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European Report Recommends Smoke Hoods for Passengers

Smoke hoods and cabin water-mist systems have been controversial since the fatal 1985 on-airport aircraft fire accident in Manchester, England. A European Transport Safety Council report advocates providing passenger smoke hoods in all commercial aircraft and water-mist systems in new aircraft models.

FSF Editorial Staff

Smoke hoods should be provided in all commercial aircraft and cabin water-mist systems should be fitted in new commercial aircraft types to increase the passenger survival rate in accidents involving fire, according to a recent study report published by the European Transport Safety Council (ETSC).[1] The report also recommended, as impact-protection measures deserving "priority attention," improvements to seat-floor strength; three-point restraint harnesses for passengers; and greater strength of overhead-stowage compartments.

The ETSC is "an international nongovernmental organization" formed in 1993 to provide impartial advice on transportation safety to the European Commission and the European Parliament, the report said.

"Statistical trends indicate that fire is an important factor in aircraft accident survivability," the report said. "A particularly well-documented and, in many ways, typical example of a survivable accident with spilled fuel and fire is the ... accident at Manchester [England] in 1985." The report frequently referred to the Manchester accident to illustrate aspects of fire survivability.

[On Aug. 22, 1985, a British Airtours Boeing 737-236 experienced an uncontained engine failure during a takeoff roll. The failure punctured a wing fuel-tank access panel, and fuel leaking from the wing ignited, producing a large fire plume trailing the engine. The pilots rejected the takeoff, halted the aircraft and ordered an evacuation. Although passengers and crew suffered no impact injury, wind directed the fire onto the fuselage, and two flight attendants and 53 passengers were killed as a result of the fire that penetrated the cabin.]

The report considered the problem of toxic fumes as the lethal agent in many aircraft fires, and smoke hoods as protection against fumes generated by burning materials. "Survivors from the Manchester accident spoke of 'lungs feeling as though they had solidified after one breath of smoke' and after two breaths of feeling 'like falling asleep,'" the report said. "Of those who died, only nine were reported as having died as a direct result of the flames. Smoke and toxic fumes, hydrogen cyanide and carbon monoxide, overpowered the other 46."

The report referred to the debate about whether passenger smoke hoods would on balance offer more benefit, by their protection against fumes, or harm, by increasing evacuation time.

The report said, "Although it is not known how passengers would actually react in a Manchester or similar cabin fire if smoke hoods had been available to them, it seems reasonable to say that smoke hoods might lead to some delay in starting the evacuation. However, this does not have necessarily any detrimental effect. As the House of Commons Transport Committee in its report on aircraft cabin safety concluded: 'It is no use passengers being able theoretically to evacuate an aircraft in 60 seconds if, in toxic smoke and without a smoke hood, they collapse unconscious in half that time. The possibility that it may take 10 seconds longer to evacuate with a smoke hood on is of little consequence if indeed passengers can actually evacuate in 70 seconds from a cabin full of toxic smoke and live to tell the tale.'[2]

"The probable reasoning behind the assumption that any delay in the evacuation may lead to more deaths may arise from a genuine misunderstanding of the nature of real cabin fires. The results of the valuable cabin fire trials at the FAA [U.S. Federal Aviation Administration] Test Center at Atlantic City [New Jersey, U.S.] may have been used to arrive at a conclusion that is not valid for the majority of real cabin fires. The fuselage used for cabin fire trials at Atlantic City is fire-hardened in such a way that it can be used many times over without the roof burning through. Thus in most, if not all, trials, conditions are reached after a few minutes where flashover (the almost explosive ignition of unburned gases along the length of the cabin ceiling) is almost certain to occur. It is generally recognized that the chances of surviving after flashover, even with a smoke hood, are practically zero.

"It, therefore, follows that if flashover does occur then any delay in evacuation could well cost lives. The trap that is easy to fall into is to assume that flashover always or nearly always occurs in actual cabin fires. In the Manchester report,[3] the AAIB concluded that 'there are powerful reasons to question whether flashover occurs at all often in real aircraft fires, as opposed to test fires.' ...

"Furthermore, it is important to remember that people collapsing from the effects of toxic smoke may cause delays to those having to get past or over them, and this actually occurred at Manchester. It is also important to remember that the long-term effects of inhaling smoke and toxic matter on those who do escape from the aircraft, and which may lead to permanent and disabling lung damage of those who survive the accident. ...

"Although there are a few practical problems to be resolved, such as stowage, accessibility and suitability to all (or at least an acceptable proportion of) passengers, there do not seem to be any major, justified arguments against the introduction of smoke hoods in all commercial aircraft."

[In its comprehensive *Cabin Crew Safety* report on smoke hoods,[4] Flight Safety Foundation reviewed reports and interviewed aviation safety researchers. Among the sources cited, some believed that smoke hoods would offer safety benefits, but others believed that smoke hoods would make evacuations more difficult.

