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CAA Paper 90013

Aircraft evacuations: preliminary investigation of the effect of non-toxic smoke and cabin configuration adjacent to the exit

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Aircraft evacuations: preliminary investigation of the effect of non-toxic smoke and cabin configuration adjacent to the exit

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ABSTRACT

In 1987 the United Kingdom Civil Aviation Authority (CAA) commissioned Cranfield Institute of Technology to conduct an experimental programme of research into passenger behaviour in aircraft emergencies. The results from the programme suggested that changes to the configuration in the cabin adjacent to the exits, would influence the rate at which passengers would be able to evacuate the aircraft in an emergency (Ref 1).

In 1989, the CAA extended the programme of evacuation research at Cranfield to include a preliminary investigation of the influence of the presence of non-toxic smoke in the cabin. The research objective was to determine whether changes to the cabin configuration adjacent to the exit would determine the rate at which passengers could evacuate the aircraft in the presence of non-toxic smoke.

254 volunteers were recruited from the public to perform a series of evacuations from a Trident Aircraft parked on the airfield at Cranfield. For reasons of safety, the number of volunteers performing each evacuation was restricted to 30–35. Their behaviour in the smoke was continuously monitored using heat sensitive cameras.

The presence of non-toxic smoke in the cabin significantly reduced the rate at which volunteers were able to evacuate the aircraft.

The initial results also appeared to indicate that in the presence of non-toxic smoke changing the configuration of the cabin adjacent to the exits will influence the rate at which passengers are able to evacuate an aircraft in an emergency. Further tests are required to obtain statistical confirmation of this finding.

The use of non-toxic smoke in order to produce conditions of reduced visibility, was shown to have the potential to provide some of the data required for the assessment of design options and safety procedures for use in emergency evacuations.

CONTENTS

1 INTRODUCTION

In 1987 the United Kingdom Civil Aviation Authority (CAA) commissioned the Cranfield Institute of Technology to conduct an experimental programme of research into passenger behaviour in aircraft emergencies. The main objective was to investigate the influence of changes to the cabin configuration involving access to the emergency exits, on the rate at which passengers could evacuate an aircraft. The configurations evaluated involved a range of widths for the passageway through a bulkhead leading to floor level exits, and a range of seating configurations adjacent to a Type III overwing exit. The configurations were evaluated (a) when passengers were competing to evacuate the aircraft, as can happen in an accident when the conditions in the cabin become life threatening, and (b) when passengers were evacuating in an orderly manner as occurs in aircraft certification evacuations and in some emergency incidents.

When the width of the bulkhead was considered, the data suggested that the blockages known to occur in some emergency evacuations, can be significantly reduced when the passageway through a bulkhead is greater than 30″. The minimum seating configurations specified by the Civil Aviation Authority in Airworthiness Notice No. 79 in 1986 were shown to have significantly increased the rate at which passengers can evacuate through Type III overwing exits in an emergency. Blockages at the overwing exit were also found to occur in evacuations involving a three inch vertical projection between the seats (pre AN79). The six inch vertical projection with the outboard seat removed (an AN79 configuration) led to a rapid evacuation flow rate but had a tendency to give rise to blockages and the opening and disposing of the exit was found to be more difficult in this configuration. The results suggested that the optimum distance between the seat rows bounding the exit would involve a vertically projected distance between the seat rows of between 13″ and 25″.

A report in which a description of the methodology and results obtained from the programme was published in November 1989. (Ref 1).

In 1989, the CAA extended the programme of passenger evacuation research. They commissioned a preliminary programme of evacuation trials to investigate the influence of the presence of smoke in the cabin on the rate at which passengers could evacuate an aircraft.

The objectives of this research were to determine:

(a) The influence of increasing the width of the passageway through the floor to ceiling bulkhead leading to floor level Type I exits, on the time taken for passengers to evacuate the aircraft when their vision was impaired by the presence of non-toxic smoke within the cabin.

(b) The extent to which an increased distance between the seat rows adjacent to the overwing exit, or the removal of the outboard seat beside the overwing exit, would improve the rate at which passengers could pass through the Type III exit in a simulated emergency when their vision was impaired by the presence of non-toxic smoke in the cabin.

