CIVIL AVIATION AUTHORITY

CAP 586

IMPROVING PASSENGER SURVIVABILITY IN AIRCRAFT FIRES: A REVIEW

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1. INTRODUCTION

The Civil Aviation Authority has the responsibility, placed upon it by Parliament, of making professional judgements on safety matters. These judgements are necessary for the Authority to set the standards for UK airlines, which are designed to maintain and where possible improve the safety of passengers. This is a responsibility necessitating careful evaluation of the issues and requiring decisions to be taken only after all relevant factors have been considered.

The Authority's philosophy, like that of other major aviation authorities world-wide, is to ensure that aircraft are designed to the best standards of safety provided by human knowledge and technological advances, but that if a failure does occur then the design will have other lines of defence - the belt and braces approach. It is against this background that the Authority's approach to fire safety on aeroplanes has developed - prevention, "hardening", detection, suppression and rapid evacuation. Since certain aspects of the fire safety issue have attracted considerable public interest - more so in recent years - it is right to stress that all such aspects, and the circumstances of particular accidents can only usefully be examined against the background of the general context. Modern aircraft offer a safe and economic means of transport, but in doing so they carry large quantities of volatile fuel in relatively close proximity to passengers. Typically the passengers are accommodated in a pressure vessel designed for high speed, high altitude, travel. Because of the pressurisation the number of openings or exits needs to be limited. Furthermore, unlike most other forms of mass transport, aircraft cannot stop suddenly and when landing they are travelling relatively fast.

Greater emphasis is being placed on improving passenger survivability in the rare event of an accident and steady progress has been made, particularly in the field of fire prevention and containment.

Major improvements were already in hand, but not yet implemented, when the tragic accident occurred to a British Airtours Boeing 737 at Manchester Airport in August 1985 (Reference 1). The circumstances were such that 55 people lost their lives in an aircraft which had not yet left the ground and nor had it suffered any crash damage. This prompted a wide review of all aspects of cabin safety and, in particular, resulted not only in the upgrading of existing standards, but also in the evaluation of new ideas and ideas which had previously been considered impracticable. The Authority not only sets the standards, it also closely monitors compliance.

Because this accident has had such a profound effect on CAA actions, it is worth recalling the precise circumstances in some detail.

The Boeing 737 is a twinjet airliner with the engines mounted immediately under the wings. It carried 130 passengers in the British Airtours configuration, with two full size doors on each side of the aircraft, one at the front and one at the rear. All four doors are equipped with automatic inflatable slides for evacuation in an emergency. On each side of the aircraft there is also a smaller supplementary hatch at the overwing position, which is not equipped with an escape slide; passengers leaving the aircraft step over a sill onto the wing.

During the take-off run, there was an explosive failure of the left engine and the head of the failed combustion chamber struck a fuel tank access panel in the lower surface of the wing which fractured leaving a substantial hole. The resulting fuel released reached the hot engine rapidly and a major fire developed. The Captain abandoned the take-off, turned off the runway and stopped. The fuel pool fire to the left of the aircraft spread under the rear fuselage, and, with the aid of a light wind, rapidly penetrated the cabin. The right rear door was opened before the aircraft stopped but no-one was able to escape that way. That part of the cabin quickly became non-survivable. The whole of the cabin filled with dense black smoke, initially in the upper levels. No evacuation command was heard in the cabin, but evacuation through the two forward exits and the right overwing exit proceeded until the fire, smoke and fumes rendered the cabin non-survivable. Some features of the aircraft resulted in delays to the commencement of evacuation. When the steward in the forward galley tried to open the right hand forward door, it jammed but he crossed to the other side and was able to open the left hand door which was usable despite the fire on that side. With great presence of mind, he returned to the right hand door and was able to un-jam and open it. At the overwing exit, too, there was a delay. It is a "self-help" exit and the young women sitting next to it were unable initially to find the handle. When they did, they needed assistance from other passengers to move the hatch out of the way. It appears that later in the evacuation a man's foot became trapped in the seat next to the exit, with the result that he effectively blocked it.

The fire in the cabin eventually consumed about half the seats, and much of the panelling at the higher levels, such as the ceilings and lockers.

All accidents are unusual in some respect and that at Manchester was no exception. The broader context must always be kept in mind before any useful lessons can be learnt from particular tragedies.

The purpose of this paper is to describe the improvements that were in hand when the Manchester accident occurred and those that have been introduced since, in many cases because of that accident. New ideas which are still the subject of research and development are also described. The question of fire safety will never be a closed book: the international aviation authorities will continue to seek improvements and the CAA will continue to play a leading role in that effort (see Section 8).

It is, perhaps, significant that in the twenty years up to and including the accident at Manchester there were three fire accidents every ten million jet flying hours world-wide and, in the five years since, that rate appears to have halved. The corresponding figures for fire deaths are 11 per million hours for the earlier period and have decreased to less than 4 per million hours; again an important improvement.

2. FIRE PREVENTION, DETECTION AND SUPPRESSION

When considering in-flight fires the dominant factor is prevention. In-flight fire must be considered as potentially catastrophic, and therefore any design or maintenance precautions associated with fire prevention must be given the appropriate priority. Major fires starting in the cabin are rare and would be immediately detectable, as is the case in galleys where cabin crew are in close proximity during the flight. A particular hazard may however be present in the toilet compartments and a continued programme of improvements in fire prevention and detection has been implemented.

The effectiveness of fire suppression in the cabin depends on the availability of adequate fire fighting equipment and crews trained in their effective use (see Section 4.4). Sophisticated protective breathing equipment for use by crew members for fire fighting has been significantly improved and is now mandatory.

2.1 Toilet Fire Precautions

It has long been recognised, based to some extent on accident experience, that toilets in passenger aircraft are areas where the risk of an in-flight fire is relatively high in comparison with the rest of the cabin. This potential hazard is the result of a combination of factors:

- there may be long periods when nobody goes into the compartment;
- passengers may smoke, even though specifically prohibited; and
- the disposal bins contain a lot of paper and other flammable products.

In view of this, the fire prevention, detection, and suppression provisions in toilet compartments have been under continued review and, as a result, progressively improved over the last 15-20 years. In 1974, the CAA issued requirements to improve the maintenance and design of stowages and receptacles in toilets and to formally prohibit smoking in toilets including the provision of placards and ashtrays inside and outside the compartment (Reference 2).

In 1985, as the result of a foreign accident involving a toilet compartment fire, where the toilet flush motor came under suspicion as the fire source, the CAA issued an Airworthiness Notice requiring electrical toilet flush motors to be fitted with a thermal protection device to prevent overheating and resulting fire hazard (Reference 3).

Toilet fire precautions were again the subject of UK airworthiness regulation in 1986 when further action was considered necessary because, despite the continued vigilance in inspecting compartments, the harsh "in-service" wear and tear was resulting in deterioration of the fire containment capabilities of waste receptacles. It was also recognised that despite passenger briefings and placards, it is practically impossible to prevent the most determined passenger from smoking in the toilet compartment. In order to address these specific problems a requirement for a smoke detector in each compartment was introduced (Reference 4).

2.2 Fire Extinguishing

In addition the 1986 airworthiness regulation (Reference 4) also introduced requirements for increased provision of portable fire extinguishers in the cabin, specifying that a minimum number should contain Halon 1211 extinguishant or equivalent, and that they be strategically located throughout the passenger cabin. The location and availability of fire fighting equipment in the cabin has also been kept under particular review by CAA in recent years, with operators being required to install equipment where it is readily accessible to cabin crew and close to possible fire sources.

The fire fighting capability of the cabin crew has been significantly improved with the introduction of a new standard of protective breathing equipment, mandated by the requirements of the Air Navigation Order from January 1990. This equipment is of a higher standard than that previously used and, provides the wearer with a much greater work load capacity for fire fighting. Such equipment must be provided for each of the cabin crew required to be carried under safety regulations (as opposed to those carried for the airlines' own reasons) and must be readily accessible to them at their assigned stations.