[Some research, such as a 1987 U.K. Civil Aviation Authority (CAA) report, advanced arguments similar to those of the ETSC.

[That U.K. CAA report, for example, said that the "essential contribution (of a smoke hood) would be a substantial improvement to survivability in the cabin-fire atmosphere. It would not be expected to improve evacuation rates but would sustain evacuation up to the point where the cabin becomes unsurvivable even with smoke hoods."[5]

[But a number of reports and safety specialists suggested that the purported life-saving benefits of smoke hoods were based on questionable assumptions or were false. Some samples of that skepticism include the following:

[A 1988 FAA report, which examined the same 20 accidents that had been analyzed for the 1987 U.K. CAA report, said that the "effectiveness of protective breathing equipment was shown to be greatly influenced by the assumed time to don the (smoke hoods), and a delay of 15 seconds in donning time (would have) resulted in 82 additional fire deaths."[6]

[Constantine P. "Gus" Sarkos, manager of the Fire Safety Branch at the FAA Technical Center, said, "Using a model tied into full-scale fire data, we showed that if there was even a 10-second delay ... in past accidents, more people would have died than would have been saved. The role of the passenger is to get the hell out of the airplane as quickly as possible using the nearest available exit. Smoke hoods could potentially be a counterproductive measure. In a lot of accidents, they have enough problems getting out of the airplane without donning something that is foreign to them."[7]

[Even the U.K. CAA reversed itself in a 1991 report: "The Authority is concerned that in a crash situation, with passengers experiencing shock and perhaps panicking, any delay in putting on a smoke hood, particularly by parents of young children or partners helping each other, would reduce the benefit (of smoke hoods). It would only require one or two people to get into difficulty with their smoke hoods, for the whole evacuation to be in jeopardy. This, the Authority feels, is an unacceptable safety risk and it is for this reason that it has decided not to require the provision of passenger smoke hoods in British-registered aircraft."[8]]

The airport fire service responded quickly and efficiently in the Manchester accident, and was generating fire-suppressant foam within 30 seconds of the aircraft stopping. Yet personnel were unable to rescue many of the aircraft's occupants.

"It has long been recognized that the airport fire service, so well equipped for dealing with fuel and other external fires around a crashed aircraft, is virtually powerless to deal with an internal cabin fire," the ETSC report said. "In 1993 the U.K. Civil Aviation Authority (CAA) issued a summary[9] of the extensive work done on water-mist systems and concluded that they were likely to be effective and presented no insurmountable problem areas. It was estimated that water spray would save an average of 14 lives annually worldwide or six lives in the [United States], Canada and European countries of the JAA [Joint Aviation Authorities] ... . It is believed that these figures underestimate the number of lives that could be saved, and with costs minimized if features are introduced at design stage, future aircraft should be equipped accordingly."

[In a discussion of three reports about tools for improving the survival rate in aircraft fires, a *Cabin Crew Safety* article noted two objections to water-mist (also called water-spray) systems.

[The article said, "Some critics have cited two potential drawbacks: that steam created from the contact of the water spray with fire might cause respiratory-tract injuries, and that steam might also change temperatures in parts of the aircraft cabin in a way that might increase the risk of thermal injury to occupants."[10]

[But the *Cabin Crew Safety* article also reported on the results of research undertaken by the FAA Civil Aeromedical Institute (CAMI) to assess the validity of such concerns. The CAMI evaluation was presented in a report by Robert P. Garner.

[The Garner report said, "(The) risk due to increased latent heat in the environment resulting from activation of a (cabin water-spray system) is relatively small. Although a potential hazard from steam and hot water vapor–saturated air does exist, exposure to these conditions for more than a second or two is highly unlikely and could theoretically be avoided by maintaining the correct posture and quickly evacuating the aircraft."[11]]

The ETSC report discussed less-flammable fuel alternatives to Jet A and Jet A1, the types of kerosene used in most civil aircraft. Two such fuels are antimisting kerosene (AMK) and high-flashpoint kerosene (such as AVCAT or JP5). Because AMK's properties have not been fully evaluated in operational experience and research on it has dwindled, AMK remains "something of a dream solution," the report said.

But the report endorsed a U.K. House of Commons committee recommendation[2] that a thorough technical and financial study be undertaken to determine the suitability of high-flashpoint kerosene as the principal commercial aviation fuel.

The report said, "It is accepted that JP5 is more expensive at present, but it is not known how much this is due to the very much smaller production quantities of JP5 and how much to more expensive production processes that would remain even if a version of JP5 became the principal fuel. It is recommended that the current and future price differential (if any) between JP5 and Jet A1 should be established on the basis of a suitable high-flashpoint JP5-type fuel becoming the principal fuel used by air transport aircraft."