Concern was expressed by members of the Cranfield Ethics Committee and the CAA Fire Service that volunteer members of the public could panic on finding themselves in smoke on an aircraft. For this reason, it was decided that in the initial investigation volunteers should be required to perform only two evacuations from the stationary aircraft and that the alternate cabin configuration would only be tested on two occasions.

2 METHOD

2.1 Research Design

The Trident Three aircraft permanently sited on the airfield at Cranfield Institute of Technology, and used in previous investigations for the CAA, was used for the evacuations. Volunteers from the public were recruited in groups of approximately 30 to take part in evacuations from the Trident. The aircraft provided an element of realism which was considered necessary. The aircraft had a similar cabin layout to many of the narrow bodied aircraft in operation at the time of the investigation.

(a) *Evacuations through the Bulkhead*

The following configurations were assessed:

(i) A bulkhead which is typically seen on aircraft, a width between the galley units of 24 inches (61 cm)
(ii) A width between the galley units of 30 inches (76 cm)
(iii) A width between the galley units of 36 inches (91 cm)
(iv) Port galley unit totally removed.

The configurations are illustrated in Appendix A.

The flow of volunteers through the bulkhead was of prime importance in the evaluation of the optimum width between the galley units. It was therefore important that the number of volunteers attempting to reach the bulkhead was not influenced by a blockage at an exit downstream of the bulkhead. Consequently, both of the port Type I exits forward of the vestibule were utilised in all of the evacuations through the bulkhead. (See Appendix C.)

In order to direct the volunteers in a way which would ensure that the only restriction to the rate of evacuation was that of the bulkhead, a member of cabin staff was positioned in the vestibule area forward of the bulkhead in order to direct passengers to the exits. (See Appendix C.)

In order to avoid any interaction between the seating configuration at the overwing exit and the evaluation of the impact of the width between the bulkheads, the seating layout throughout the aircraft remained constant during all of the evacuations through the bulkheads.

The behaviour of passengers using evacuation chutes and their associated flow rate was not within the scope of this investigation. The use of ramps, rather than chutes, eliminated this variable from the design. It also removed the risk of volunteers being injured whilst using the chute. (See Appendix C.)

(b) *Evacuations through the Type III Overwing Exit*

In 1986 the CAA introduced Airworthiness Notice No. 79 in which it was stated that two alternate minimum requirements would apply to the seating beside the overwing exit. (Ref 2.) The following seating configurations adjacent to the Type III Exit were assessed which included both Airworthiness Notice No. 79 configurations.

(i) The CAA standard in Airworthiness Notice No. 79 paragraph 4.1.2 (Ref 2) in which 'Seats may only be located beyond the centre line of the Type III exit provided there is a space immediately adjacent to the exit which projects inboard from the exit a distance no less than the width of a passenger seat and the seats are so arranged as to provide two access routes between seat rows from the cabin aisle to the exit'. In the research programme the seat row adjacent to the exit had the outboard seat removed and the seat rows fore and aft of the Type III exit were at a seat pitch of approximately 32 inches (81.2 cm), with the vertical projection between the seat rows being 6 inches (15.2 cm).

(ii) The CAA standard, specified in Airworthiness Notice No. 79, paragraph 4.1.1 (Ref 2), in which 'All forward or aft facing seats are arranged such that there is a single access route between seat rows form the aisle to a Type III exit, the access shall be of sufficient width and located fore and aft so that no part of any seat which is beneath the exit extends beyond the exit centre line and the access width between seats vertically projected, shall not be less than half the exit hatch width including any trim, or 10 inches, whichever is the greater'. In the research programme the seats fore and aft of the Type III exit were at a seat pitch of approximately 39 inches (99 cm), with the vertical projection between the seat rows being 13 inches (33 cm).

(iii) A configuration in which the access to the exit between the seat rows vertically projected was approximately 18 inches (46.1 cm), with a corresponding seat pitch of 44 inches (111 cm).

(iv) A configuration in which all the seats located in line with the exit were removed, leaving a pitch of approximately 60 inches (152 cm) between the seats fore and aft of the exit. The resultant vertical projection between the seat rows was 34 inches (86.3 cm).

The configurations are illustrated in Appendix B.