The continued use of halon as an extinguishant will undoubtedly come into question in view of these substances' potential to damage the ozone layer. Suitable replacements may prove hard to find.

2.3 Summary

More fire extinguishers and improved crew smoke hoods have been provided on board aircraft for fire-fighting principally in the event of an in-flight fire.

Toilets have been the focus of increased attention in view of the possibility that a fire can start in a waste bin and remain undetected. Smoke detectors are now required.

3. FIRE HARDENING

The fire hardening of aircraft in relation to improvement in cabin fire safety can be divided into two primary areas, the flammability of materials inside the passenger cabin and the fire hardening of areas outside the cabin, such as cargo holds and aircraft exterior skin, which prevents or delays the ingress of exterior fire.

Extensive testing has shown that a significant reduction in fire hazard has resulted from the CAA's recently introduced requirements for cabin interiors, justifying the great effort which their adoption caused the manufacturing and operating industry to make. Fire hardening of areas exterior to the cabin provides a field for further research and possible future regulatory action.

3.1 Cabin Material Flammability

When flammability standards for cabin materials were first introduced, the prime concern was with preventing in-flight fire which could originate from a low-energy ignition source such as a lighted match or cigarette. In the early 1960s attention turned to the behaviour of cabin material in a ground fire emergency. Since then a great deal of effort has been devoted by authorities and industry to the subject. Much more stringent standards of thermal stability and flame resistance reduce the spread of fire and thereby minimise the emission of smoke and toxic fumes and increase the survival time within the cabin.

(a) ***Seat Cushion Fire Blocking***

The lightness and strength of polyurethane foam results in it being widely adopted as an aircraft upholstery material. Flame retardants can be added to render it relatively resistant to the propagation of fire from a low-energy source. However, full-scale fire tests have shown that once there is sufficient thermal energy available, as occasioned by a major aircraft fire, polyurethane foam, whether or not treated with flame retardant, significantly contributes to the fire by the release of large quantities of flammable gases.

In the early 1980s, research in the United Kingdom and the USA into post-crash survivability showed that the flammability of seat cushions plays an important part in the rate of spread of a cabin fire. Tests demonstrated that by encapsulating seat cushions within a layer of "fire-blocking" material, the onset of ignition could be delayed and survival time within the cabin extended. New test standards and acceptance criteria were, therefore, developed and published in 1985 (Reference 5). All new aircraft on the United Kingdom register were required to comply by mid 1986, and all existing ones by mid 1987. Although until now compliance has generally been achieved by incorporating a fire blocking layer between the exterior cover and the foam, industry is developing new foam materials which do not require the separate fire blocking layer.

(b) ***Sidewall and Ceiling Panels***

Full-scale fire testing by the FAA has shown that sidewall and ceiling panels materials also play a major part in the rate of cabin fire propagation and therefore affect survival time. The research also demonstrated that the materials which gave the greatest increase in predicted survival time were those which exhibited the lowest heat release when subject to high levels of thermal radiation.

Airworthiness requirements in both the United Kingdom and USA have been revised to introduce these new heat release standards for all new aircraft and for existing aircraft when subject to major interior refit (Reference 6). These have been introduced in two phases; an interim standard applicable from mid 1988 and a more stringent standard, which also includes a limit on the amount of smoke produced, from mid 1990.

The requirement, particularly the more severe second stage, has been introduced by the CAA over a short period, and consequently with a major impact on industry, both in relation to the development of new materials and the provision of acceptable test apparatus and procedures. This latest standard is seen as a major contribution to cabin fire safety but at present its applicability is limited to new aircraft and aircraft subject to major interior replacement. The Authority will monitor the rate at which interiors of the old standard are being replaced under this arrangement and if it considers it to be necessary will introduce an end date for all aircraft to comply.

3.2 Cargo Hold Fire Containment

During 1982-83, research carried out by the FAA showed that requirements for baggage hold fire containment provided insufficient protection against the more severe fires. The research also showed that there was scope for significant improvement in the fire containment capability of some cargo hold liner material. As a result, an enhanced fire test standard for cargo hold liners was introduced for newly designed aircraft and early in 1988, the CAA introduced a mandatory requirement for the replacement of certain types of liner with liners having better resistance to fire penetration (Reference 7).

The standards of fire containment, detection and means of extinguishing for baggage and cargo compartments is one that is under continual review by international authorities and it is possible that further changes in regulations addressing these aspects will be developed. One area which has received a great deal of attention is that of combi configurations, *ie* where cargo compartments are located on the main passenger cabin deck. Debate with industry continues over the final form of a JAA (European Joint Aviation Authorities) Airworthiness Directive (AD) for combi aircraft operating under the control of these authorities. This JAA AD generally reflects a similar FAA AD but it may also include a design requirement for fire containment within each cargo container or pallet. A recent series of tests by the CAA at its Fire Service Training School has demonstrated that with special covers, fire containment can be extended from about 3 minutes to at least 3 hours.

The Authority strongly favours the use of fire containment covers or fire proof containers, and sees their provision as possibly paving the way to some reduction of the special fire fighting training for crews and additional fire extinguishing and protection systems already required.

3.3 Fuselage Fire Hardening

The CAA has closely monitored FAA research studies addressing the ability of existing aircraft fuselage skins to resist penetration in a ground fire condition.

Preliminary results from this work have identified that fibre-glass thermal/acoustical insulation has the potential to be an effective fire barrier if it can be held in place. In addition, research into cabin water spray systems has suggested that fire penetration will be delayed if a structure is wetted on the inside. The subject of water spray systems is discussed more fully in Section 7.

CAA is planning to fund a programme to evaluate techniques which may offer further protection for cabin occupants against the effects of external ground fires. Industry has been invited to tender for such a programme to start this year which will include research and development of materials in addition to full scale testing. The results may form the initial basis for future airworthiness requirement action.

3.4 Summary

The evidence shows that the improved standards laid down by the CAA for the flammability of aircraft seats and interior trim panels significantly slow down the rate with which an external post crash fuel fire can gain a hold in the cabin.

In response to major accidents, improvements have been made to the fire containment standards of baggage and freight holds. Should a fire start in these spaces, it is now less likely to spread to the rest of the aircraft.

4. PROCEDURES AND CREW TRAINING

In addition to the many cabin safety improvements which have involved changes to the aircraft itself, the Authority has made many changes to operational procedures relevant to its cabin fire safety improvement programme.

4.1 Seat Allocation and the Briefing of Passengers at Type III and Type IV Overwing Exits

Many aircraft have supplementary overwing exits which are "self-help" hatches rather than full-size doors manned by cabin crew; these are known as Types III and IV exits. In these cases the Authority considers it prudent to allocate the seats on the access routes from the cabin aisle to the emergency exit only to passengers who appear physically capable of opening the exit.

The Authority issued a Notice to public transport operators in May 1986, reminding them of the importance of correct seat allocation at self-help exits, listing the categories of passengers who must not be allocated such seats. These include disabled, obese, elderly or frail passengers, and children or infants.

Operators have also been recommended in the Notice to include a briefing of the passengers seated in the seat rows near self-help exits, drawing their attention to the exit operating information provided on the seat back instruction placard.

4.2 Effect of Wind Direction on Aircraft Fire

In October 1986 the Authority issued a Notice to public transport operators, based on the views of the Air Accidents Investigation Branch on the effect that a cross-wind might have when an aircraft is on fire on the ground. It drew attention to the significance of even small degrees of cross-flow and pointed out that, if the aircraft is brought to a stop with the fire on the upwind side of the fuselage as happened during the Manchester accident, the fire will be driven against the fuselage and may rapidly penetrate the aircraft skin. Fire penetration of the fuselage skin can occur very quickly, possibly in less than one minute. However, if the aircraft is stopped with the fire on the downwind side of the fuselage, it is not likely be driven against the aircraft, and, as a consequence, the potential for the fire directly to penetrate the fuselage will be significantly reduced. If fire penetration does occur, it will probably happen at a much later stage.