The report recommended "fitment of an external camera/cockpit monitor, following study of procedures required to guarantee safe operation," and cited the Manchester accident as an example of the need for a means by which pilots can view the aircraft exterior.

"This accident was one of many where the flight deck crew members were unaware of the problem they had," the report said. "They and, indeed, the cabin crew at the front of the cabin did not know about the engine [fire] until the aircraft was nearly at rest. Had they known the position and the extent of the fire while still on the runway, from a small monitor on the flight deck, they could have stopped straight along the runway or even turned to the left so that the wind blew the fire away from the fuselage ... ."

The U.K. Air Accidents Investigation Branch (AAIB) recommended incorporating an external viewing system following the Manchester accident,[3] and reiterated the recommendation later.

"The original proposal for the evaluation of this idea suggested that the most important issue was the incorporation of ... such a system into the normal operational procedures on the flight deck," said the ETSC report. "It was suggested that this could be studied in a flight simulator and that procedures could be developed that would not introduce any significant additional hazard, such as distraction from primary tasks or misleading or confusing information.

"Despite extensive trials, however, we are little nearer to having an external viewing system in operation. The objective should now be to explore further operational needs which could to a large extent be accomplished in a nonmoving flight simulator and therefore at reasonable cost."

The report put a low priority on improvements to fireworthiness standards for cabin materials. Although recommending that further improvements should be pursued, the report said, "There is a limit to what can be achieved so long as passengers can bring on, or are supplied with, plastic bags, newspapers, magazines and clothing, all of which of course fall well short of the standards appropriate for cabin furnishings and fittings."

The report noted the importance of applying improvements aimed at accident survivability systematically.

"There is no point in improving the survivability of impact if passengers and crew are then killed by the subsequent fire," said the report. A "package of steps" to increase the survival rate in aircraft would include:

- "Training of crew and cabin staff to share critical information;
- "Improving the energy-absorbing qualities [of aircraft] in the event of an impact;
- "Reducing the chance of fire, in particular in the cabin;
- "Avoiding the development of toxic fumes; [and,]
- "Maximizing the opportunities for an orderly and quick evacuation."

The ETSC Air Safety Working Party that drafted the report classified aviation accidents into three survivability categories: nonsurvivable (in which no passengers survive); survivable (in which all passengers survive); and technically survivable (in which some passengers or crew members survive).

"In round and, of course, fluctuating figures it is estimated that of the 1,500 who die each year worldwide in air transport accidents, some 900 die in nonsurvivable accidents," said the report. "The other 600, die in technically survivable accidents, where crashworthiness, fire and evacuation issues are all important. Of these 600, it is estimated that around 330 die as a direct result of the impact and 270 due to the effects of smoke, toxic fumes, heat and resulting evacuation problems."

Besides fire survival, factors that might be improved in technically survivable accidents were considered in the areas of impact protection and aircraft evacuation.

Impact protection. "In ... technically survivable accidents, around 55 percent of the fatalities occur as a result of impact," said the report. "Measures to improve impact protection will, therefore, have considerable life-saving potential.

"The advantage of impact-related safety measures is that they bring about largely 'cabin-wide' effects since in any one crash, [all] occupants are exposed to similar impact conditions. Fire protection or evacuation measures, on the other hand, often involve a time element, which usually means that in a particular crash only some passengers will benefit from the improvement. Secondly, impact protection does not have to rely on changing human behavior for its effectiveness. It should be noted, however, that someone who survives the impact ... may still become a victim of the postcrash fire."

In addition to calling for further research concerning side-facing seats, child-restraint devices, energy-absorbing mechanisms for cabin-crew seats, aft-facing seats for passengers, brace positions and airbags, the report made several specific recommendations.

Providing three-point lap-and-shoulder harnesses rather than the standard lap belt was recommended.

"If all passengers assumed the brace position prior to impact, the additional benefits of a three-point shoulder harness would be small," said the report. "In reality, however, for a variety of reasons, occupants generally do not assume a proper brace position, so a three-point lap-and-shoulder harness would be likely to improve occupant protection substantially."

In accidents, overhead stowage bins can be exposed to dynamic loads considerably greater than the maximum static loads addressed by airworthiness requirements, and have sometimes failed.

"A revision of the requirements," said the report, "is necessary such that the overhead luggage bins will be able to meet the same dynamic loading requirements which must be met by passenger seats."

Deriving its conclusions from a study by R.G.W. Cherry and Associates,[12] the report cited improvements in seat-floor strength, among structural factors, as likely to bring about the greatest reduction in avoidable impact fatalities (Table 1). [For a discussion of the Cherry study, see *Cabin Crew Safety*, January–February 1997.]