In all of the evaluations of the seating configurations bounding the Type III exit, the egress took place through the port overwing exit (Appendix C). Data which had been collected by the FAA indicated that laterality of exits did not affect the rate of evacuation (Ref 5). The FAA report indicated that an interaction was obtained between the method of opening the Type III exit and the seat configuration on egress rate. To remove this interaction, the method of opening the exit was held constant throughout the trials. This was achieved by a member of the research team being employed to open the exit, and hand it to a trained observer on the wing.

2.2 Equipment

The modifications which were made to the structure of the Trident Three aircraft in order to make it a suitable test vehicle for the previous series of evacuations (Ref 1) were retained.

This included the removal of the port galley unit and the introduction of wooden sections which allowed the three aisle widths under consideration to be produced. A modification of the overwing hatch in order to bring its height to the minimum standard (43") and a lower handle fitted to the inside of the hatch to enable the operator to open the exit as quickly as possible.

On all civil aircraft, individual blocks of seats (three on the Trident aircraft) are positioned on tracks on the floor. It was therefore possible to manoeuvre the seats adjacent to the overwing exit along the tracks on the floor in order to achieve the correct vertical projection for three of the four seating configurations. To achieve the CAA standard specified in Airworthiness Notice No. 79, in which the seat row beside the exit must have the outboard seat removed (configuration (i)) a double seat unit was constructed. The unit was located on a metal base which provided stability together with the correct vertical projection.

The seat back strength on the rows adjacent to the exit was increased to a standard higher than the minimum specified in Airworthiness Notice No. 79. Additionally, the webbing and springs supporting the cushions were covered by a diaphragm. These steps were taken to prevent the risk of injury to volunteers caused by either the seats being broken or by people falling between the support webbing in their attempts to egress.

In order to allow comparisons to be made with the previous series of evacuations the seats available for the volunteers were restricted to the aft cabin, with the seven rows at the rear of this section of the aircraft being boarded off. 'Passengers' were therefore seated between rows 8 and 19.

The alterations which were made to the structure were designed to be as unobtrusive as possible. The modifications to the bulkhead and the false wall at the rear of the cabin were decorated in order to resemble the original aircraft decor. Additionally, the double seat unit utilised in the evaluation of the configuration adjacent to the Type III exit was constructed from Trident seating stock.

In addition to the modifications to the structure of the aircraft, exit ramps were constructed on scaffolding which enabled subjects to evacuate quickly and safely. The ramps were mounted on the port side of the aircraft, outside both the Type I doors and the Type III exit. Hand rails and a non-slip surface were utilised on each ramp in order to reduce the risk of injury to disembarking passengers.

Audio equipment was installed on the Trident which allowed the aircraft engine sounds and instructions from the captain and cabin staff to be relayed to the volunteers. In order to identify individual volunteers on the video recordings, and to be aware of their seat location prior to the evacuation, white cotton vests were worn by volunteers during the evacuation. Each vest was stencilled with a number which indicated the seat to which they had been allocated for that evacuation.

The non-toxic smoke was produced using two generators located at the rear of the cabin which were operated until a relatively homogeneous visual environment with an optical density of approximately 0.5 per foot had been obtained. An optical density of 0.5 per foot is calculated to be the density that occurs during fires associated with a maximum survivable temperature for a period of 90 to 120 seconds. (Refs 3 & 4.)

Two heat sensitive cameras were employed in order to monitor the progress of volunteers through the cabin in the smoke and to enable members of the research team to rapidly locate and assist any volunteers experiencing difficulties.

2.3 Procedure

Volunteers were recruited in groups of approximately thirty to take part in each experimental session which comprised two evacuations from the Trident aircraft. In one of the evacuations, all of the volunteers passed between the bulkheads and evacuated from the aircraft through either of the two Type I exits. In the other evacuation, all of the volunteers evacuated through the port Type III overwing exit. The four bulkhead configurations at the entrance to the vestibule area and the four seating configurations adjacent to the overwing exit were each tested on two occasions. The test programme involved eight separate test days with two evacuations on each day. In order to account for the possible effect of practice, the order in which the configurations under review were tested was systematically varied using a counterbalanced design. The volunteers were told that they would be required to take part in some evacuations from the aircraft, in conditions of non-toxic smoke. They were however not given any information about the configuration under review, or the order in which the evacuations would be performed.

On arriving at Cranfield they were also told that they would be paid a £20 attendance fee, after they had completed the two evacuations. the volunteers were instructed that their task was to evacuate the aircraft as quickly as possible, once the doors had been opened by the Cranfield staff.