The permutations and combination of circumstances offering advantages and disadvantages appear, however, to be too numerous for an aircraft commander to consider properly in a rapidly developing emergency. The general advice in the Notice is to halt the aircraft heading into the wind if this can be done within the confines of the runway or taxiway, and without causing undue delay to the evacuation of the aircraft.

4.3 Flight Deck Drills for Aircraft Evacuation

In the event of a serious fire on the ground, an immediate evacuation of the aircraft will be necessary. A review of flight deck procedures showed that some flight deck emergency evacuation drills were longer than is absolutely necessary, and included items which were perhaps superfluous in the circumstances. In particular, the order to the cabin attendants to evacuate the aircraft was sometimes placed further down the list than it should be. In a notice to public transport operators issued in late 1986, the Authority drew the attention of operators to this problem, requiring them to review their drills and to amend them if necessary.

4.4 Flight Crew Training Aimed at Improved Survivability

The Authority's requirements for emergency and survival training were substantially revised in late 1987 (Reference 8). Major changes can be summarised as follows:

1. Greater emphasis on the training of cabin attendants in fire fighting techniques. Cabin attendants are now required to extinguish a fire which is representative of an interior aircraft fire, with the same type of extinguisher carried on their aircraft, every 3 years.

2. Introduction of initial and three-yearly practice in the use of protective breathing equipment (PBE) in association with a smoke-filled environment, for both flight deck crew and cabin attendants.

3. Greater emphasis on the training of cabin attendants in emergency evacuation procedures and crowd control techniques.

4. Greater emphasis on hands-on training and practical demonstrations of proficiency for flight deck crew and cabin attendants.

The authority requires that training must be of a sufficient level for cabin attendants to deal effectively with the most severe in-flight fires, without relying on assistance from the flight deck crew, who may otherwise be engaged in procedures for an emergency descent and diversion.

4.5 Flight Deck and Cabin Crew Co-ordination

In recent years there have been several accidents and incidents world-wide where a lack of effective co-ordination between flight deck crew and cabin attendants might have contributed to loss of life. It is of paramount importance that flight deck crew and cabin attendants are familiar with each other's basic responsibilities and procedures in different emergency situations. In order to enhance co-ordination between flight deck crew and cabin attendants, the Authority (Reference 8) is requiring operators to review both their training procedures and their training requirements. Training is the most effective way of improving crew awareness and co-ordination, and should include flight deck crew and cabin attendants being instructed in each other's basic emergency procedures. Furthermore, steps are being taken to ensure that crews are trained to pass clear and concise information between the flight deck and the cabin.

Flight deck crew are now being trained to tell the cabin attendants the nature of the emergency, the intended plan of action, and the time available for cabin and passenger preparation, and also to seek information from cabin attendants, especially where additional visual and aural clues might be available to those in the passenger cabin. Cabin attendants are to be trained to communicate effectively with the flight deck crew and to report any incidents that might affect the safety of the aircraft, including unusual sights or sounds outside the cabin observed by themselves or reported by a passenger. New cabin attendants should sit in one of the pilot's seats of a parked aircraft so that they can see how little of the aircraft is visible from the flight deck.

4.6 Specialist Fire Courses for Safety and Survival Instructors

To assist UK operators and their safety and survival instructors, the CAA Fire Service Training School offers a two-day course in practical fire-fighting. This course was developed as a result of requests by UK airlines. The course is held five times each year and is well attended by both UK and foreign airlines. Its purpose is to assist those involved in emergency and survival training by providing first hand practical experience of the problems associated with aircraft cabin fires and the techniques required to deal successfully with such an emergency. The Fire Service Training School is equipped with training apparatus for all types of aircraft fire training and this includes aircraft internal fire training units which incorporate facilities for simulation of galley fires, oven fires, toilet fires, etc.

4.7 Passenger Education

In an information leaflet "The Air Travellers' Code" the CAA has drawn the attention of passengers to measures they themselves can take to improve safety. The code offers advice on such matters as the safety briefing, carriage of dangerous goods, observing no smoking requirements and the stowage of cabin baggage. First published in 1990, over three million copies have now been distributed.

4.8 Summary

Changes to cabin crew procedures and training have been introduced which are intended to reduce the time taken to evacuate the aircraft, complementing the engineering changes described in Section 5. Cabin crew training in fighting fires is now more effective, with particular emphasis on in-flight fires.

Flight deck procedures have been improved to provide guidance on how the aircraft should be positioned on the ground in the event of an external fire, to minimise the fire threat to the passenger cabin. Aircraft shut-down procedures have been amended in order to achieve an earlier initiation of the evacuation.

To improve two-way communication, flight and cabin crews are being trained to communicate more effectively between the flight deck and the passenger cabin to improve the information available to the flight crew on the nature of an emergency and the information available to the cabin crew on the way it is to be handled.

5. EVACUATION

Although an aircraft may have to be evacuated for reasons other than fire, it is the rapidly developing fire which lays most stress on the need to be able to do so quickly. Each aircraft type is approved for a maximum passenger load based on the evacuation provisions. A number of different exit types are used including the large passenger doors common on wide-body jets, the normal entry doors on smaller aircraft and overwing hatches. Each door type has in effect a rated capacity which has been established by testing and experience, and the total passenger load for the aircraft cannot exceed the sum of the rated capacities for its exits.

Speed of evacuation also depends on the configuration within the aircraft, widths of aisles and other access routes to the exits. Explicit minimum dimensions are specified in the airworthiness standards. Escape slides are required where the door sill is too high above the ground for passengers to evacuate directly (which is the case on virtually all public transport aircraft).

However, compliance with all the detailed provisions relating to evacuation is not all that is required. The standards also include a stylised, semi-realistic evacuation demonstration to be carried out. The maximum approved passenger load must be evacuated within ninety seconds in darkness, using only the aircraft's emergency lighting, through half of the emergency exits. This provides a final check that the overall standard, achieved by the application of the detailed requirements, is satisfactory, and comparable with the standard achieved by other aircraft types.

5.1 Overwing Exits

The investigation into the Manchester accident suggested that the space next to the overwing exits should be considered urgently. The configuration was based on well established industry practice which permitted a seat to be next to the exit provided the seatback did not intrude into the exit opening and the armrest was designed to come away with the hatch when it was opened. Passengers evacuating through this exit would reach it over the seats and testing had shown that this did not slow down the evacuation.

However, early in the investigation it became clear that the seating layout allowed insufficient space for the passenger seated near the exit to stand up "square" to the exit so that the heavy (about 22 kg/48 lb) hatch could be removed and disposed of. In the accident, the passengers had difficulty in removing the hatch and when they had done so fell back in the seat with the hatch on top of them. Based on tests the CAA issued a requirement in January 1986 (Reference 9), for implementation on all applicable UK aircraft by July 1986. This stipulated either considerably increased minimum spacing between the relevant seat rows and no overlap of the exit centre-line, or the removal of the seat adjacent to the exit, thereby creating two access routes to it. It was also required that all the seats bounding the exit routes should be prevented from breaking forward or reclining, effectively providing a protected channel from the aisle to the exit.

Additionally, there was concern that in an accident like Manchester where the passengers are subjected to a rapidly developing fire threat, their behaviour may be very different from the orderly behaviour on which the standards were based. The CAA set in hand research which made use of financial incentives to induce competitive behaviour in large-scale evacuation from a real aeroplane in a simulated emergency (Reference 10). This work examined the configuration before the accident, the new standard prescribed by the CAA and some alternatives. Remembering that the revised configurations were put in place by the CAA to improve the opening of the exit, it is satisfying that this research also showed them to be close to optimum from the point of view of evacuation and to be a considerable improvement over the original layout. The research also showed that, if the space between the seat rows were increased still further, then the improvement to speed of evacuation diminished.

