Aviation Safety Study SA9501

A SAFETY STUDY OF
EVACUATIONS OF LARGE,
PASSENGER-CARRYING AIRCRAFT

Report Number SA9501

1.0 INTRODUCTION

1.1 Background

When the airplane landed the visibility in the cabin was virtually non-existent at heights higher than one foot above the cabin floor. The survivors stated that they barely possessed the strength and mental capacity to negotiate the exits.[1] (A83F0006)

From 1978 through 1991 there were 18 evacuations of large, Canadian-registered, passenger-carrying aircraft. In addition, there were 3 evacuations in Canada of foreign aircraft. These 21 occurrences involved 2,305 passengers and 139 crew members and resulted in 91 fatalities and 78 serious injuries. Some 36 fatalities and 8 serious injuries occurred during the evacuation process.

1.2 Objective

This safety study examines the Canadian experience with respect to the evacuation of passengers from large aircraft and identifies safety deficiencies associated with communications during evacuations, exit operation, passenger preparedness for evacuations, and the presence of fire, smoke, and toxic fumes.

1.3 Scope and Methodology

The selection criteria for this study were aviation occurrences involving large, Canadian-registered, passenger-carrying aircraft with cabin attendants as crew members, which resulted in an evacuation and which occurred between 1978 and 1991. Occurrences involving foreign-registered aircraft were also considered if the occurrence was in Canadian airspace and the other criteria were met. The 21 occurrences selected are listed in the Appendix.'

The occurrence data were reviewed on a file-by-file basis. When information was not available in published reports, then statements given by crew members, passengers, and airport personnel were considered.

Related studies conducted by foreign organizations were reviewed, as were foreign reports of occurrences involving remarkably successful or catastrophic evacuations. The proceedings of selected symposia and conferences, aviation journals, periodicals, and newsletters related to cabin safety were also reviewed.

Relevant Canadian Air Navigation Orders (ANO), Airworthiness Standards and Directives, Notices of Proposed Amendments, and Technical Directives in relation to cabin safety were studied.

Corresponding regulatory documentation from the United States Federal Aviation Administration (FAA) and the Civil Aviation Authority (CAA) in the United Kingdom was also reviewed. In addition, Canadian air carrier guidelines and procedures were consulted.

2.0 OVERVIEW OF THE CANADIAN EVACUATION EXPERIENCE

2.1 General

For the purpose of this study, an evacuation is defined as the disembarkation (planned or otherwise) of passengers because of an existing or perceived emergency. The term evacuation is used in a generic sense and includes precautionary evacuations, abnormal deplanings, and emergency egress situations.

This section provides a brief overview of the characteristics and outcomes of the 21 evacuations studied. Table 1 contains general data as to: the reason why an evacuation was required, or the lead event; the phase of flight during which the lead event occurred; whether the evacuation was "planned" or "unplanned"[2]; whether the evacuation occurred on land or in the water; and the time required to complete the evacuation.[3]

Table 1 – General Data on Occurrences Studied

LEAD EVENT	
Fire	8
Engine Failure	5
Runway Excursion	3
Component/System Failure	2
Misc.	3
PHASE of FLIGHT	
Ground	1
Take-Off	6
En Route	5
Landing	9
PLANNED / UNPLANNED	
Planned	8
Unplanned	13
LAND / WATER	
Land	21
Water	0
TIME TO EVACUATE	
More Than 90 Seconds	14
90 Seconds or Less	5
Unknown	2

2.2 Injuries

Four occurrences resulted in fatalities. Non-fatal injuries were incurred in 15 occurrences, while six evacuations were injury-free. Table 2 summarizes the injuries recorded in the 21 evacuations.

Table 2 – Injuries

	Fatal	Serious	Minor/None	Total
Crew	7	6	126	139
Passengers	84	72	2149	2305
Total	91	78	2275	2444

Thirty-six fatalities occurred during the evacuation process, while 13 resulted from impact. The cause of death was not documented for 42 passengers.

Eight serious injuries occurred during the evacuation process. The cause of injury was not recorded for 52 occupants who suffered serious injuries.

Six passengers were known to have been injured when they exited via over-wing exits.

At Calgary, three passengers sustained bone fractures of varying severity when they jumped to the ground from the leading edge of the wing. A fourth fractured his ribs and pelvis when he fell from the wing to the ground after slipping on fire suppressant foam. (A84H0003)

In 1986, one passenger chipped an ankle bone when he exited a B-737 via the over-wing exit at Kelowna. (A86P4053)

At Regina, a passenger injured his back when he exited a DC-9 by the over-wing exit. (A83H0005)

Minor injuries were also sustained by passengers using the evacuation slides. Examples include a bruised tailbone when a passenger was not caught at the bottom of the slide, bruises and lacerations when several people fell off the slide onto the tarmac, and injuries which occurred because of people "piling-up" on the bottom of the slide when they were not able to get off quickly enough before the next passenger came down.

2.3 The Cabin Environment

The presence of fire, smoke, or toxic fumes created evacuation difficulties in 11 of the evacuations reviewed. (This issue is discussed further in Section 3.)

In 3 of these 11 evacuations, there were 89 deaths and 25 serious injuries.

Visibility was severely restricted or totally obscured in four evacuations where a cabin fire existed.

The combination of fire, smoke, and/or toxic fumes was lethal in three of four occurrences where fatalities were incurred.

A reduction in the number of available exits was recorded in 9 of 11 evacuations where fire and smoke were factors.

Passenger seats failed in three of the four fatal occurrences. Failed passenger seats impeded egress and resulted in some passengers being trapped inside the aircraft.

There were two occurrences where passengers were trapped in seats which had failed, one seat piled on top of the other. (A78H0002, A89C0048)

On one occasion, the forward cabin attendant seat was in the folded-down position throughout the evacuation, creating an obstruction at a primary exit door. There was no explanation documented as to why the seat was in the down position. (A78H0002)

There was no record of restraint systems having failed on impact.

In one occurrence, 9 of 45 survivors indicated that they had experienced difficulties with seat-belts. Some had difficulty releasing the seat buckle. Others had been unable to locate the seat buckle because their bodies had shifted during the crash and the seat buckles were not positioned where the passengers had expected them to be. (A89C0048)

Debris was a significant obstruction to the evacuation process in four of the occurrences reviewed. As a result of debris, escape paths and access to exits were blocked, passenger movement was hindered, and the evacuation process was prolonged.

In the 1978 evacuation at Toronto, debris seriously restricted egress, hindered passenger movement, and prolonged the evacuation process. Three of seven exits, two of which were primary door exits, were completely blocked by debris. Overhead bins collapsed on top of people, injuring and trapping many of them. The spilled contents in the aisle obstructed passenger flow and blocked the right forward over-wing exit. A heavy water tank, located directly above the rear cabin attendant's seat, fell, hitting the cabin attendant and fracturing his hip. Not only was the cabin attendant unable to assist in the evacuation, but the water tank blocked the entrance to the rear tail cone exit. The right forward galley-door exit was completely blocked by galley debris. (A78H0002)

At Cranbrook, B.C., in an evacuation of a B-737, two survivors who escaped through the right rear emergency door encountered difficulty opening the door because of debris blocking access to the exit. (A78H0001)

In 1983, at Regina, the galley refrigerator door and side liquor unit did not remain secure and the contents spilled on the floor, blocking access to the two primary front door exits. The purser had to scramble to clear the debris before the evacuation could commence. (A83H0005)

At Dryden, evacuation difficulties were also encountered as a result of debris, consisting of bodies, failed passenger seats, some with occupants still in them, parts of the aircraft, collapsed overhead bins, carry-on-baggage, clothes, etc. Survivors described debris in varying depths of 2-3 feet, in some cases totally covering and immobilizing them. (A89C0048)

2.4 Exit Operation

Cabin attendants reported difficulty operating emergency exit doors in four evacuations and difficulties associated with over-wing exits were encountered in three occurrences. Over-wing exits are frequently opened by passengers, as cabin attendants are often not stationed at these exits.