The safety of volunteers was an important consideration. To this end, only volunteers who claimed to be reasonably fit and were between the ages of 20–50 were recruited. On arrival, all volunteers were given a medical examination. They were also asked to complete a questionnaire indicating that (i) they had fully understood the purpose of the trials, (ii) the medical information which they had supplied was correct and (iii) that they were satisfied with the insurance cover. A doctor and the airfield fire service were present at all times. A system of alarms was employed to stop any evacuation should a real emergency occur or should there be concern for the safety of any volunteer. Volunteers were given a briefing before boarding the aircraft in which they were advised not to take part in the evacuations if they were at all concerned about the presence of the non-toxic smoke.

In order to introduce as much realism as possible, not only did the evacuations take place from an aircraft, but on their arrival at the airfield the volunteers were met by members of the research team trained and dressed as cabin staff. After boarding the aircraft, they were given a standard pre-flight briefing by the cabin staff, they then heard a sound recording of an aircraft starting up and taxiing to a runway. This sequence of recording lasted for approximately five minutes before giving way to the simulated sounds of an aborted take-off. This sequence was subsequently followed by a period of silence, in which time the pilots were supposedly shutting down engines and communicating with the cabin staff. The shut down period was pre-determined for each evacuation, being either 7 or 25 seconds. The variation ensured that the subjects could not anticipate the precise time at which the call to evacuate would be given.

Two seconds before the end of the shut down period non-toxic smoke was rapidly pumped into the cabin, this was followed by the command 'Undo your seatbelts and get out', at which time the appropriate exits were opened by research personnel and volunteers evacuated the aircraft.

After each evacuation all of the volunteers were required to complete a questionnaire indicating the route which they had taken from their seat to the exit, whether any person or object had hindered their progress and their assessment on a scale of 1 to 10 of the difficulty of their evacuation. Demographic information relating to each volunteer's sex, age, height and weight was also collected.

Before volunteers left the site they were given a debriefing in which they were reminded of the safety of air travel and advised that they should get back in touch with Cranfield if they experienced any physical or mental problems as a result of the evacuations.

3 RESULTS

3.1 Test Programme

From the test series of evacuations the final data base included information from 16 evacuations. Eight evacuations were conducted through the bulkhead aperture (two evacuations were conducted for each of the four configurations tested) and eight evacuations were conducted through the Type III overwing exit (two evacuations for each of the four configurations tested). Over the series of trials, 265 volunteers participated. The volunteers were aged between 20 and 50 and 65% were male. All of the planned evacuations were successfully completed as it did not become necessary to halt any of the evacuations as a result of blockages, damage to the equipment or concern for the safety of volunteers.

The passenger flow rates through the exits were obtained from the video recordings, with the evacuation time for each volunteer being taken from the call to evacuate the aircraft rather than from the elapsed time from the first individual to reach the exit.

3.2 Evacuations through the Bulkhead

Comparisons between the mean evacuation times for the four configurations tested were made for the thirtieth individual through the exits. This was in order that the data could be compared to the times obtained for the first thirty volunteers to egress in the competitive and non-competitive evacuations in the previous series of tests. (Ref 1.)

Table 1 Mean evacuation times for the thirtieth individual (time in seconds)

Bulkhead aperture	*Mean*	*SD*
24″	40.1	2.9
30″	37.9	4.4
36″	32.6	7.0
PGR	55.8	1.7

PGR = Port galley removed
SD = Standard deviation

As the means suggest statistical treatment of the data indicated a significant difference between the evacuation rates for the various configurations ($F_{3,7} = 9.76$ $p < .02$).

Individual comparison of means indicated that the configuration involving the removal of the port galley unit gave rise to significantly increased evacuation times when compared to the other configurations tested. (See Appendix D.)

3.3 Evacuations through the Overwing Type III Exit

Table 2 Mean evacuation times for the thirtieth individual (time in seconds)

Vertical Projection	Mean	SD
6″ (OBR)	59.6	9.9
13″	51.6	14.9
18″	49.4	6.7
34″	57.9	3.2

OBR = Outboard seat removed
SD = Standard deviation

At first sight, the means suggest that changes to the vertical projection between the seats leads to a small reduction in the evacuation times. However, statistically there was no significant difference between the mean evacuation times for the first thirty to evacuate the aircraft ($F_{3, 7} = 0.5$ NS) through the four configurations. This result may have been due to the fact that only two evacuations were conducted through each configuration.