Another improvement required by the Authority at the overwing exit was the provision of graphic instructions on the seat backs of the row or rows adjacent to the exit route(s).

Some seat backs failed in the accident under the pressure of escaping passengers and so it was also required that the strength of all the seat backs bounding the exit routes should meet higher standards. Finally, the CAA required the seat cushion supports to be engineered so as to avoid the possibility of a passenger being trapped, for example by a foot passing between the support webs.

5.2 Bulkhead Exit

In common with the vast majority of others, the aeroplane in the Manchester accident had vestibules at each pair of main doors which serve as galleys in flight. Passengers evacuating from the aircraft had therefore to pass through a doorway at either end of the aisle (but without a door) to reach the vestibule and hence the main doors. In the case of the Manchester accident the front pair of exits was used for the evacuation and the cabin staff reported that the crush of passengers trying to get through these exits had resulted in some intermittent jamming, with consequent delays. At 22½" the doorway on this aircraft was wider than the international standard of 20" and previous experience had not suggested that it presented a potential problem . At Manchester there was a crush of passengers at the door, because they were not only reaching it along the aisle but also over the seats, the backs of which they were able to fold forward. As in the case of the overwing exit, the CAA made this problem the subject of research with the introduction of competitive behaviour in the evacuating "passengers". The results indicate that, with openings of the width of those on the accident aircraft, intermittent blockage can be expected, but that if the width is increased to 30" the problem disappears. This kind of change is less readily introduced on aircraft that are already in service than are the changes at the overwing position, but is appropriate to new designs or to the introduction of new layouts.

The CAA has, therefore, proposed that the international standard should be amended, to increase the minimum width of such openings to 30". This proposal is supported by the European authorities Cabin Safety Working Group and is currently a Notice of Proposed Amendment for the European requirements; (See Appendix 2 regarding European co-operation and JAA and EC activities).

5.3 Seat Spacing

The space provided between seat rows needs to be adequate both for impact survivability and to permit rapid egress from the seat to the aisle. Traditionally, this spacing has been governed by defining the minimum seat pitch for which each individual seat type is approved. This minimum pitch is based on the assumption that the seats forward and behind are of the same type and are located immediately fore and aft of one another. Increasingly, however, this is not the case, because the row in front or behind may be of a different type or in a different configuration. In order to take account of such variations and to provide a more consistent standard of access to the aisle, the CAA has developed "space envelope" criteria that define minimum clearances between seats. Dimensions are specified to provide:

a. adequate clearance at knee level, when seated, to assist the act of standing up;

b. a minimum vertically projected gap between seat rows, to make it easier to stand; and

c. a minimum gap, at arm rest level and below, to permit the sideways movement necessary to reach the aisle.

These new requirements, which may well also offer a coincidental benefit to general passenger comfort, were issued on 16 March 1989 (Reference 12) and are already being applied to all new seating configurations, and all existing layouts will be required to conform by January 1992. Although it is at present only a United Kingdom requirement, it has been tabled internationally, and the CAA is optimistic that international adoption may follow. A significant number of current UK aircraft will need to be provided with increased seat pitch this year to ensure compliance.

5.4 Escape Path Lighting

Generally, the emergency lighting in aircraft cabins to aid evacuation in darkness is located overhead. This has the disadvantage that, in the event of a fire, any smoke entering the cabin is likely to be buoyant and to rise to the ceiling and the emergency lighting would then, effectively, be lost.

Tests in the United States had shown that lighting at or near floor level could provide escaping passengers with the information they need to reach the emergency exits in those conditions. Accordingly, in 1986 the CAA, in common with other authorities, required that such lighting should be provided in passenger aircraft (Reference 11).

5.5 Emergency Evacuation Demonstration

When all the features of a proposed cabin layout and associated escape facilities have been shown to meet the CAA's requirements, an evacuation demonstration is conducted as a condition of type certification. This demonstration takes place only when the general layout requirements have been met. It is not an alternative to meeting the requirements or a means of justifying a deficiency.

The demonstration is conducted using participants representative of a typical passenger load (except that infants are simulated by dummies) and who have no recent experience of such an exercise. Only half of the total number of exits are available, but the participants do not know in advance which they are. The demonstration is carried out in darkness, using only the emergency lighting, and with carry-on baggage scattered throughout the cabin. The purpose is to show that under these standardised test conditions an evacuation can be completed within 90 seconds from the time the order is given to the moment the last participant reaches the ground. To avoid repeating the exercise for every possible seating configuration, the demonstration usually represents the highest passenger density for which Type Certification has been requested. It is also usually arranged so that aisle widths and exit access routes are of the minimum dimensions likely to be encountered in service.

A popular misconception is that the demonstration is intended to provide a guarantee that the aircraft type would be fully evacuated in 90 seconds under any circumstances. This is not so. It is a standardised test which assesses the main features of the aircraft's escape facilities and is the means by which the performance of one aircraft can be compared with others. Although the demonstration represents a severe condition, in any real evacuation the time taken will vary according to the circumstances. If, for example, all the exits are usable the time may very well be less than the 90 seconds of the standard, and if fewer exits are available it may be greater. The purpose of the test is to ensure that aircraft types of widely differing size and configuration meet the same standard for rapid evacuation in adverse circumstances.

It is sometimes suggested that the test should represent a still more severe condition, but this could not be done without introducing an unacceptable risk of injury to the participants. The present demonstrations involve some hazard. For example, out of 553 participants in a Boeing 747-300 demonstration on 15 February 1986, there were 51 cases of skin abrasion and 18 cases of back contusion or assorted sprains.

Over the years a wide range of aircraft types and variants has been subjected to this test. There is, therefore, a large pool of data available. There are also computer methods being developed capable of modelling evacuation and consequently the Authority is exploring the possibility of making use of this data and these techniques to examine a wider range of conditions than is currently possible with just one test. For example, the current test does not simulate the loss of all exits at one or other end of the aircraft due, say, to a widespread ground fire.

5.6 Summary

The Authority has introduced new standards for seating configurations at overwing exits which make it easier and quicker for the passengers to open such exits, and also improves the evacuation rate especially in circumstances where there is a rapidly developing fire. Recent accidents in other parts of the world appear to support the CAA actions and may well lead to their wider adoption.

The Authority has also taken the lead in adopting a minimum standard for the space available to the seated passenger. This issue has up to now been generally regarded as a comfort or "market-place" matter. In adopting a minimum standard the Authority is recognising that ease of egress into the aisle can be jeopardised if the space available is reduced below reasonable limits.

As a result of research the Authority has identified a need for wider openings in bulkheads which passengers must pass through en route from the cabin to exits. The current minimum standard and the standard in service in many aircraft is vulnerable to intermittent blockage if passengers are pressing to get through in the event, say, of fire.

The Authority is examining computer modelling of evacuation with a view to its possible use to complement the certification evacuation test now used as a final check of an aircraft type's evacuation provisions. Modelling will allow a wider range of scenarios to be explored.

6. SMOKE HOODS

The question of whether or not passenger smoke hoods should be required equipment on British-registered aircraft has attracted considerable public interest and comment, with deeply held views being expressed for and against.

The Authority's view on passenger smoke hoods is that the subject cannot be viewed in isolation. If it is possible to prevent a fire, steps must be taken to do so. If a fire does start, then means must be provided to fight it and measures taken to ensure the best possible chances of survival following an accident.