In four occurrences, the captain made a decision to disembark the passengers via the forward airstairs because no immediate threat to life was perceived. In each instance, the crew was unable to deploy the airstairs and, following significant delays, was forced to use the evacuation slides.

Slides were deployed in 15 of the evacuations. There were problems related to the slides in seven occurrences. The two most common problems were the angle of the slide and deployment. Both problems occurred five times each. (This issue is discussed further in Section 4.)

2.5 Communications

In eight evacuations, the cabin crew and/or passengers were unable to hear the initial evacuation command and/or subsequent directions. Public Address (PA) systems were inoperable during four of these evacuations and were inaudible during the other four evacuations.

Communication difficulties between the flight and cabin crew were seen to have jeopardized or potentially jeopardized the evacuation process in two occurrences. (This issue is discussed further in Section 5.)

2.6 Passenger Behaviour

In 11 occurrences, inappropriate passenger behaviour was encountered. Faced with an unexpected life-threatening situation, passengers typically reacted in one of two ways: overt panic (screaming, crying, hysteria, aggressiveness) or negative panic (inaction, freezing). (The issue of the behaviour of passengers seated in exit row seats is discussed further in Section 4.)

There were two occurrences in which passengers might not have perceived the danger they were in and therefore reacted in an inappropriate manner.

There were nine occurrences in which passengers stopped to retrieve carry-on baggage and attempted to take it with them as they exited the aircraft. This was despite having been specifically told not to by the cabin attendants.

Passengers often insisted on exiting the aircraft via the same door they entered. There were also several occasions when passengers seemed to be fixated on a particular exit and made no attempt to look for an alternative escape route.

As the chance for survival decreases, passenger motivation for survival increases, resulting in competitive behaviour. The accident report from the Calgary accident states, "There was some pushing, and several people went over seat backs to get to the exit ahead of others already in the aisle." (A84H0003) Commenting on passenger behaviour in an emergency, Muir concludes:

"In a situation where an immediate threat to life is perceived, ... the main objective which will govern their [passenger] behaviour will be survival for themselves, ... In this situation when the primary survival instinct takes over, people do not work collaboratively. The evacuation can become very disorganized, with some individuals competing to get through the exits. The behaviour observed in the accident which occurred at Manchester (Air Accidents Investigation Branch, 1989), and in other accidents, including the fire at Bradford City, UK (Taylor, 1990), supports this contention."[4]

2.7 Evacuations Post 1991

A search of the Transportation Safety Board (TSB) data base identified seven occurrences involving evacuations of large passenger-carrying aircraft from 1992 to mid 1994. Preliminary analysis indicates that evacuation difficulties similar to those identified in this study were encountered. Wind hampered and/or prevented use of evacuation slides in two occurrences. The PA system was inoperable in one occurrence and inaudible in a second. Inappropriate passenger behaviour was documented in two occurrences as was ineffective crew communication.

3.0 FIRE, SMOKE, AND TOXIC FUMES

Fire, smoke, and/or toxic fumes were present in three of four fatal accidents examined in this study and caused serious injuries to many of the survivors.

The following excerpts from the report of the occurrence at Calgary help to illustrate the severe conditions that can exist during an evacuation when fire, smoke, and/or toxic fumes are present.

Shortly after the evacuation commenced, fire melted windows along the left side of the aircraft. When the windows melted through, heat and smoke entered the aircraft, and the cabin environment quickly deteriorated. Substantial quantities of smoke also entered through the right over-wing exit and right rear service door.

Those passengers who had been seated beside the windows nearest the fire experienced some singeing of hair and clothing. Smoke obscured visibility almost totally during the latter stages of the evacuation.

Smoke conditions were worse in the aft section of the cabin. Passengers who exited via the rear exit reported that they were unable to see the exit and were required to follow the person ahead to locate it. By the time most had reached this exit, the smoke had lowered to about knee height. The bottom portion of the door and the slide were all that was visible. The passenger who was the last one to exit via the over-wing exit reported he had to drop to his knees to breathe fresh air before he was able to reach the exit. Only when he neared the exit, did it become visible through the smoke. (A84H0003)

The presence of fire, smoke, and/or toxic fumes presented the greatest risk to a successful evacuation by restricting visibility, limiting communications, reducing the number of available exits, affecting passenger behaviour, and decreasing occupants' mental and physical capacities. Fire, smoke, and/or toxic fumes were identified as hazards in 11 evacuations and were present in three of four fatal occurrences.

Thick black smoke severely restricted or totally obscured visibility in four occurrences where a cabin fire existed. As a result, passengers were unable to see the exits. In Cincinnati, the location of two passengers' bodies indicated that, in their attempt to get out of the aircraft, they had unknowingly passed an available exit.[5]

In the same occurrence, cabin attendants who were exposed to smoke and toxic fumes experienced great difficulty communicating orally. As a result, some passengers were unable to hear the emergency briefing.

A reduction in the number of available exits was recorded in nine occurrences. Fire and smoke also blocked egress in those occurrences where breaks in the fuselage were avenues of escape.

In three occurrences, it was found that burns and inhalation of smoke and toxic fumes limited passengers' mental and physical abilities, thereby obstructing or prohibiting their attempts to reach, operate, and negotiate emergency exits or egress through breaks in the fuselage.

Existing Risk Mitigation

There are several regulatory provisions which are designed to protect aircraft occupants from the risks associated with the presence of fire, smoke, and toxic fumes and thus increase the chances for a successful evacuation. As well, the industry has developed operating procedures to reduce or eliminate the effects of these hazards to crew and passengers. In the light of the high risks associated with the presence of fire and smoke as evidenced by the Canadian experience, the Board examined two areas of risk mitigation related to fire, smoke, and toxic fumes, namely protective breathing equipment for both crew members and passengers, and fire hardening of aircraft interiors. These areas were examined in the context of their potential to limit the risks encountered during the evacuation process.

3.1 Protective Breathing Equipment

She [the flight attendant] saw light grey smoke had filled the lavatory from the floor to the ceiling, but she saw no flames. The flight attendant closed the door but not before she had become dizzy from inhaling the smoke. (A83F0006)

Twenty-three passengers died from smoke and toxic fume inhalation as a result of an in-flight fire in the rear lavatory of a DC-9. (A83F0006) The lavatory was completely filled with smoke that severely restricted visibility and impaired breathing. As a result, the cabin attendant in-charge was unable to locate the source and exact nature of the fire or to fight it effectively. In the investigation report of this occurrence, the National Transportation Safety Board (NTSB) stated;

"... had an oxygen bottle with a full-face smoke mask been available and used, it might have encouraged and enabled him to take immediate and aggressive actions to fight the fire, as set forth in the company manual."[6]

Canadian Industry Practice

In addition to the protective breathing equipment (PBE) provided for the flight crew, some air carriers provide at least one portable PBE unit for crew members who may be required to fight cabin fires on non-combi aircraft. Such units are normally located on the flight deck. Portable PBE is carried either to fulfil operating requirements, as specified in the type certification of some aircraft, or as a result of a particular carrier's desire to enhance cabin attendants' capabilities to fight fires. The TSB has been advised that some air carriers do carry PBE units in the cabin.

Regulations in the United States and United Kingdom

PBE for flight crews has been a mandatory requirement in the United States for over 45 years. In 1987, partly as a result of the DC-9 occurrence at Cincinnati, the FAA amended Federal Aviation Regulation (FAR) 121-337, Protective Breathing Equipment, such that air carriers operating transport category aircraft must provide PBE, not only to flight crew, but also to other crew members who are responsible for fighting fires on board the aircraft. One portable PBE unit is required at each hand-held extinguisher station. There is no requirement to provide passengers with any form of PBE; indeed, there are regulations which specifically prohibit passengers from bringing PBE which contains compressed oxygen on board air transport aircraft.

In the United Kingdom, PBE is mandatory for both flight and cabin crew. Such equipment must be provided for each cabin attendant required to be carried under safety regulations and must be readily accessible to them at their assigned stations. Supernumerary cabin attendants would not figure in the number of PBE units required. PBE is not required for passengers.