3.4 Comparison between the competitive, non-competitive and non-toxic smoke evacuations

The results from the evacuation in smoke were compared with the results of previous evacuations (Ref 1). Comparisons were made between the times for the first thirty volunteers to evacuate the aircraft when passengers were competing (competitive), when passengers were evacuating following the procedure for a certification drill (non-competitive) and when smoke was present in the cabin.

3.4.1 *Comparison between the times for the evacuations through the Bulkhead and Type I exits*

Table 3 Competitive, non-competitive and non-toxic smoke evacuation times for the thirtieth person to exit over the four bulkhead conditions

Bulkhead Aperture	Competitive		Non-Competitive		Non-Toxic Smoke	
	Mean	SD	Mean	SD	Mean	SD
24″	24.5	5.8	21.8	1.4	40.1	2.9
30″	18.4	1.9	23.4	0.0	37.9	4.4
36″	17.2	3.1	21.4	3.4	32.6	7.0
PGR	14.7	1.4	17.6	0.5	55.6	2.0

PGR = Port galley removed
SD = Standard deviation

As the means suggest, statistical treatment of the data indicates a significant reduction in the evacuation rates in the presence of the smoke ($F2, 43 = 148.3$ $p < .01$). The fact that the configuration with the port galley removed produced the faster evacuation times in the competitive and non-competitive evacuations in clean air, but the slowest in the presence of smoke is of particular importance.

3.4.2 *Comparison between the times for the evacuations through the Overwing Type III Exit*

Table 4 Competitive, non-competitive and non-toxic smoke mean evacuation times for the thirtieth person to exit over the four overwing conditions

Vertical Projection	*Competitive*		*Non-Competitive*		*Non-Toxic Smoke*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
6″(OBR)	53.2	10.0	39.6	2.5	59.6	9.9
13″	55.9	10.3	39.9	3.3	51.6	14.9
18″	53.7	8.2	37.2	0.2	49.6	7.0
34″	62.3	8.1	35.3	0.6	57.9	3.2

OBR = Outboard seat removed
SD = Standard deviation

As the means suggest, statistical treatment of the data indicated a significant difference between the evacuation rates for the non-competitive evacuations and those with non-toxic smoke in the cabin ($F1, 19 = 17.01$ $p < .01$). There was however no significant difference between the evacuation rates for the competitive evacuations and those with non-toxic smoke in the cabin ($F1, 58 = 0.86$ NS). It is interesting to observe that in both the competitive and non-toxic smoke evacuations, the configuration involving a 34″ vertical projection gave rise to a longer evacuation time than the configuration involving an 18″ vertical projection between the seats.

4 DISCUSSION

All of the planned evacuations were successfully completed and none of the volunteers sustained injuries or became upset. This suggests that given adequate medical screening and briefing, it is possible to conduct aircraft evacuations involving the introduction of non-toxic smoke in the cabin, without putting members of the public at serious risk.

The results for the evacuation times through the bulkhead indicated that the configuration in which the port galley unit was removed reduced the rate at which passengers were able to evacuate the aircraft. In these evacuations, volunteers were observed to be grouping and trying to feel for something to hold onto beside the exit. The results clearly suggest the value of a solid structure, such as a bulkhead for passengers to feel their way along when their vision is obscured by smoke.

The results from the evacuations through the overwing Type III exit suggested that the configuration involving a 6″ vertical projection and the outboard seat removed gave rise to the greatest difficulties. This may be due to the fact that the removal of the outboard seat meant that there was a gap in front of the exit and volunteers had nothing to guide them across the space in front of the exit. To a lesser extent the longer evacuation time for the configuration involving the removal of a whole row of seats (34″ vertical projection) may have been a consequence of increased space along the access to the exit.

The results from both the evacuations through the bulkhead aperture and the Type III exit clearly indicate the value of tactile cues. Consideration could be given to the introduction of additional tactile cues in the cabin to assist passengers to evacuate quickly when smoke is present in the cabin.