Since 48 out of the 55 deaths resulting from the Manchester accident were caused by inhalation of smoke and toxic gases, the AAIB asked the CAA in December 1985 to consider formulating a requirement for a passenger smoke hood. The CAA responded to the AAIB's recommendation by developing a draft specification. This work also involved the United States Federal Aviation Administration, the French Direction Générale de l'Aviation Civile and Transport Canada in a general review of regulatory policy on smoke hoods.

All four Authorities concluded in 1987 that passenger smoke hoods should not be required equipment on transport aircraft, the United States after twice previously considering the issue following air accidents involving fire. The CAA Board supported this position in December 1987 but agreed to review the case for regulatory action in the future in the light of developments.

In its report on Aircraft Cabin Safety published in January 1991, the House of Commons Transport Committee recommended the mandatory carriage by UK-registered aircraft of the best smoke hoods currently available. The Committee also recommended that this should be implemented without delay.

6.1 Equipment Specification

In response to the AAIB's recommendation CAA published a draft passenger smoke hood specification in July 1986 and issued it in final form in May 1988. Although the specification has been criticised for being too demanding, it was finalised only after consultation with industry both nationally and internationally, and with other authorities. Most manufacturers felt it was about right, but some thought that an even higher standard was justified.

At that time the CAA was presented with four types of hood which were felt by their proposers to offer sufficient protection, though the manufacturers did not claim that they met the Authority's draft specification. The Authority took the view that none of the four hoods was adequate and that in certain circumstances some could, in fact, be positively dangerous. Though no smoke hood has been shown to meet the specification, some manufacturers are now expressing confidence in their ability to produce smoke hoods which will do so.

6.2 Net Safety Benefit

In 1987 the CAA, in collaboration with the three other safety authorities, carried out an analysis of world-wide accidents where fire was a feature. This covered the 20 year period up to the Manchester accident and was used to determine which were survivable and which, if smoke hoods had been available, might have resulted in lives being saved.

The analysis showed that 9 lives per annum might have been saved world-wide (Reference 13), and 0.5 in the UK if smoke hoods were fitted to transport aircraft of more than 30 seats. These figures assume that there would have been no delay in the evacuation due to the use of smoke hoods and that the smoke hood would have been 100% effective and reliable. In reality, there will inevitably be some delay caused by the donning of smoke hoods and the evacuation will be slower. The analysis shows that if this is taken into account there would be a reduced benefit overall and in some accidents additional loss of life was likely.

The steps which have already been taken by the Authority to suppress or contain fires in aircraft, and to assist their rapid evacuation, have tended to reduce still further the potential for smoke hoods to save lives. The CAA has now assessed the accidents which have occurred in the five years since Manchester (Appendix 1) and has concluded that the frequency of fire accidents has halved and that the potential for smoke hoods to save lives has reduced to about one life per year world-wide, even on the unrealistic assumption that smoke hoods would have introduced no additional delay in the evacuation. The more likely outcome is that delays in the evacuation would have led to the loss of eight or more lives per year.

In-flight fires are usually less severe than ground fires because they are not normally fuel-fed. For this reason, the effective solution has been to provide fire fighting training and equipment for cabin crew, smoke detectors in toilets and enhanced cargo compartment fire containment measures.

Since 1985, there have been no fatalities world-wide from an in-flight cabin fire following which the aircraft made a successful landing. In the previous 20 years there had been three such accidents (B707 Paris July 1973, L1011 Riyadh August 1980, DC-9 Cincinnati June 1983). These were included in the Authority's Net Safety Benefit Analysis and their contribution to the net safety benefit was small. There is, therefore, little justification for passenger smoke hoods for in-flight use.

6.3 Disadvantages of Smoke Hoods

Opposition to the mandatory provision of passenger smoke hoods has been expressed by fire safety specialists in other aviation authorites, fire services, research organisations, the airline industry and various representative bodies.

The major concern of these specialists is <u>not</u> with the technical design of passenger smoke hoods so long as they comply with the recognised aviation specification. It is mainly the unpredictable response of untrained passengers to a strange piece of equipment in rapidly changing conditions that causes professionals to argue against the value of smoke hoods on transport aircraft. It is unlikely that smoke hoods will be less complicated to don than the flotation life jackets required for over-water flights. Although data is difficult to come by, it is not thought that high levels of life jacket use have been attained in unpremeditated ditchings. In this respect it should be noted that in a recent fire accident, one of the few fatalities is attributed to the inability of the passenger, even though uninjured, to do something as simple as undoing his seat belt.

In the past, the CAA and the FAA have emphasised the probable loss of life resulting from the likely delay in an emergency evacuation due to the extra time needed to don smoke hoods. Tests by Linacre College and the FAA's Civil Aeromedical Institute (CAMI) have suggested donning time delay is small and evacuation rate is little reduced so long as floor level exits of sufficient size are provided. However, no laboratory test can get anywhere near to simulating the real ground fire accident. Even the Cranfield Applied Psychology Unit's competitive behaviour evacuation tests in smoke are far removed from simulating actual human response to the rapidly changing conditions of some post crash ground fires with the associated shock, disorientation and possible injury.

For smoke hoods to have any potential to save life, they must be readily available to passengers in their seats, easy to don by the old, the infirm and the very young, capable of providing adequate means to see and hear, and reliable in respect of fire and toxic gas protection. The deaths by suffocation of four Israelis reported earlier this year, due to their inexperience in donning gas masks, illustrates the hazard of using unfamiliar equipment.

Furthermore, it is important to understand how smoke hoods might affect the ground fire evacuation. Where passengers have survived a crash, are mobile but shocked, and threatened by a developing fuel-fed fire, they will immediately evaluate and respond to:

- the need to get out of their seat and evacuate the aircraft quickly;
- the safety of others, particularly children and partners;
- the instinct to take personal belongings;

and were smoke hoods available,

- the need to protect themselves by donning the smoke hood.

Each passenger has to develop a strategy for his own survival. This strategy must not be unduly complicated, otherwise precious seconds will be lost. When threatened by fire passengers would be faced with the dilemma - "Do I put on a smoke hood or do I just get out as quickly as possible?". It would only take a few passengers to hesitate over the question before a disciplined and orderly evacuation becomes disorganised and chaotic. Worse still, if some passengers had donned their hoods and others not, some of the latter may try to get back to their seats to fetch theirs, effectively blocking the aisle and stopping evacuation.

Other issues cited by professional safety specialists are:

(a) Passengers could easily be lulled into a false sense of security once smoke hoods are donned. Generally, once protected, people will tend to stand up rather than get down as low as possible. This usually means they are more exposed to the effects of high temperatures and more likely to be within the fire/smoke layer.

(b) Smoke hoods could increase the evacuation time due to impaired vision and communication.

(c) Some passengers, such as parents or spouses, may delay evacuating in order to ensure that their children or their partners have correctly donned their hoods. This might cause blocking of aisles.

(d) The importance of training in the use of smoke hoods should not be underestimated. Trials have shown that untrained people do the most improbable things.

(e) It is probable that passengers will, due to trauma in an emergency, forget about smoke hoods. In cases where aircraft have ditched only 50% of life-jackets have been used.

6.4 Regulatory Position

In view of the risk that smoke hoods will jeopardise the evacuation process and may in some circumstances lead to increased loss of life, the Authority has concluded that it should not require the carriage of passenger smoke hoods in UK transport aircraft even if one were to be available which met the specification. Furthermore, it should discourage any airline from doing so voluntarily.

The position is different in relation to personal equipment. Where an individual has gone to the effort of acquiring his own smoke hood, it is reasonable to suppose that he will take the trouble to familiarise himself with its use. It should not therefore jeopardise the evacuation. However, the Authority will strongly advocate that individuals carrying their own equipment should ensure that it complies with a recognised aviation specification (see Section 6.1 above).