Transport Canada Regulations

ANO Series II, No. 9, the *Oxygen Equipment Order*, stipulates PBE requirements for operation of large commercial aircraft. PBE is defined in the Order as "... equipment to cover the eyes, nose and mouth, or the nose and mouth if accessory equipment is provided to protect the eyes, that will protect the wearer from the effects of smoke, carbon dioxide or other harmful gases." In accordance with the Order, air carriers operating pressurized aircraft in a commercial air service must provide "each flight crew member on duty at his station protective breathing equipment." There is no regulatory requirement to provide cabin attendants, other than those working on combi aircraft, with PBE.[7] Nevertheless, ANO Series VII No. 2, Section 45, "Emergency Procedures Training" clearly implies that all cabin attendants are expected to fight cabin fire.

Similarly, there is no regulatory requirement to provide passengers with PBE. Several years ago, Transport Canada participated in an international feasibility study addressing the safety benefit of providing "smoke hoods"[8] for passengers. The results of the study were published by the CAA in 1987.[9] It was concluded that the number of lives saved by smoke hoods each year would be "modest" (179 lives over 20 years, or approximately 9 lives per year world-wide) and that the time required to don the apparatus might increase the time required to evacuate an aircraft, thereby causing a greater loss of life. Mandatory carriage of smoke hoods as passenger safety equipment was not recommended. Neither Transport Canada nor any of the other countries who participated in the study (United Kingdom, United States and France) have subsequently proposed any regulatory amendments to require PBE for passengers.[10]

There remains the question of voluntary carriage of passenger PBE, by carriers

or by individuals. In accordance with *The Transportation of Dangerous Goods Act*, passengers travelling on Canadian commercial air carriers are prohibited from bringing on board passenger transport aircraft those smoke hoods which provide oxygen from a cylinder of compressed gas. Introduction of oxygen into the cabin environment, other than the oxygen found in the emergency overhead oxygen-mask system, which is designed for passenger use during an in-flight depressurization, is currently viewed as a hazard in the event of an in-flight fire. However, small, gaseous oxygen or air cylinders required by passengers for medical use are accepted as carry-on baggage or, with the operator's approval, as checked baggage. Canada has recently asked ICAO to examine, from a dangerous goods perspective, the issue of smoke hoods containing a cylinder of compressed gas.

Passengers are permitted to carry filtration-type smoke hoods on board Canadian aircraft but current filtration-type smoke hoods would not be as effective as smoke hoods which have a self-contained source of breathable oxygen.

Recommendations

In the context of the actual evacuation process, there is no direct evidence that a lack of PBE for cabin crew resulted in fatalities or injuries during evacuations. Yet, there is a paradox in that cabin attendants are expected to fight cabin fires, but, in many cases, they are not provided with PBE in the aircraft cabin. Ready access to portable PBE could improve their ability to fight fires and have the effect of reducing the risks faced by occupants during an evacuation. Therefore, the Board recommends that:

The Department of Transport require that sufficient portable protective breathing equipment units with full-face masks be carried in the passenger cabins of transport aircraft for cabin crew. A95-01

In the light of the number of fatalities that occur when fire, smoke, and/or toxic fumes are present, the Board believes that further research is required to determine whether passengers should be given the opportunity to carry appropriate protective breathing equipment. Accordingly, the Board recommends that:

The Department of Transport re-evaluate research regarding protective breathing equipment (PBE) for passengers with a view to determining the feasibility of the carriage of appropriate protective breathing equipment, on a voluntary basis. A95-02

3.2 Flammability Requirements for Aircraft Cabin Interiors

Smoke inhalation or burns was the primary cause of death for 36 of the 49 fatalities where cause of death was recorded. (Although the cause of death for 42 passengers was undocumented, it is suspected that a large number of these deaths were also fire-related as they occurred in accidents where there was a fire in the aircraft cabin.)

The FAA at the Civil Aeromedical Institute (CAMI) in the United States analyzed the reports of 58 survivable or partially survivable aircraft accidents that occurred between 1970 and 1993; preliminary findings are that smoke inhalation and/or burns were the primary causes of death in 95% of the fatalities which occurred during evacuations.[11]

United States Regulations

In 1986, and again in 1988, the FAA issued improved flammability standards or requirements for materials used in the interiors of passenger transport aircraft.[12] Current standards further restrict the amount of heat that can be released and smoke that can be emitted when aircraft cabin interior materials are exposed to fire, i.e., all large interior surface materials installed above the floor in compartments occupied by the crew or passengers.

The new standards were based on the results of full scale fire-testing conducted by the FAA and apply to all aircraft manufactured after 19 August 1990 and operated under Part 121 (Certification and Operations: Domestic, Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft) and 135 (Air Taxi Operators and Commercial Operators). The FAA predicted that, potentially, 9-16 lives per year could be saved if all aircraft operated by American air carriers were equipped with interiors that met the improved flammability standards. Aircraft already in service are required to comply when they undergo the first substantially complete replacement of the cabin interior components. Therefore, a mandatory retrofit by a specific compliance date is not required.

Notwithstanding the intent of the regulations, the FAA is currently beingcriticized by the United States General Accounting Office (GAO), an independent government monitoring agency, for slow progress in fireproofing aircraft cabins. The GAO suggests that "Under the airlines' current practice of replacing, rather than modifying, aircraft, the entire fleet is not expected to comply with the stricter flammability standards until 2018 at the earliest."[13] Consequently the GAO recommended that the "FAA reassess whether to issue a regulatory requirement mandating a specific date for all aircraft in the fleet to comply with the latest flammability standards for cabin interiors."[14]

Regulations in United Kingdom

Airworthiness requirements in the United Kingdom (UK) mirror the improved flammability standards established by the United States (US). In 1987, CAA Airworthiness Directive 61 was

revised to introduce new heat release and smoke emission standards.[15] As in the US, application is limited to new aircraft and

in-service aircraft subject to major interior replacement. In a 1991 report[16], the CAA stated that, "This latest standard is seen as a major contribution to cabin fire safety ...."

Transport Canada Regulations

Air Navigation Order, Series II, No. 28, entitled the *Flammability Requirements for Aeroplane Seat Cushions Order*, specifies the flammability requirements for seat cushions and compartment interiors of large aircraft operated by Canadian air carriers. The intent of the legislation is to minimize fire propagation when it does occur and to limit the amount of heat, smoke, and toxic fumes released during combustion. The legislation is applicable to those aircraft for which an initial type approval or an initial type certificate was issued after 01 January 1958. While the Order is consistent with the original cabin-fire protection standards issued by the FAA and the CAA,[17] it does not meet the current improved flammability standards of either country.

One of the findings of the commission of inquiry into the F-28 crash at Dryden, Ontario, in 1989 was that "Aircraft interior furnishings burned and gave off heavy sooty smoke and toxic gases; and burning, molten-plastic-like material fell on passengers."[18] Numerous aircraft occupants sustained serious or fatal injuries as a result of smoke inhalation and burns. It was noted that although "... Transport Canada has attempted to adopt the new FAA standards for cabin interiors in the proposed *Improved Flammability Standards for Compartment Interior Materials Order* (ANO Series II, No. 32) ... As of October 1, 1991, ANO Series II, No. 32, had not been promulgated...."[19] The Commissioner recommended that "Transport Canada press for the adoption of standards for aircraft interiors that would prevent the rapid spread of fire and the emission of toxic fumes."[20] It is understood that Transport Canada is currently addressing this issue.

Conclusion

Since Transport Canada is in the process of developing improved flammability standards, the Board is not recommending that further safety action be taken at this time. However, the Board is concerned about the length of time required to put such new standards into effect and will monitor industry progress in this area.

4.0 EXIT AND SLIDE OPERATION

Problems in operating emergency exits and deploying emergency slides delayed many evacuations, potentially compromising the success of the evacuation.