The overwing hatch was removed by a member of the Cranfield team seated on the seat next to the exit and passed to an observer on the wing who carried it well away from the path of passengers evacuating the aircraft. In an emergency in which passengers vision was obscured by the presence of smoke, and they were also required to remove and dispose of the hatch, additional problems could occur if the hatch was either retained in the cabin or thrown out of the exit but remained on the wing adjacent to the exit.

As part of the pre-flight briefing given to the volunteers the floor proximity lighting was demonstrated. In all evacuations it was switched on when the smoke entered the cabin. After the first evacuation which they undertook, many volunteers reported that the floor proximity lighting had not been working (when it had). After the second evacuation, many said that they had not been able to see the lighting as to do so they would have had to bend down, causing them to delay and possibly be pushed by others from behind. Volunteers therefore chose to feel their way through the cabin and listen to instructions from the cabin staff regarding the exit which was to be used, rather than take advantage of the floor proximity lighting.

The behaviour of the volunteers during the evacuations was calm and orderly, and in many respects similar to the behaviour observed during aircraft certification evacuation drills and the Cranfield non-competitive evacuations. (Ref 1.) There were no instances of passengers pushing or competing to pass through the exits to escape from the smoke filled cabin.

5 CONCLUSIONS

1. The experimental programme successfully met the objective to produce a series of evacuations in order to explore the influence of (a) increasing the width of the aperture in the bulkhead at the entrance to the galley vestibule leading to the Type I exits and (b) increasing the distance between seat rows next to the Type III overwing exit when passengers vision was impaired by the presence of smoke in the cabin.

2. The results suggested that increasing the width of the aperture through the bulkhead will lead to an increase in the speed at which passengers can evacuate the aircraft in conditions of reduced visibility, as long as there is a bulkhead present in front of the exit. Removal of the port galley unit significantly reduces the rate of evacuation when smoke is present in the cabin.

3. The initial results from the evacuations through the Type III overwing exit, suggested that changes to the distances between the seat rows either side of the

exit may influence the speed of the evacuation in conditions of reduced visibility. Further evacuations are recommended in order to obtain statistical confirmation of this result.

4 In reduced visibility, the CAA minimum (in AN 79) in which the outboard seat was removed, and with a 6″ vertical projection between the seat rows, appears to give rise to a slower evacuation flow rate than either the alternate CAA minimum (in AN 79) involving a 13″ vertical projection, or an 18″ vertical projection between the seats. This finding will require additional evacuation tests in order to obtain a statistically reliable result.

5 The presence of non-toxic smoke in the cabin significantly reduced the rate at which volunteers in an orderly situation were able to evacuate the aircraft.

6 Further investigations are recommended to study the influence of (i) the seating configuration on the ease of operating the exit and (ii) the positioning of the hatch in the cabin on the evacuation rate, when smoke is present in the cabin.

7 The use of non-toxic smoke in order to produce conditions of reduced visibility has been shown to have the potential to provide some of the data required for the assessment of design options and safety procedures for use in emergency evacuations.

8 In order to reproduce a simulated emergency evacuation in which the orderly pattern of egress has been broken down, as frequently happens when toxic smoke fills the cabin, consideration could be given to a programme of emergency evacuations involving non-toxic smoke with the introduction of bonus payments to the first 75% of volunteers evacuating the aircraft.

6 CONTRIBUTORS TO THE RESEARCH

1 The programme was initiated and funded by the UK Civil Aviation Authority.

2 Dr H Muir, from the Applied Psychology Unit, was responsible for the management of the project.

3 Ms C Marrison, from the Applied Psychology Unit, was responsible for the majority of the implementation of the evacuation programme and analysis of the experimental data.

4 Ms A Evans, from the Applied Psychology Unit provided assistance with the collection and analysis of the data.

5 Mr F Taylor, of the College of Aeronautics, was responsible for the management of the changes to the structure of the cabin and the aircraft seating.

6 The support of the Applied Psychology Unit and other members of the College of Aeronautics and the Airfield Fire Service should also be acknowledged.

7 The professional services of the Doctors from Asplands Surgery are gratefully acknowledged.

8 Cranfield Institute wish to express their thanks to Mr R Small, owner of the Trident Aircraft used for the evacuations and to the many volunteers who took part in the experiment.

7 REFERENCES

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2 Airworthiness Notice No. 79, *'Access to and Opening of Type III and Type IV Emergency Exits'* published by the Civil Aviation Authority, 1986.