In reaching these decisions, the Authority has considered carefully the recommendation of the House of Commons Transport Committee, but it believes strongly that its concerns on speed of evacuation are overriding. Furthermore smoke hoods which are not to the standard of the specification may well be dangerous in themselves.

No other aviation safety authority has adopted a requirement for the mandatory carriage of smoke hoods for passenger use, nor is any known to be considering doing so.

NOTE: Sophisticated breathing apparatus is provided for members of the crew who may be called upon to fight a fire and are trained in its use. This equipment is considerably different from the type which could be used by a passenger and should not be confused with it. It is approved to a different specification (see Section 2.2 and 4.4.).

6.5 Summary

The Authority has always considered smoke hoods in the context of other survival developments as well as on their own merits. Its approach is to consider the overall standard of safety and measures which developments have the potential to raise those standards - both those achieved so far and those likely in the future.

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. 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. It will, however, keep under review all technological developments, both in smoke hoods and other survival techniques.

7. CABIN WATER SPRAY SYSTEMS

Soon after the Manchester Boeing 737 accident, the CAA was approached by the SAVE company with the proposal that a water spray system could be used to improve survivability in the event of an aircraft fire.

Historically, water-based systems have been designed to extinguish fire with high flow-rate jets or sprinklers, which use large quantities of water. The essential feature of the proposed system is that it is not designed to extinguish fires but, using a relatively small supply of water carried on board the aircraft, to produce a water mist within the cabin using a low flow-rate (about 15 gallons per minute for a Boeing 737-sized system). The company's initial testing had shown that this would prevent the occurrence of a "flash" fire within the cabin by the absorption of radiant and convective heat. It also has the potential to remove water-soluble gases and solid particles from smoke in the cabin and to "fire harden" the fuselage; this would maintain a survivable environment within the cabin. This would, in turn, extend the time available for safe evacuation.

The Authority agreed to sponsor some of the necessary work and a series of development tests culminated in three full-scale fire tests using a CAA Trident 2 aircraft at the Authority's Fire Service Training School at Teesside in 1988. The results of these tests (Reference 14) showed the concept to have promise. The CAA then invited the airworthiness authorities of the USA, and Canada and the JAA to participate in a joint research programme to examine more fully the system's potential.

In October 1988 the CAA, FAA and Transport Canada agreed the details of a research programme which was designed to:-

(a) evaluate the effectiveness of the system in maintaining a survivable cabin atmosphere under a representative range of post-crash conditions;

(b) evaluate the likely increase in evacuation time available;

(c) determine the adverse consequences associated with carriage of the system and especially any hazards due to its intentional or unintentional activation, for example on the aircraft's systems and structure;

(d) carry out a net safety benefit analysis; and

(e) optimise the water spray systems and examine any other similar concepts so that a design and performance specification can be prepared.

In addition to the joint programme, the CAA independently issued a Discussion Paper in 1988 (Reference 15) to elicit views on the technical regulatory issues. Comments were received from some 29 interested organisations and individuals in the UK and overseas, and a digest of these comments has been issued.

Most of the work described above is nearing completion, and confirms that the potential benefit of a water spray system is high. The Authority is convening a seminar in May 1991 to which all interested parties will be invited. At this meeting the results of the work will be presented together with the CAA views on the form and content of a system specification. This meeting can be regarded as a preliminary to consultation on regulatory action.

Although not part of the current programme, a proposal has been made for an extension to the on-board system to provide the capability of extinguishing an internal cabin fire. In this case, the spray system would have to be capable of handling a high flow-rate and would need to be provided with water from a fire appliance by means of couplings accessible to the ground fire services.

7.1 Testing

The full-scale tests at Teesside were carried out in the open air in varying wind conditions and with increasing destruction of the aircraft in each test. To gain quantitative information on the benefit provided by the system it was necessary to test repeatedly under controlled conditions, and to carry out datum tests without system activation. To achieve this, tests were carried out indoors and with a fuselage where the area attacked by fire is controlled by protecting other areas with steel plate.

The FAA also undertook to carry out a range of tests in their fire test hangar at Atlantic City. A SAVE system was installed in a Boeing 707 fuselage replicating the nozzles and geometry used in the Teesside Trident tests. The principal test condition represented a pooled fuel fire next to a break in the fuselage at which there are seats and other representative furnishing materials. The effect of an external wind blowing the fire into the cabin was simulated. Other test conditions included a fire burning through the floor from below, and both pan and seat fires set within the cabin. The results showed very substantial increases in the time for which the cabin remained survivable under all but the most severe simulated wind condition. The major part of the benefit was seen to be as a result of the wetting of the furnishings so that they are not so easily set on fire by the intense radiant heat without. The radiant heat is, in any case, itself attenuated by the spray. There is also a very rapid cooling of the smoke as it moves through the spray and washout of the soluble toxic gases. The FAA went on to carry out a complementary series of tests on a wide-body fuselage to very similar effect.

The CAA commissioned a two phase test programme at the Fire Research Station. The first part used laboratory tests to examine in more detail the way in which the system derives its benefits and to see if the SAVE nozzle design or system configuration could be improved upon. No such improvement could be identified in this work so that the second phase, full-scale tests, again centred on the SAVE system. A Boeing 707 fuselage was used and the test set up, in the Cardington airship shed, so as reproduce as closely as possible the FAA results. In addition to confirming the FAA results, the programme included a "zoned" test in which water was only sprayed in the region of the fire and a full system in which reduced flow rate nozzles were used with the system otherwise representing the SAVE design. The zoned system gave results which were no worse than the full spray. Whilst the reduced spray gave a good account of itself, it was measurably less effective than the full spray.

In both the FAA and the CAA testing, the only noticeable disbenefit was the effect of the spray on visibility. In the absence of a spray, the natural buoyancy of smoke will result in a smoke layer at high level and clear air below. The effect of the spray is to entrain the smoke and to bring it down to all levels. The extent to which smoke particles are washed out by the spray is insufficient to compensate for this effect. In the zoned spray tested by FRS for CAA, the smoke emerging from the sprayed region still retained sufficient buoyancy to re-establish a clear zone beneath, in the dry zone.

Reports of the FAA and the CAA/FRS work have yet to be published.

The Authority is also aware that industry is now also taking a strong interest in the design and development of cabin spray systems. At least two companies have carried out fire tests of their own and a third has built a test rig with that intention.

Another part of the CAA investigation was into the toxicity aspects. Because several of the toxic fire products are readily soluble in water it is important that the spray droplets should not be respirable. This places a lower limit on droplet diameter and is a constraint on nozzle designers (Reference 16).

7.2 Safety Benefit

The case for regulatory action on cabin water sprays cannot be made or rejected without an appreciation of the likely safety benefit. Although there may be other ways of making such an assessment, CAA believes that the approach which carries the most conviction is based on the examination of previous accidents. The circumstances of each accident are examined and a judgement made of the saving of life which could reasonably be expected to have resulted if the cabin water sprays had been available. This judgement must take account of the extension to cabin survivability likely in the circumstances and any factors affecting the evacuation, such as the non-availability of some doors. The purpose of the analysis is to assess the incremental effect of water sprays so that any savings of life expected from the measures taken previously, such as the fire blocking of seats, must first be assessed and accounted for. A similar type of analysis was made in the case of smoke hoods (Reference 13) which made use of a simplified computer model where sufficient detail of the accident was available.

The safety benefit analysis for water sprays could not start until the fire test work had been completed and had indicated the likely extension of cabin survivability in various circumstances. The CAA's preliminary assessment will be completed in May and it is planned that an analysis agreed by the other authorities in the joint programme will be published later in the year.

7.3 Disbenefit Studies

At the beginning of the programme, the authorities agreed that "disbenefit" studies should be carried out in parallel with the fire test work, principally to establish what steps might need to be taken to avoid any hazard arising from system operation including inadvertent operation. Two studies were envisaged, one with Airbus Industrie particularly directed towards the company's "fly-by-wire" technology, and one with the Boeing Company directed towards more conventional flying controls but otherwise incorporating modern digital technology.