4.1 Emergency Exit Doors, Over-wing Exits, Airstairs

Cabin attendants reported experiencing difficulty operating emergency exit doors in four evacuations.

In one instance, high winds made it extremely difficult to open the exit door on a B-737. (A82H0001)

In another occurrence, the purser was able to "crack the door open," or unlatch it, but experienced problems moving the door to the fully open position due to "drag" from the slide. (A84H0003)

In December 1986, at Goose Bay, Labrador, one cabin attendant was unable to open the emergency exit door. She was then assisted by a male, "able bodied" passenger to no avail. When a second male passenger provided assistance, the door was finally opened. During the investigation interview, the cabin attendant stated that she felt the aircraft's "power assist" system did not work. In the same occurrence, the cabin attendant assigned to another exit started to open the exit door, but a male cabin attendant stepped in and opened it for her. From their statements, it appeared that both the cabin attendants felt that males could open the door faster because of their strength. (A86H4902)

At Toronto in 1978, one of the cabin attendants cracked an emergency exit door open but was unable to fully open the door with the slide attached. Cabin attendants are required to be taught how to open a door under adverse conditions, and the resistance to expect[21]. In this particular accident, the cabin attendant had sustained back injuries. It was not possible to determine to what extent her injuries might have prevented her from opening the door or if her difficulties were due to inadequate training. This particular exit door was closed and opened after the accident. There was no evidence of structural damage. (A78H0002)

Difficulties associated with over-wing exits were encountered in two occurrences because of inappropriate passenger behaviour. This type of exit is frequently opened by passengers, as cabin attendants are not normally stationed at an over-wing exit. (Passenger behaviour in exit row seats is discussed further in section 4.3)

In three separate occurrences, all involving B-737 aircraft, the captain decided to disembark the passengers via the forward airstairs because no immediate threat to life was perceived. In each instance, the crew could not deploy the airstairs; following significant delays, the evacuation slides were used. It is suspected that the airstairs could not be lowered because there was no power source available. (A86A0024, A89C0115, A89P0018)

A fourth occurrence in which it appeared that the immediate danger had passed also resulted in the captain ordering an evacuation via the airstairs. The cabin crew were unable to lower the airstairs of the DC-9 aircraft. The airstairs had been difficult to retract on two previous stops. Eight minutes later, passengers were evacuated using the slides. It was subsequently determined that the difficulty in operating the airstairs was caused by a sticking airstair hand-rail actuator. (A86Q4036)

Conclusion

The Board does not consider that specific safety action regarding operation of emergency doors or over-wing exits is warranted at this time. However, the Board is concerned that four evacuations were significantly delayed because crew could not deploy the airstairs, possibly due to their false expectations that the airstairs could be deployed without power.

4.2 Slide Failures

Slides were deployed in 15 of the 21 evacuations examined. In seven of the evacuations where slides were used, there were problems related to their deployment or to their angle of inclination. These problems occurred five times each.

In one occurrence, the aircraft's attitude at rest was such that the escape slides did not reach the ground. In another occurrence, the slides were so steep that it was felt serious injuries would arise if they were used. In a third occurrence, the rear slide was at a very steep angle but was used anyway. Passengers' body weight increased the slide angle even more, resulting in minor injuries.

There were two occurrences where the slides did not deploy automatically. (A82H0001, A89C0115) In both occurrences, they were deployed manually. However, on deployment, one slide went straight down into the ground and had to be repositioned from the outside before the exit was usable.

At Wabush, neither of the rear slides deployed properly. The slides were twisted, tangled, and curled back, almost under the aircraft, and they were only partially inflated. Both exits were temporarily blocked while fire fighters repositioned the slides. (A86A0024) At Gatwick, one slide deployed in a manner such that the top of the slide was at an angle relative to the door sill. The slide was above the sill level at the aft end of the door aperture, but could still be used. (AAIB EW/C1174) Finally, there was one occurrence where the R4 slide would not deploy either automatically or manually. (A86A4936)

Wind had an adverse effect on the use of escape slides. In two evacuations where slides were used, the wind blew them up against the sides of the aircraft, thereby preventing their use until someone was able to exit the aircraft via another exit, reposition the affected slide, and hold it in place. Other exits were unusable for the entire evacuation. Wind velocity was recorded as southeast 17 knots gusting to 22 knots in one of these occurrences and at approximately 18 gusting to 28 knots in the second. (A82H0001, A83H0005)

There does not appear to be a simple explanation why some slides did not deploy automatically or properly. In one instance, the problem was traced to excessive clearance between the bar on the door and the aft latch on the floor, which allowed the bar to pull free. In other cases, the attitude of the aircraft at rest was unusually nose high or low. As a result, slides were either too steep (such that they didn't reach the ground, or were so steep that passengers would have been injured had they used the slide) or curled up under the aircraft as there was not enough space to deploy properly.

In cases where the angle of the slide was too steep to be used safely or the slide did not reach the ground, either the main aircraft landing gear or the nose gear had collapsed, altering the normal attitude of the aircraft at rest. The optimal sliding angle for normal sill heights is approximately 36 degrees. As the angle of the slide "... increases beyond 45 degrees, the speed of sliding increases fairly rapidly. At approximately 48 degrees the evacuees have a tendency to hesitate before entering the slide because of its steep appearance."[22] Even when an exit is still usable, if the angle of the slide is steep, the evacuation may be slowed as a result of passenger behaviour.

Existing Risk Mitigation

Canadian Industry Practice

Canadian air carriers train cabin attendants to pull the manual slide deployment handle as a precautionary measure each time an inflatable slide is required. Therefore, should the slide not deploy automatically as designed, manual deployment has already been activated and no time is lost. In addition, cabin attendants are trained to assess slide conditions (angle, inflation, etc.) to determine if the slide can safely be used before commencing evacuation of passengers from that particular exit. Some air carriers train their cabin attendants to brief the first two passengers who go down the slide to stay at the bottom of the slide and assist other passengers who are evacuating, as well as to hold the slide steady if it is being buffeted by the wind.

Transport Canada Regulations

A Transport Canada Airworthiness Standard[23] covers evacuation slides and states that, for every aircraft exit that is more than six feet above the ground, there must be a self-supporting slide

which deploys automatically when the exit opening mechanism is actuated and which must be fully inflated within 10 seconds. The slide must be of sufficient length such that, if any of the landing gear has collapsed, the slide will reach the ground at an angle which allows for a safe evacuation of the aircraft occupants. In addition, escape slides must be designed to withstand 25-knot winds directed from the most critical angle such that, with the assistance of one person, the slides remain usable throughout an evacuation.

Recommendation

Since 7 of 15 evacuations requiring slides were hindered as a result of problems related to deployment and/or angle of inclination, it appears that the intent of the current Airworthiness Standard is not being achieved. Given that the use of effectively deployed escape slides may be critical to the success of an aircraft evacuation, the Board recommends that:

The Department of Transport, in concert with industry, re-evaluate the performance of escape slides on all large passenger-carrying aircraft registered in Canada, to confirm that they can be functionally deployed in accordance with the criteria of the Airworthiness Standard. A95-03

4.3 Passenger Behaviour in Exit Row Seats

I asked one guy to open a door and he wouldn't, he just stood there...I told another fellow, I got stern with him "open that door"...before he opened it, he said to me "How? How do you open it?"...after the hatch was opened he just set it down then, right in the doorway, he didn't bother getting out of the window...he just stood there with the door open and the wind blowing in and the snow blowing in and I said to myself that's the last straw, if nobody is going to move, I am. (A83H0005)

There was no direct evidence to demonstrate that persons who were not capable of performing the prerequisite duties for an emergency evacuation were seated in exit row seats. However, some passengers who were seated in exit row seats did not quickly or correctly open emergency exits, resulting in delays in evacuations. In addition to the example at Regina cited above, the following examples also illustrate inappropriate passenger behaviour:

Following the uncontained engine failure on take-off at Calgary, the right over-wing exit was eventually opened by the male passenger seated next to it; he did so only after the urging of several passengers seated nearby. He then placed the hatch inside the aircraft in such a way that it obstructed passenger movement. The exit hatch was later thrown out of the aircraft by someone else. (A84H0003)

At Kelowna, the passenger sitting in the seat adjacent to the left over-wing exit made no attempt to open the exit, nor did she respond when directed to open the exit by a cabin attendant. A second passenger sitting in the exit row reached over the woman and opened the over-wing exit, but was unable to throw the hatch out the opening as the first passenger was in the way. The exit hatch was placed on the seat but slid unto the floor, creating an obstruction to egress. The hatch was later removed by a cabin attendant who, at that point, took control, and oversaw the evacuation at the left over-wing exit. (A86P4053)

The ability to successfully perform a given task depends, to a large extent, on familiarity with the task. Most airline passengers have never opened an aircraft emergency exit before. Although passengers might obtain some degree of task familiarity by reading the safety information card, a 1989 survey of Canadian air travellers revealed that only 29% read or looked at the card.[24,25]

Existing Risk Mitigation

Canadian Industry Practice

It is common practice for Canadian air carriers to prohibit certain passengers from sitting in emergency exit rows. Such "restricted" passengers commonly include families with infants or children, pregnant women, unaccompanied children, incapacitated passengers, and disabled passengers. Identification of restricted passengers is based on visual screening by customer service agents when passengers check in for flights at the airport and by the cabin crew during boarding.

Regulations in the United States and United Kingdom

In March 1990, the FAA amended the FARs such that air carriers operating under 14 CFR 121 and 135 (except on-demand air taxis with nine or fewer passenger seats) must screen and brief passengers seated in exit row seats. In addition, a crew member must verify that no unqualified person occupies an exit seat. Air carriers "may not seat a passenger in an exit row seat who is not able (as defined by the amendment) and willing, without assistance, to activate an emergency exit and to take certain additional actions needed to ensure safe use of the exit in an emergency in which a crew member is not available ...."[26]

The CAA has taken a similar position with regard to exit row seating. In May 1986, and again in July 1986, the CAA issued a notice to public transport operators concerning seat allocation and passenger briefings at Type III and Type IV exits. "Many self-help exits are heavy, some are in excess of 60 lbs., and we [the CAA] therefore consider it prudent to allocate the seats which form the access route from the cabin aisle to the exit only to passengers who appear physically capable of operating and/or assisting with the operation of the exit."[27] Operators are encouraged to provide a discrete briefing to passengers seated in Type III and IV exit rows directing their attention to the passenger safety card containing exit operation information.

Transport Canada Regulations

On 23 April 1994, a proposed amendment to Air Navigation Order Series VII was published in the Canada Gazette Part I. The amendment states that "An air carrier shall ensure that, prior to take-off, every passenger seated next to a window emergency exit is informed by a crew member that the window is an emergency exit and how the exit operates."

The proposed amendment does not state which passengers are prohibited from sitting next to a window emergency exit. However, operating procedures specifying restrictions regarding exit row seating are normally found in air carriers' Flight Attendant Manuals which must be approved by Transport Canada before an air carrier can obtain an operating certificate.

Conclusion

The evidence shows that passengers occupying exit-row seats have frequently demonstrated a lack of knowledge and determination to open the exits under emergency situations. However, in view of the proposed amendment and in the light of the restrictions regarding exit row seating which are included in Flight Attendant Manuals, the Board does not believe that further safety action is required at this time.

5.0 COMMUNICATION

In an emergency evacuation, effective communications among the crew members and with the passengers is essential for a timely, orderly, effective response.

5.1 Public Address Systems

In eight evacuations, the cabin crew and/or passengers were unable to hear the initial evacuation command and/or subsequent directions. PA systems were inoperable during four evacuations.

In the DC-9 occurrence at Toronto, the cabin attendant in-charge advised the passengers via the PA system to stay calm and remain seated until the exits were opened. Those passengers seated beside over-wing exits were instructed to open them. The PA was inoperative and no one heard these instructions. (A78H0002)

In a second DC-9 occurrence, the cabin attendant in-charge discovered that the PA system was not working when she attempted to conduct an emergency briefing prior to the evacuation. Subsequently, the emergency briefing and command to evacuate the aircraft were given without the aid of the PA system. The cabin attendants experienced great difficulty shouting their instructions because of thick black acrid smoke and toxic fumes which filled the cabin. As a result, many passengers were unable to hear the pre-landing emergency briefing, the command to evacuate, or the shouted verbal commands directing them to the exits. (A83F0006)

At Saskatoon, immediately following the runway overrun, the PA system was operable and was used to make two announcements. The first, made by the cabin attendant in-charge, advised the passengers to stay calm and remain seated. The second announcement was made by the captain of the B-737. He explained what had happened, that he did not feel there was any immediate danger, and that he would get back to the passengers with additional information. The aft cabin attendant could not hear the PA announcement and walked forward to row 18 before she was able to hear what was being said. (A89C0115)

After assessing the situation, the captain decided to evacuate the aircraft via the forward airstairs. By this time the engines had been shut down and there was no power source for the PA system. Because the PA system was inoperable and verbal commands could not be heard clearly throughout the cabin, cabin attendants were forced to walk from one end of the aircraft to the other to relay information, thereby delaying the evacuation.

In a similar situation, also involving a B-737, the final transmission given over the PA system was to evacuate the aircraft. From that point, the PA was inoperative. Unfortunately, the passengers did not respond to the initial command to evacuate. Using the PA system, the right forward cabin attendant issued a second command to evacuate. (She was unaware the PA was not working until advised by an investigator following the occurrence.) Finally, the right aft cabin attendant began to shout verbal commands when she realized that the passengers did not perceive danger and were unaware they were to evacuate the aircraft. On this third command to evacuate, the passengers responded. (A89P0018)

PA systems were inaudible during four evacuations.

In one occurrence, the captain made an announcement on the PA to evacuate the aircraft using the slides. The cabin attendant in-charge, seated at the rear of the aircraft, was unable to hear the evacuation command. A cabin attendant in the forward cabin heard a male voice on the PA system but could not hear what was being said. The cabin attendant in-charge walked from the

aft cabin to the flight deck where the captain gave her the command to evacuate. It is unknown if the cabin attendants were unable to hear the evacuation command as a result of some problem with the system or because of noise being made by the passengers. (A82H0001)

A similar problem was experienced on an L-1011. The command to evacuate was made on the PA, but the cabin attendant stationed at the rear of the aircraft did not hear it. She began evacuating passengers from the rear cabin only after she saw other doors being opened. (A86A4936)

During the evacuation at Regina in 1983, the flight crew allowed the engines to continue operating during the evacuation. As a result, the captain's announcement to evacuate the aircraft, made with the PA system, was not heard over the roar of the engines. (A83H0005)

Realizing there was an emergency and that an evacuation was required, the cabin attendant in-charge shouted the command to evacuate the aircraft. She was not heard beyond the mid-cabin area. Since the cabin attendant at the rear of the aircraft did not hear the evacuation command, she did not begin to evacuate passengers until she saw that the front main exit had been opened. Throughout the evacuation process, the passengers located beyond mid-cabin were unable to hear any instructions given by the forward cabin attendants. As a result, the cabin attendant in-charge had to walk through the cabin to alert passengers who were waiting in line to use the over-wing exit that the front exit was available.

In 1983, following a double engine flame-out due to fuel exhaustion, the cabin attendant in-charge gave a full emergency briefing using the aircraft PA system. Due to the nature of the emergency, the PA system was operating on battery electrical power. Volume on the PA system is designed to decrease by 6 decibels on engine shutdown. This, coupled with the fact that battery power was continuously being drained, caused the output level of the PA system to be very low towards the end of the briefing. As a result, it was difficult for passengers to hear the emergency briefing. (A83H0006)

It is noted that at least one battery-operated hand held megaphone is available on most large passenger-carrying aircraft. Such megaphones are carried for use inside the aircraft when the PA system is not working (e.g., to give the passenger emergency briefing for a planned evacuation); following an evacuation, they may be used outside the aircraft to facilitate communication. However, the Board understands that the majority of air carriers train cabin attendants not to use megaphones during the actual conduct of an evacuation. It is felt that using megaphones to issue commands during an evacuation would expose cabin attendants to an unacceptable risk of being injured.