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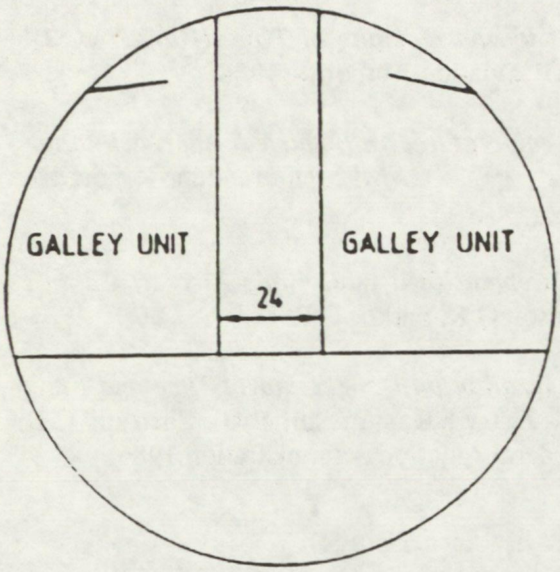
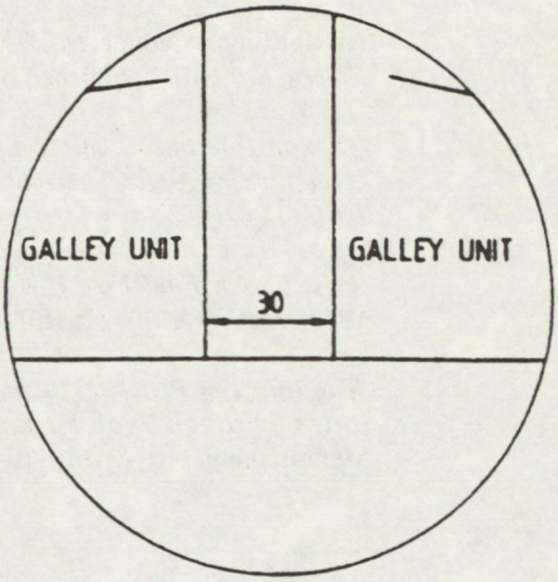
5 *'The Effect of Proximal Seating Configuration on Door Removal Time and Flow Rates Through Type III Emergency Exits'*. Rasmussen P G, Chittum C B. Memorandum No. AAM–119–86–8 Federal Aviation Administration 1986.

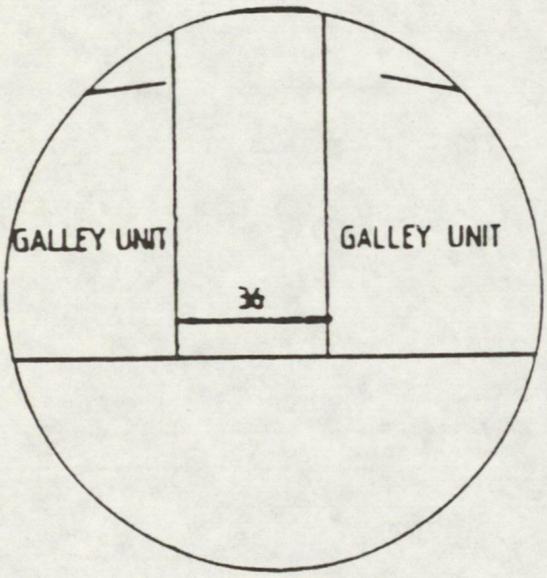
APPENDIX A



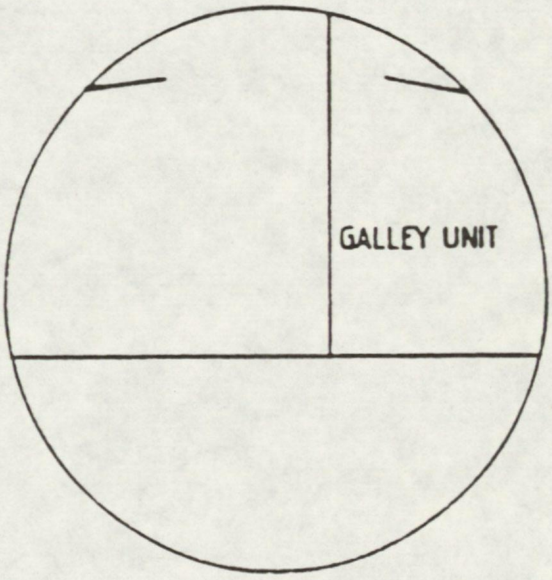
Width between the galley units
= 24 inches