The Airbus programme was funded jointly by the European Commission, CAA and DGAC/France. It concluded that in-flight operation would have to be precluded because the cost of modifications to make this option available would be prohibitive. No serious problem was identified in relation to use on the ground, although some minor design changes were recommended. In their analysis Airbus made the pessimistic assumption that no water would be absorbed by furnishings or carpet on the main deck and that it would all find its way into the underfloor area. It is unlikely however that this assumption affected the main conclusions of the analysis, especially in relation to a full duration activation. The report currently only exists as a limited circulation company document but CAA hopes to be able to publish an executive summary later this year.

Funding difficulties have delayed the start of the Boeing programme.

Other possible disbenefits which have been identified reflect more directly on the individual passenger and include:

- wetting with particular reference to the subsequent evacuation into cold ambient conditions;

- the effect of the wetted floors on the speed of evacuation; and

- the effect of the reduced visibility in the smoky spray on the speed of evacuation.

Paper studies of these questions are planned, but it is too soon to say whether further experimental work will be seen to be needed.

7.4 System Specification - Function

The CAA is planning to initiate early discussions on the requirements for a system in respect of its design and installation. These will include the following major issues:

- duration of protection, currently assumed to be three minutes;
- disposition and configuration of arming and activation controls;
- crash survivability features for the system; etc

The minimum standard for many other features of the system will also need to be specified. Some will depend on analysis of the test results, others may require special studies or investigation.

7.5 System Specification - Performance

The system approval process will require a demonstration that each candidate system meets a minimum standard of performance in respect of the protection it provides. Analysis of the test results is the starting point for identifying the individual components of that protection, and the level which is needed for each, including:

- wetting of cabin furnishings;
- radiation attenuation;
- smoke and gas wash out;
- cooling of smoke, etc.

The objective is then to define a test rig which can be built by any manufacturer who can then use it to optimise his system design and gain approval for it against defined test procedures. Such rigs and procedures should be capable of repeatable results from one to another.

7.6 Summary

Full-scale fire test programmes under controlled conditions in both the UK and the US have confirmed the effectiveness of low volume cabin water spray systems in providing considerably enhanced protection to passengers in the event of fire on the ground.

The Authority considers that serious consideration should now be given to introducing regulations requiring the installation of such systems in large transport aircraft. To this end it is initiating broad discussions with industry to review the results of the tests and studies carried out so far. Work on the preparation of functions and performance specifications is commencing to provide standards against which industry can seek to optimise their systems and seek approval.

8. INTERNATIONAL CO-OPERATION (see also Appendix 2)

As a signatory to the Chicago Convention the United Kingdom is a member of the International Civil Aviation Organisation and plays an active part in its business. However, ICAO has chosen not to become involved in specifying detailed technical standards for aircraft; it was considered more appropriate if that task were to be left to the manufacturing States.

Dating back to the development of joint Franco-British standards for Concorde there has been increasing co-operation within Europe which now involves 18 countries, working as the Joint Aviation Authorities. In addition to developing European standards, the JAA has considered it to be important to collaborate closely with the US FAA with a view to minimising differences. Although the CAA and the other European authorities have a long history of working closely with the FAA on individual issues as the need arose, much more structured and effective co-operation is now coming into being.

With this background, in October 1986 the CAA proposed to the FAA the formation of a committee of authorities to work on cabin safety matters. The Group was formally initiated following a letter from the CAA to the FAA in May 1987, and included representatives from the airworthiness authorities of the European JAA countries, the FAA and Transport Canada. The Group meets twice per year and its objectives are to exchange experience and expertise at the pre-rulemaking stage and identify research needs, with the aim of proposing common policies and rules.

9. DISCUSSION AND REGULATORY OBJECTIVES

Passenger survivability in the event of an aircraft cabin fire has attracted wide public interest and the Authority gives very high priority to achieving improvements in this field. The steps taken in recent years, described earlier in this Review, demonstrate the Authority's commitment to identify, research, specify and introduce requirements which it considers will either indivudally or together effect major benefit to the safety of the travelling public.

It has been suggested that some of the Manchester fatalities would have been prevented if smoke hoods had been available and the Authority has been called upon to consider their adoption on civil aircraft. Depending on the degree of delay caused by the need to don them, there may have been some benefit from smoke hoods at Manchester, but in some other accidents involving fire their provision is likely to cause increased loss of life. The Authority is convinced that its duty is to set regulatory objectives which can be applied generally to fire hazards in all aircraft, and not just to the unusual circumstances in one particular accident. The Authority is firmly of the view that its regulatory priorities should be to reduce the fire threat and to procure better exit routes to ensure a rapid evacuation. Smoke hoods do nothing to support these objectives and some specialists believe that the additional confusion and delay involved in their use could result in more lives being lost. The Authority considers this is an unacceptable safety risk and has accordingly decided not to require that smoke hoods be provided on British-registered aircraft.

The Authority is, however, much encouraged by the test results which have been achieved by cabin water spray systems in inhibiting the initiation and spread of cabin fires. Where fires have become established in the cabin, water sprays will maintain survivable temperatures outside the immediate fire zone. Fire hardening of the exterior also appears to have the potential to minimise fire risks.

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APPENDIX 1 WORLD-WIDE FATAL ACCIDENTS INVOLVING FIRE SINCE MANCHESTER (1986-1990)

The frequency of accidents to jet aircraft involving fire has notably reduced since Manchester. There were 68 accidents in the 221 million hours flown before that time, a rate of 3.1 per ten million hours, and 14 in the 88 million hours in the subsequent five years, a rate of 1.5 per ten million hours. It is reasonable to assume that the fire protection measures introduced since 1985 have been a factor in this reduction.

This Appendix details the eleven accidents for which information is available and shows that a maximum of one life per year would have been saved if smoke hoods had been available. A more realistic "best estimate", taking account of donning time and a slightly slower evacuation rate, is that some eight additional lives would have been lost per year. However, no allowance has been made for confusion which could further significantly increase the number of lives lost.

1. **Northwest DC-9 at Detroit 16.8.87**

Aircraft crashed and broke up shortly after take-off
Fatalities - 154 (148 pax + 6 crew)
Survivors - 1 (1 pax). One small child "miraculously" survived
It is assumed that the fatalities were due to impact
Smoke Hood benefit/disbenefit = 0 lives

2. **Continental DC-9 at Denver 15.11.87**

Post crash fire which was not sustained
Fatalities - 28 (19 impact trauma, 9 mechanical asphyxia). No fire deaths
Survivors - 54 (52 pax + 2 crew)
Numerous cases of serious injuries - some trapped for 5 hours - fuselage sections inverted
Smoke Hood benefit/disbenefit = 0 lives

3. **SAA B747 Near Mauritius 28.11.87**

In-flight fire. Passengers overcome by smoke and fumes
Fatalities - 159 (140 pax + 19 crew)
Survivors - 0
Non survivable mid-ocean impact
Smoke Hood benefit/disbenefit = 0 lives

4. **Air France A320 at Habsheim 26.6.88**

Severe post crash fire which destroyed complete passenger cabin
Fatalities - 3 pax
Survivors - 133 pax and crew
Rapid evacuation was essential - survivors' hair and clothes caught fire during evacuation - 11 pax stated they had difficulty undoing seat belts - some required help
Smoke Hood benefit/disbenefit:
* Maximum benefit = 3 lives saved
** Best estimate = up to 27 lives lost

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* "Maximum" assumes no confusion/access/donning delay and no reduction in evacuation rate.

** "Best estimate" assumes 15 second access/donning delay and a 10% reduction in evacuation, but still no account for confusion.