"Not only does a strong floor improve the capability of the cabin to maintain habitable space during a crash, [a strong floor] … influence[s] the ability of the seats and safety belts to remain attached and provide their passenger-restraint function, and the attenuation of the shock load applied to the aircraft structure at impact," said the report. "Following some accidents where the seats had remained intact, but the floor had failed, it was suggested that cabin floors should be designed to a tougher and more realistic standard. At least, the strength of the floor should be such that the maximum load capability of the seats and restraints is available in accident environments."

The type of anthropomorphic test dummy (ATD), called the Hybrid II ATD, that is currently used specified in regulations

Table 1
Expected Reduction in Fatalities after Safety-enhancing Changes

Safety Measure	Percent Reduction in Avoidable Impact Fatalities	Percent Reduction in Overall Fatalities
Seat-floor strength	31	8.3
Aft-facing seats	19	5.0
Occupant restraint	18	4.7
Strength of overhead stowage	13	3.3
Head-strike adequacy	10	2.7
Structural strength of cabins	10	2.7
Infant seats	1	<1.0

Source: European Transport Safety Council, derived from R.G.W. Cherry and Associates for crashworthiness testing is “an outdated ATD technology,” the report said. “Newer designs (Hybrid III) as used in automotive applications are not necessarily suitable for use in aircraft situations.”

The report supported the need for computer models that simulate accidents.

“To perform a proper analysis of how cabin safety can be improved through impact-related safety measures, an adequate understanding of each of the mechanisms involved in the sequence of events ... is required,” said the report. “It is ... not practically feasible to carry out full-scale crash tests every time a new impact-safety measure has been devised and must be evaluated. Similarly, when making trade-offs between various structural design options, full-scale tests of the alternatives are usually not feasible. It is, therefore, essential to have highly accurate theoretical models for calculating impact decelerations, deformations and structural responses of aircraft hull designs and cabin structural features.”

Nevertheless, for some purposes there is no substitute for full-scale testing.

“To ensure that the analytical models utilized in design provide an adequate representation of actual crash behavior, full-scale tests are required,” said the report. “The results of these tests are used to validate the models. In addition, the tests provide an opportunity to observe the sequence of events during the crash in great detail due to the availability of extensive instrumentation and a controlled environment.

“Real accidents obviously provide limited opportunities in this regard because the exact sequence of events can only be deduced from the resulting wreckage after the accident. The efficiency of this source of data is limited because much of the evidence may be altered by secondary crash effects or consumed by fire, and also because the accident investigation is primarily aimed at finding the cause of the accident. The investigators are usually not crashworthiness experts and the [crashworthiness] experts are not often part of an investigation team.”

The report concluded its discussion of impact protection: “No single solution exists which, if introduced in isolation, would lead to a very significant improvement ... . Rather, a package approach which makes several enhancements aimed at a large improvement will be necessary. This calls for a proper balance in the state of the art of the various aspects of impact safety, instead of a very detailed effort in one field and none in another.”

Aircraft evacuation. The report cited a U.K. CAA program of development and evaluation for a new Type III exit design. [Type III exits are the emergency-only, removable-hatch exits often placed over wings on commercial aircraft.]

“The design has involved the development of an ‘up-and-over door’ at the exit with no modification to aperture,” the report said. “In addition to improving the ease of operation, the new design removes the problem of exit [hatch] disposal during the evacuation.”

The report endorsed the findings of a study by Muir et al.[13] of increasing the aperture in bulkheads separating sections of the cabin. “The results indicated that increasing the minimum distance between these units from 50.8 centimeters to 76.2 centimeters (20 inches to 30 inches) would lead to a significant improvement in the evacuation rate and a reduction in the likelihood of blockages,” the ETSC report said.

Based on research by Muir and Cobbett[14] on the role of assertive behavior by cabin crew members, which significantly increased evacuation speed in a simulated emergency, the report called for increased attention to this factor in training. The report said, “The demonstration of an ability to perform assertively in a simulated emergency should, therefore, be a requirement for all students during initial training before they go onto the line. Any student[s] who cannot achieve the standard will be placing themselves and members of the public at increased risk in the event of an accident. ... The requirement to demonstrate assertive behavior during evacuations should also be introduced into recurrent training.”

In a final section about implementing accident-survivability improvements, the report said, “In such a highly competitive industry, improvements in aircraft survivability will come primarily from regulatory action. On the national level, some commendable efforts have been initiated ... . However, further and more extensively coordinated work is required to realize progress on a wider scale.

“ETSC firmly believes that, for EU [European Union]-registered aircraft, a strong, single EU air safety authority has a crucial role to play in promoting and realizing such a package of measures. This single EU air safety authority would be able to set binding safety standards which reflect best knowledge and which are in line with EU Treaty obligations.”♦

Editorial note: This article is based on *Increasing the Survival Rate in Aircraft Accidents: Impact Protection, Fire Survivability and Evacuation*, published in December 1996 by the European Transport Safety Council, Brussels, Belgium. The 43-page report contains a list of references and a bibliography.

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