recommendations, the board will be better prepared to comment on proposed rule making related to evacuations.

Study by Gross recommends routine investigations. In 1995, Gross studied worldwide air-carrier emergency evacuation data for the years 1987 through 1993, omitting evacuations in "fatal accidents or major air disasters." Evacuation data for airlines operating under Part 135 were excluded. He primarily used the *FAA Administrator's Daily Alert Bulletin* (ADAB) to identify aircraft incidents and compared evacuation causes to NASA's ASRS. Gross also used ASRS narrative information as the basis for identifying problems and making preliminary recommendations to solve them.

The ADAB — a restricted internal FAA data source — has significant limitations for research purposes, said Marcus.

"FAA Flight Standards District Offices almost always will file a quick report to ADAB about an event. ADAB is the most current information, but not the most accurate. [The concept] is that the information later can be corrected [in other types of reports]," Marcus said.

The study by Gross, published in two safety journals [see references at the end of this article], said that there was no wide variation in numbers when comparing the ADAB and ASRS data regarding the causes of an evacuation.

"A significant number of ground evacuations were due to APU torching or a cockpit warning indication of an APU fire," said the study.[8]

"In order to develop methodologies which reduce the occurrence of unnecessary evacuations and minimize the risk [of injury] to passengers, a primary tool is evacuation investigation," said the report. "The importance of obtaining accurate and comprehensive data on emergency evacuations is critical if the flying public is to be protected."

Gross's study made the following findings and recommendations: a glossary of terms and uniform reporting guidelines should be developed for all aviation professionals who may report fire indications; briefings for passengers, flight crews and cabin crews should explain that engine or APU torching are not cause for alarm; systems should be developed to deactivate remote alarm sounds during aircraft evacuations; and annunciators (cockpit warning indicators) should be developed to notify flight crews about opening of emergency exits.♦

Editorial note: The evacuation research by Michael K. Hynes, Ed.D., comprises two studies under contract to the FAA's Civil Aeromedical Institute. See the related article concerning this research and the author's background. The evacuation research by Richard L. Gross, M.S., comprises a 1995 study presented in *ISASI Forum* and *SAFE Journal*. At the time of the study, Gross was an aviation consultant with subspecialties in human-factors and system-safety engineering. A former U.S. Navy pilot, he was an engineering manager-flight test safety for Douglas Aircraft Co. and developed accident-prevention programs for that firm and Flight Safety Foundation. Gross had an airline-transport-pilot certificate with more than 5,700 flight hours and served as manager of flight safety for Northwest Airlines until his death in May 1998.

References

1. U.S. National Transportation Safety Board, from 1997 preliminary data compiled by the U.S. Federal Aviation Administration.

2. Air Carrier Emergency Egress Reports [1994–1998], Search Request No. 5349, June 26, 1998, Aviation Safety Reporting System, U.S. National Aeronautics and Space Administration.

3. Hynes, Michael K. "Emergency Egress System Use and Emergency Evacuation Events by Part 121 and 135 Air Carriers from 1988 to 1996 (FAA Contract 96-P-51602)," February 1997. "Demographic and Injury Data on Persons Injured during Part 121 Air Carrier Precautionary Emergency Evacuation Events (FAA Contract 97-P-53815)," April 1998.

4. Gross, Richard L. "Air Carrier Emergency Evacuation: The Current State of Affairs," *ISASI Forum*, vol. 28 no. 2, June 1995, pp. 3-6, and "Air Carrier Emergency Evacuation Investigation: A Critical Review," *SAFE Journal*, vol. 25 no. 3, September 1995, pp. 228–233.

5. U.S. National Transportation Safety Board. "Accidents and Accident Rates by NTSB Classification, 1982 through 1997, for U.S. Air Carriers Operating under 14 CFR 121."

6. U.S. National Transportation Safety Board. "Safety Aspects of Emergency Evacuations from Air Carrier Aircraft." Document no. NTSB-AAS-74-3, November 1974.

7. U.S. National Transportation Safety Board. "Safety Aspects of Emergency Evacuations from Air Carrier Aircraft." Document no. NTSB-AAS-74-3, 1974. "Air Carrier Over-water Emergency Equipment and Procedures." Document no. NTSB-SS-85-2, 1985. "Airline Passenger Safety Education: A Review of Methods Used to Present Safety Information." Document no. NTSB-SS-85-9, 1985. "Flight Attendant Training and Performance during Emergency Situations." Document no. NTSB-SIR-92-2, 1992.

8. Gross, "Air Carrier Emergency Evacuation Investigation: A Critical Review."

Visit our World Wide Web site at http://www.flightsafety.org