Recommendation

The Board is concerned that, as a result of inoperable or inaudible PA systems, some cabin crew and/or passengers were unable to hear the initial command to evacuate and/or subsequent directions in eight occurrences. The Board is currently investigating the evacuation of a DHC-8 where announcements made by the captain on the PA system were inaudible by the cabin attendant and the passengers. Since cabin crew and passengers continue to be placed in a position of increased risk of delay in evacuations due to inaudible commands or instructions, the Board recommends that:

The Department of Transport review the adequacy of power supplies and standard operating procedures for PA systems in an emergency for all Canadian operators of large passenger aircraft. A95-04

5.2 Crew Communication

Ineffective crew communication jeopardized or potentially jeopardized the likelihood of a successful evacuation in three occurrences. A brief description of the communication problems identified in each of the three occurrences follows.

Following the double engine flame-out due to fuel exhaustion on a B-767, at least two cabin attendants were under the impression they were about to crash, partially as a result of the use of improper terminology by the cabin attendant in-charge. They were briefed by the cabin attendant in-charge that "they were going in." The accepted terminology would be a "forced landing," which implies some element of control by the flight crew. In this case, inappropriate communication may have contributed to the stress and anxiety felt by the cabin crew, and could have adversely affected their judgement and decision-making ability. (A83H0006)

At Calgary, following the uncontained engine failure, approximately 45 seconds elapsed before the cabin attendant in-charge was able to enter the flight deck to tell the flight crew there was a fire. The flight deck door had been locked in accordance with standard company procedures. (A84H0003)

Meanwhile, the aft cabin attendant attempted to notify the flight deck of an engine fire by using the aircraft interphone system. Although the signal tone was heard on the flight deck, it went unanswered because the first officer mistook the tone for that associated with the passenger cabin attendant call button. The aft cabin attendant contacted the cabin attendant in-charge stationed at the front of the aircraft via the interphone. He advised the cabin attendant in-charge that there was a fire and the aircraft should be stopped. The cabin attendant in-charge did not confirm that the information had been received and understood; consequently, the aft cabin attendant did not know if he had been successful in transmitting this vital message.

Inadequate communication between the cabin and the flight deck resulted in a significant delay before the flight crew was aware of the existence and seriousness of the fire and contributed to the fact that the evacuation was not initiated until one minute 55 seconds following the rejected take-off.

No specific command to evacuate the aircraft was given to the passengers. Furthermore, it does not appear that additional instruction or commands normally given during the evacuation process (e.g., "Leave everything behind," "Come this way," etc.) were given. In a situation such as this, where the cabin was filled with smoke and visibility was obscured, a loud voice can act as a beacon guiding passengers to the nearest exit.

The success of the evacuation was attributed in part to the fact that almost all the passengers were frequent air travellers familiar with the Boeing 737 and that there were no children, elderly, or disabled passengers on the flight.

The planned evacuation of the B-737 in Vancouver was delayed when the cabin attendant in-charge attempted to lower the forward airstairs to evacuate the aircraft with no power source available. The captain maintains that he said to evacuate via the "front exits." The cabin attendant in-charge believes he said "front airstairs." The passengers heard "front doors." Everyone seemed to hear something different. In addition, the cabin attendant in-charge was not advised, nor did she question, why the aircraft was being evacuated. Therefore, she was unaware that, after the aircraft engines had been shut down because of a fire in the APU, there would be no power source available to operate the airstairs. (A89P0018)

Effective crew coordination is crucial to a successful evacuation, but ineffective crew communication leads to ineffective crew coordination. As evidenced by the occurrence data, poor crew communication may result in unnecessary injuries or fatalities and unnecessary exposure to risk for passengers and aircrew alike.

In 1987, the Canadian Aviation Safety Board (CASB), predecessor agency to the TSB, made recommendations to enhance crew communication.[28] Currently, the TSB is investigating at least four occurrences where the absence of effective crew communication might have placed both passengers and aircrew in positions of unnecessary risk.

Research published by both the FAA and the NTSB reflects the communication concerns highlighted by the Canadian occurrence data. In 1988, the FAA published a study which stated "... the key to improving cockpit and cabin crew coordination lies in improving the communication between the two crews and in increasing each crew's awareness of the other crew's duties and concerns."[29] As recently as 1992, the NTSB determined that ineffective crew coordination as a result of ineffective crew communication remained a serious problem in emergency situations.[30]

Existing Risk Mitigation

Canadian Industry Practice

Two common approaches to improve crew communication are joint crew training and enhanced aircraft communication systems.

The Board understands that some large air carriers conduct some form of joint crew training, while others have plans to do so. The extent or the frequency of such joint training is not known (e.g., briefings versus realistic simulation); nor is it known how many of the smaller carriers provide any joint crew training.

Crew communications are normally transmitted via the interphone or the PA system. For example, in an emergency situation, the cabin crew contacts the flight deck using the aircraft interphone system. The interphone chimes on the flight deck and has to be answered by one of the flight crew. In those aircraft where an interphone is not available or immediately accessible, the cabin crew must go to the flight deck to communicate directly with the flight crew.

The Board has been advised that one large air carrier has installed a "hot-line" or "open interphone" system in many of their aircraft which provides an open communication line between certain cabin attendant stations and the flight deck. In addition, on aircraft such as the B-747, B-767, B-757, and the A320, conference call capabilities provide direct access between cabin attendant stations and the flight deck.

On the flight deck, standard operating procedures require confirmation of communication between flight crew (e.g., "You have control," "I have control"). Similar procedures are also in place for certain communications between Air Traffic Control (ATC) or ground personnel and the flight crew. Standard operating procedures, facilitating communication feedback or acknowledging receipt of communication, do not exist between cabin and flight crew or among cabin crew.

Transport Canada Regulations

In 1987 (in response to safety recommendations made by the CASB) and again in 1989 (Policy Letter AARBC 1989, No. 19), Transport Canada voiced concern that "the lack of crew

communication during recent aircraft accidents, particularly those involving fire-on-the-ground and evacuation, reinforces the need for joint crew training." In January 1993, Transport Canada assured the TSB that it was its practice to encourage commercial operators to review their "... training procedures to ensure that information critical to the safe operation of their aircraft can be communicated to the cockpit crew in a timely and effective manner."[31]

While Transport Canada strongly suggests that air carriers provide joint crew training, to date, such training is not mandatory. Air carriers are required to incorporate in their Operations Manual a section providing guidance for operational personnel entitled "Aeroplane Ground Emergency Procedures and Co-ordination." Cabin attendant training syllabi and manuals must contain the same type of information. Both are approved by Transport Canada.

With regard to effective aircraft communication systems, Transport Canada requires that all air carriers operating aircraft employing cabin attendants employ an interphone system or other direct means of communication with the flight deck. In 1988, following consultation with industry, Transport Canada determined that it was not feasible to require modification of aircraft systems to allow alternative emergency alerting in transport category aircraft.

Recommendation

Ineffective crew communication created an environment in which passengers and crew were exposed to unnecessary risks during the evacuation process in at least 3 of the 21 occurrences examined.

Notwithstanding Transport Canada's efforts to promote effective crew communication by encouraging air carriers to implement joint crew training, the Board believes that lack of, or ineffective, crew communication continues to place the lives of aircraft occupants at risk during evacuation of large passenger-carrying aircraft. In view of the Canadian accident experience and demonstrated problems in crew coordination on a global basis, the Board recommends that:

The Department of Transport require that air carriers implement an approved joint crew emergency training program with emergency simulations for all air crew operating large passenger-carrying aircraft. A95-05

6.0 PASSENGER PREPAREDNESS

Passengers' lack of preparedness to act appropriately during an evacuation was evident in several occurrences.