5. **Delta B727 at Dallas 31.8.88**

Aircraft crashed shortly after take-off. Fuselage broke followed by severe fire
Fatalities - 13 (11 pax + 2 crew)
Survivors - 94 (89 pax + 5 crew)
No floor level exits were available for evacuation. All passengers and cabin crew survivors from main (central) section. Two fatalities in this area might have been helped by smoke hoods. However many escaped through torn wreckage where smoke hoods would probably have constituted an additional impediment. 11 fatalities were trapped in rear section and were subjected to an intense fire such that smoke hoods would not have helped.
Evacuation time (4-5 minutes) was critical in view of exit routes available and injuries sustained.
Smoke Hood benefit/disbenefit:
* Maximum benefit = 2 lives saved
** Best estimate = up to 12 lives lost

6. **Ethiopian B737 at Bahir Dar 15.9.88**

Aircraft destroyed by impact and fire
Fatalities - 35 pax
Survivors - 69 (63 pax + 6 crew)
Insufficient information to be able to determine smoke hood benefit/disbenefit.

7. **Uganda Airlines B707 at Rome 17.10.88**

Aircraft destroyed by impact and fire
Fatalities - 30 (+2 in hospital)
Survivors - 25
Insufficient information to be able to determine smoke hood benefit/disbenefit.

8. **Aeroperu F-28 at Juliaca 25.10.88**

Aircraft crashed and burned shortly after take-off
Fatalities - 12 (11 pax + 1 crew)
Survivors - 57 (54 pax + 3 crew)
Most fatalities were impact related - fuselage section was inverted. Some pax were ejected from broken fuselage. Smoke hoods are not likely to be used in such a severe crash with such fuselage damage.
Smoke Hood benefit/disbenefit = 0 lives

9. **Burma Airways F-27 at Rangoon 3.2.89**

Fire broke out on impact and destroyed aircraft
Fatalities - 26 (23 pax + 3 crew)
Survivors - 3 (1 pax + 2 crew)
Insufficient information to be able to determine smoke hood benefit/disbenefit.

10. **Air Ontario F-28 at Dryden 10.3.89**

Crashed and burned following take-off
Fatalities - 24 (21 pax + 3 crew)
Survivors - 45 (44 pax + 1 crew)
Aircraft struck trees after take-off and crashed in heavily wooded area. It broke and there was a severe post-crash fire. With this crash sequence smoke hoods unlikely to have been used.
Smoke Hoods benefit/disbenefit = 0 lives

11. **United DC-10 at Sioux City 19.7.89**

Aircraft crashed and cartwheeled during an attempted emergency landing
Fatalities - 111 (110 pax + 1 crew)
Survivors - 185
Fuselage separated into 4 sections. Centre section, containing 207 pax came to rest upside down. 21 fatalities died from smoke inhalation. Many serious injuries - very unlikely smoke hoods would have been used.
Smoke Hoods benefit/disbenefit = 0 lives

12. **Indian Airlines A320 at Bangalore 14.2.90**

Aircraft undershot on landing and caught fire
Fatalities - 90 (86 pax + 4 crew)
Survivors - 56 (24 serious/32 minor/none injuries)
73% of survivors in rear half of the aircraft. 8 had burn injuries. Slow evacuation owing to injuries. Smoke hoods may have slowed evacuation. Cabin totally burnt-out. Similar to 4.
Smoke Hood benefit/disbenefit:
* Maximum benefit = 0 lives
** Best estimate = up to 5 lives lost

13. **Philippine B737 at Manila 11.5.90**

On pushback centre fuel tank exploded resulting in intense fire
Fatalities - 7 pax
Survivors - 112 (106 pax + 6 crew)
Some fatalities were due to explosion - smoke hoods unlikely to be used
Smoke Hood benefit/disbenefit = 0 lives

14. **Northwest DC-9 at Detroit 3.12.90**

DC-9 taxied onto active runway in fog and was hit by B727
Fatalities - 8
Survivors - 35
Some fatalities were due to fire, some due to serious injuries - smoke hoods unlikely to be used.
Smoke Hood benefit/disbenefit = 0 lives

Summary

On the basis of the above information the world-wide smoke hood benefit/disbenefit is as follows:

Benefit/Disbenefit Assumptions	*5 year period*	*Annualised*
Net "Maximum" - no delay	*5 lives saved*	*1 saved*
Net "Best estimate" - donning delay/ reduced evacuation rate, but no allowance for confusion	*42 lives lost*	*8.4 lost*

Note: UK expectation would be about 5% of the above.

APPENDIX 2 ARRANGEMENTS FOR INTERNATIONAL CO-OPERATION

Under the terms of the Chicago Convention, member States are individually responsible for air safety. However, the Convention also requires member States to recognise one another's certificates of airworthiness and crew licences provided the State which issues the certificate or licence has applied minimum ICAO standards.

In recent years the international nature of air transport has been emphasised by several changes in the aviation industry - for example multinational manufactures, the emergence of cross-border aircraft leasing, the liberalisation of air transport economic regulation and, within Europe, the implications of the Single European Act. One result is that a British traveller may book a flight in the expectation of flying in a UK-registered aircraft, but in the event might well find himself travelling in an aircraft that is registered abroad and maintained to standards other than those enforced in the UK. All of this makes it highly desirable that there is wide international co-operation on safety requirements.

1. Joint Aviation Authorities

Until the early 1980s, aircraft airworthiness certification was carried out by the domestic airworthiness authority in the country of manufacture, and then re-validated by each country to which the aircraft was exported against that country's own standards. The certification codes of most states were based on the USA Federal Aviation Regulations (FAR), often with national additions; however, the UK developed its own British Civil Airworthiness Requirements (BCAR) and these were used as a basis for certification by many Commonwealth countries. Even when safety requirements were the same, there was a problem of inconsistent interpretation.

The European Joint Aviation Authorities (JAA) are a group of 18 countries - who have signed "Arrangements" documents and who manage their business of safety regulation through the JAA Committee. The Arrangements represent a commitment jointly to develop common requirements, which were at first known as "Joint Airworthiness Requirements". Since the Arrangements were drawn up, the joint requirements have expanded from aircraft design to the fields of maintenance and operations; to reflect this wider range of interests they are now called "Joint Aviation Requirements" (JAR). The JAA members contribute staff to its secretariat; the CAA is currently providing accommodation and administrative support. The organisation is now formally affiliated to the European Civil Aviation Conference (ECAC).

It has been agreed to explore the feasibility of creating a single European aviation safety regulatory agency.

By sharing work between countries, this system is removing the burden of multiple certification and differing standards and is creating common or mutually acceptable maintenance systems. Much progress has been made, although the work is probably only half complete, and it represents a major advance in efficiency for the European aviation industry.

The Commission of the European Communities, following discussions with EC States and the JAA, has completed a draft Directive to harmonise aircraft safety standards and this is now with the Council of Ministers. It provides that the JAR codes will constitute the harmonised standards and will be effective across the Community. National differences not acceptable to the majority EC States would not be allowed. This Directive is likely to be published this summer and will require JAR codes to be applied not later than the 1st January 1993 along with other "Single Market" legislation. Against this background, unilateral CAA action to introduce new standards is not only against the spirit of the JAA process but will soon be likely to be unacceptable under EC law.

2. Co-operation with the USA

The airworthiness requirements of most countries are based upon the United States' FAR. JAR 25 is similarly based upon FAR 25, although there are a number of differences - almost all to achieve a higher standard. JAA intends to maintain this close relationship, and eventually to move to a position where JAR 25 and FAR 25 are more similar, although it is not expected that they will ever be identical.

The CAA has had strong direct co-operative links with the FAA for many years; these are expected to continue in parallel with the developing co-operation between JAA and the FAA. Each year senior CAA and FAA executives meet to discuss major policy matters of mutual concern and there is extensive and continuous working-level contact on all subjects.