There were two occurrences in which passengers might not have perceived the danger they were in and therefore reacted in an inappropriate manner.

Following an APU fire as the B-737 taxied to the terminal, the captain stopped the aircraft, shut down the engines, and ordered an evacuation. However, he did so by announcing that the aircraft would have to be evacuated by the front exits. This announcement did not convey any sense of urgency. The captain did not give the standard evacuation command "Evacuate, Evacuate." Initially, no commands were shouted by the cabin attendants. (A89P0018)

The passengers did not respond to the captain's announcement to evacuate the aircraft. Given the manner in which the evacuation command was communicated, the initial lack of communication on the part of the cabin attendants, and the location of the aircraft, approximately 6-10 feet from the gate, it is possible that the passengers did not realize that

anything unusual had taken place. They were expecting to hear an announcement telling them to leave the aircraft.

Passengers continued, in an unhurried manner, to retrieve their personal belongings and prepare to deplane. Finally, the aft cabin attendant realized that the passengers were unaware of the need to evacuate the aircraft and began shouting the standard evacuation commands in a loud voice. Her actions were effective.

At Gatwick, when the Boeing 747 turned off the runway, tail pipe fires were observed on three engines. Shortly after, the aircraft was stopped and an evacuation was ordered by the captain. Statements submitted by the cabin crew indicated that passengers did not initially respond to the command to evacuate. They seemed to be under the impression that the aircraft was parked for disembarkation. Overall, there was confusion and misunderstanding as to the necessity to evacuate the aircraft as quickly as possible. Despite being advised to leave everything behind, many passengers insisted on retrieving their carry-on baggage. When confronted at the exits by the cabin attendants, some passengers tried to return to their seats to stow their baggage in the overhead bins. One cabin attendant said "There was no panic. I even heard [passengers] comment 'this is not serious, look what they are making us do.'" (AAIB EW/C1174)

During several evacuations, passengers seemed to be fixated on a particular exit and made no attempt to look for an alternative escape route. Passengers will often try to exit the aircraft via the same door they entered, regardless of better options.

In the evacuation at Calgary, passengers seated in the first seven rows chose to use the left forward exit door, the same door by which they had entered the aircraft. This despite the fact that the right forward exit door was visible, open, and manned by a cabin attendant. A cabin attendant had to stand in the middle of the passage between the two exits and aggressively direct passengers to the right forward exit door. In addition, passengers in the vicinity of the right over-wing exit continued to stand in line to use this exit even though the two forward exits were completely free for use. They did not look around to see if an alternative exit was available. (A84H0003)

At Kelowna, when the flow of passengers exiting via the over-wing exit had stopped, the cabin attendant responsible for the over-wing exits redirected passengers who were standing in line waiting for the left forward exit to use the over-wing and rear exits. She had to yell several times to get their attention and convince them to turn and come the other way. (A86P4053)

There were four occurrences where passengers did not move away from the aircraft following the evacuation, even though in some cases the aircraft was on fire. Some passengers smoked, while others took pictures. Clearly, some passengers did not perceive that danger still existed after they had managed to get out of the aircraft.

6.1 Pre-Landing Briefings

Emergencies leading to an evacuation occurred more often during the "landing" phase of flight than during any other phase of flight: such was the case in 9 of 21 occurrences[32]. As evidenced by the occurrences at Vancouver and Gatwick, passengers might be less prepared to evacuate an aircraft when an emergency happens during the landing phase.

During the landing phase, passengers might be in a state of low arousal, e.g., they may be fatigued or bored following a long flight, or perhaps they are just waking up after having slept through the flight. In addition, particularly for those passengers who are afraid of flying, there may be a feeling of relaxation as the flight nears completion, based on the expectation that "It's

almost over" or "We're down, we're safe." Again, the result is a low level of arousal. Their ability to perform life-saving actions or tasks during an evacuation may be negatively affected.

A second possible explanation that passengers might be less prepared to evacuate during the landing phase is that they forget the information presented during the pre-take-off safety briefing. There are several reasons why passengers might forget this information. The first is limited exposure or lack of repetition because the passenger safety briefing or demonstration is presented only once. In the majority of evacuations (which are unplanned), there is no time to review safety information with the passengers. Thus, passengers who did not hear the pre-take-off safety briefing are unlikely to get a second opportunity to be briefed.

Passengers can obtain and review the information they require from the safety features card. However, as previously mentioned, fewer than one third of Canadian airline passengers surveyed reported reading the safety features card. Unaided recall of specific items on the card was low.

If, during an evacuation, passengers are unable to perform certain tasks properly as a result of inappropriate arousal levels, or they are unable to remember where their nearest or alternative emergency exit is located or how to operate it, they might be unable to exit the aircraft successfully; they might also obstruct or prohibit egress of other passengers.

Existing Risk Mitigation

Canadian Industry Practice

Currently, Canadian air carriers routinely make pre-landing announcements requesting that passengers return to their seats, fasten seat-belts, place seatbacks and table trays in the upright and locked position, and stow carry-on-baggage in preparation for landing.

Transport Canada Regulations

In April 1994, a proposed amendment to ANO Series VII, Nos. 2, 3 & 6, regarding bilingual safety briefings was published in the Canada Gazette. The proposed amendment stated that "An air carrier shall ensure that all passengers on board an aeroplane are provided with a standard safety briefing, ... prior to each landing." The proposed standard safety briefing required prior to each landing would have included the basic pre-landing announcement currently made by Canadian air carriers with one addition: "on flights of two hours duration or more, the location of emergency exits and exit location signs" was to be included. Passengers would not, however, be advised to review the safety features card.

The Board has since been advised that Transport Canada has abandoned its original proposal and will now require pre-landing briefings only on flights in excess of four hours.

Over the years, various organizations and cabin safety specialists have advocated pre-landing safety briefings as an effective means of enhancing passenger preparedness and, ultimately, passenger performance during an evacuation.[33] There is a general consensus that passengers should be reminded to relocate their primary and alternative exits, review the safety card, and, when appropriate, be advised of an overwater approach.

Recommendation

While the Board agrees with Transport Canada's recent initiative to require a standard safety briefing prior to landing on certain flights, there is concern that safety information found only on the safety features card, such as exit operation, recommended brace positions, floor proximity

emergency path lighting, use of the escape slides, and life jacket location and donning instructions, will not be reinforced prior to landing.

Since most emergency evacuations are unplanned and occur during the landing phase, the Board recommends that:

The Department of Transport encourage carriers to include sufficient detail in their pre-landing briefings to prepare passengers for an unplanned emergency evacuation. A95-06

[1] All events quoted in this study are excerpts from Transportation Safety Board of Canada (TSB), Canadian Aviation Safety Board (CASB), or National Transportation Safety Board (NTSB) accident investigation reports or witness statements.

[2] Evacuations are commonly referred to as "planned" or "unplanned." In the case of a "planned" evacuation, cabin crew are advised that an evacuation is expected and some time is available to prepare the cabin and the passengers before the actual evacuation command is given. An "unplanned" evacuation is not expected and there is no time lapse between the decision to evacuate and the initiation of the evacuation.

[3] In accordance with Federal Aviation Regulation (FAR) 25, aircraft manufacturers must conduct full-scale demonstrations to show an airplane's evacuation capability. All passengers and crew must be evacuated from the aircraft to the ground within 90 seconds. The 90-second limit is a certification standard. Internationally, industry accepts 90 seconds as a reasonable estimate of the survivable time in an evacuation where fire is present.

[4] Dr. Helen Muir, "Passenger Safety," *Aviation Psychology in Practice*, ed. Neil Johnston et al., (Avebury Technical, 1994) p. 108.

[5] Following the occurrence in Cincinnati, a regulatory requirement for emergency floor path lighting was enacted. (A83F0006)

[6] Canada adheres to FAA AD 93-07-15, which states that cabin attendants responsible for fire fighting on passenger aircraft equipped with main deck, Class B, cargo compartments must be provided with PBE. Such aircraft represent only a small portion of the Canadian fleet.

[7] NTSB Aircraft Accident Report – Air Canada McDonnell Douglas DC-9-32, C-FTLU, Greater Cincinnati International Airport, Covington, Kentucky, 02 June 1983.

[8] "Smoke hoods are protective head coverings that prevent wearers from breathing the smoke, particulates and toxic gases generated in a fire. ... two general types of smoke hoods have evolved in the marketplace: one has a self-contained source of breathable oxygen, and the other filters ambient air for breathing." Flight Safety Foundation, "Getting Out Alive Would Smoke Hoods Save Airline Passengers or Put Them At Risk?" *Cabin Crew Safety*, January/February 1994.

[9] U.K. Civil Aviation Authority, "Smoke hoods: net safety benefit analysis," CAA Paper 87017, November 1987.

[10] Members of the aviation industry who continue to promote passenger smoke hoods fault the model on which the above-referenced study was based and maintain that the probability of a successful evacuation (increased survivability) will be enhanced as passengers will not be incapacitated by smoke and toxic fumes. Smoke hoods are perceived as particularly beneficial in the event of an in-flight fire where passengers may be exposed to a potentially lethal environment for a relatively long period of time.

[11] Charles B. Chittum, Protection and Survival Laboratory, FAA Civil Aeromedical Institute, Oklahoma City, Oklahoma. April 1994.

[12] "Improved Flammability Standards for Materials Used in the Interior of Transport Category Airplane Cabins," Final Rule DOT/FAA Federal Register, Vol 53, No. 165, 25 August 1988, pp. 32, 564:

FAA Regulatory Amendment No. 25-61

FAA Regulatory Amendment No. 121-189

FAA Regulatory Amendment No. 25-66

FAA Regulatory Amendment No. 121-198

[13] United States General Accounting Office, "Slow Progress in Making Aircraft Cabin Interiors Fireproof," Report to Congressional Requesters, Aviation Safety, January 1993.

[14] Ibid.

[15] "Improved Flammability Test Standards for Cabin Interior Materials," Civil Aviation Authority Airworthiness Notice No. 61, March 1987.

[16] *Improving Passenger Survivability in Aircraft Fire: A Review*, Civil Aviation Authority Report, 1991.

[17] "Flammability Requirements for Aircraft Seat Cushions," DOT/FAA Final Rule, Federal Register, Vol 49, No. 209, October 26, 1984, pp. 43, 188; and "Aircraft Seats and Berths - Resistance to Fire," Civil Aviation Authority Airworthiness Notice No. 59, Issue 3, December 1986.

[18] Virgil P. Moshansky, Commissioner, *Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario*, Final Report, Volume I (Ottawa: Minister of Supply and Services Canada, 1992) p. 300.

[19] Ibid. p. 297.

[20] Ibid. MCR 39, p. 300.

[21] ANO Series VII, No. 2

[22] Flight Safety Foundation, "Evacuation Slides... History & New Technology," *Cabin Crew Safety*, November/December 1980.

[23] "Emergency Egress Assist Means and Escape Routes," Airworthiness Standard 525.810, (a)(1)(iii).

[24] TSB, "In The Unlikely Event...," *Aviation Safety REFLEXIONS*, Issue 2, June 1993.

[25] It has been suggested that passengers who fly regularly receive specialty training in the operation of emergency exits on a voluntary basis. Such passengers could then be routinely assigned exit row seating. Industry, particularly cabin attendants, are reluctant to adopt this proposal. They are concerned that passengers trained in this manner might unnecessarily initiate an evacuation and that, without continued refresher training, passengers would be confused, as the location and operation of emergency exits varies greatly.

[26] "14 CFR 121 and 135 Exit Seating," DOT/FAA Final Rule, Federal Register Vol. 57, No. 208, October 1992.

[27] N.J. Butcher, "United Kingdom Civil Aviation Authority Policy On Cabin Safety," Proceedings of Fifth Annual International Aircraft Cabin Safety Symposium, February 22-25, 1988.

[28] CASB Recommendations 87-04 and 87-05.

[29] K.M. Cardosi & M.S. Huntly, *Cockpit and Cabin Crew Coordination*, DOT/FAA/FS-88-/1, 1988.

[30] NTSB, *Flight Attendant Training and Performance During Emergency Situations*, Special Investigation Report, PB92-917006, June 1992.

[31] Transport Canada letter on Cabin Attendant Communications, 14 January 1993.

[32] Fifty-five (35%) of 156 evacuations identified in the International Civil Aviation Organization data bank (1970-1993) followed an emergency which occurred during the landing phase of flight.

[33] FAA, Emergency Evacuation Task Force, Training and Operations Working Group, Passenger Information, 1985.

7.0 APPENDICES

Date	Number	Location	Aircraft	INJURIES			Fire / Smoke Present	Slides Used	Planned	Lead Event / Remarks
				Fatal	Serious	Minor / None				
11-Feb-78	A78H0001	Cranbrook, B.C.	B-737	42	5	2	YES	NO	NO	Go-around, obstruction on runway
26-Jun-78	A78H0002	Toronto, Ont.	DC-9-32	2	47	58	NO	YES	NO	Tire failure on take-off roll/Runway excursion
29-Dec-81	A81A0039	Sydney, N.S.	HS-748	0	1	18	NO	NO	NO	Hydraulic failure, no braking/Taxiing to ramp
2-Jan-82	A82H0001	Sault Ste. Marie Ont.	B-737	0	0	122	NO	YES	NO	Hard landing
12-May-83	A83H0005	Regina, Sask.	DC-9-32	0	0	62	NO	YES	NO	Gear collapsed on landing
2-Jun-83	A83F0006	Cincinnati, Kentucky	DC-9-32	23	3	20	YES	YES	YES	In-flight cabin fire
23-Jul-83	A83H0006	Gimli, Man.	B-767	0	0	69	YES	YES	YES	Fuel exhaustion/forced landing
22-Mar-84	A84H0003	Calgary, Alta.	B-737-200	0	4	115	YES	YES	NO	Uncontained engine failure on take-off
20-Apr-86	A86Q4036	Montreal, Que.	DC-9-32	0	0	89	NO	YES	YES	Smoke in cockpit/enroute
13-Jul-86	A86A4936	Gander, Nfld.	L1011-100	0	0	356	YES	YES	NO	Engine fire
14-Jul-86	A86P4053	Kelowna, B.C.	B737-275	0	0	81	NO	YES	NO	Runway excursion/hydroplaning
20-Jul-86	A86A0024	Wabush, Nfld.	B737-200	0	1	63	NO	YES	NO	Engine failure/rejected take-off
12-Dec-86	A86H4902	Goose Bay, Nfld.	B747-131	0	0	328	YES	NO	YES	Fire warning in cargo hold/enroute
17-Jan-88	A88H0001	Vancouver, B.C.	B737-200	0	0	38	YES	YES	NO	Engine failure/rejected take-off

18-Jan-89	A89P0018	Vancouver, B.C.	B737-217	0	0	65	YES	YES	YES	APU fire/after landing
10-Mar-89	A89C0048	Dryden, Ont.	F-28	24	17	28	YES	NO	NO	Ice on wing on take-off
5-Jun-89	A89O0249	Toronto, Ont.	F-28	0	0	69	NO	NO	YES	Smoke in cabin/during climb
22-Jun-89	A89C0115	Saskatoon, Sask.	B737-217	0	0	78	NO	YES	YES	Runway excursion on landing/Improper procedures
7-Aug-90	AAIB EW/C1174	Gatwick, England	B747-200	0	0	456	YES	YES	NO	Tail-pipe fires on three engines
18-May-91	A91W0088	Edmonton, Alta.	B767	0	0	122	NO	YES	YES	Acrid fumes in cockpit/enroute
29-Nov-91	A91H0012	Riviere-Aux-Saumons, Quebec	HS-748	0	0	36	YES	NO	NO	Engine failure/rejected take-off

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2013-10-11