Width between the galley units
= 30 inches



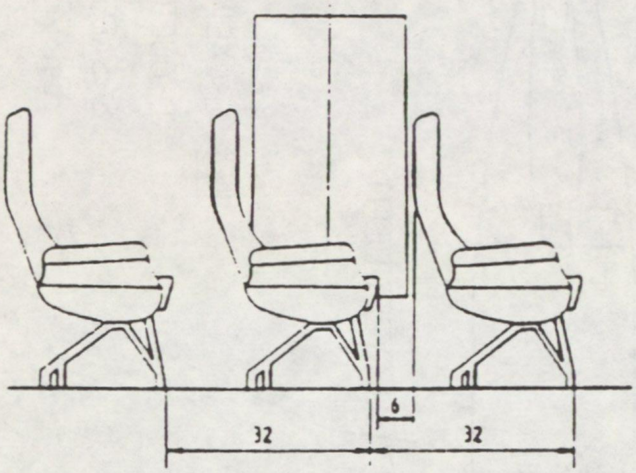
Width between the galley units
= 36 inches



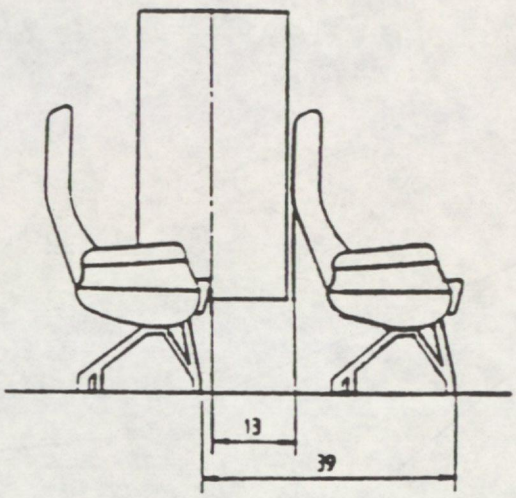
Port galley unit removed

APPENDIX B

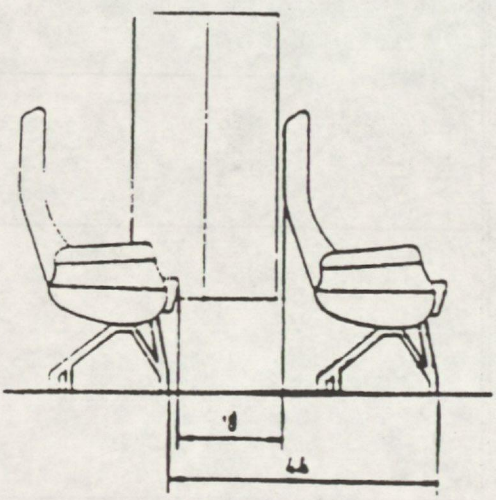
For all configurations the seat backs remained in a locked position.



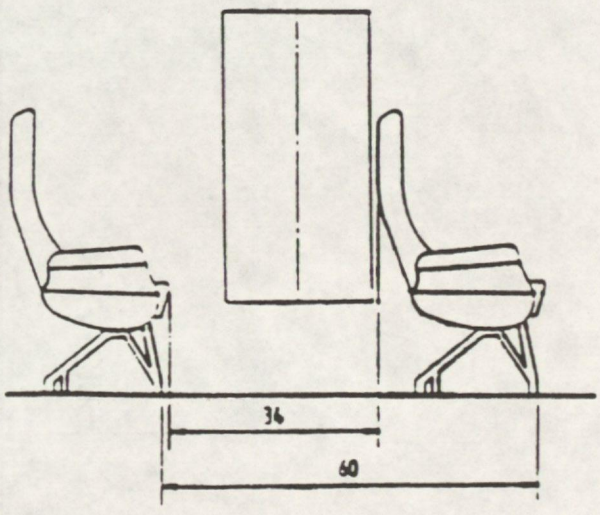
Configuration (i) Seat pitch – 32 inches
Vertical projection – 6 inches
Equivalent to An 79 requirements
with outboard seat removed



Configuration (ii) Seat pitch – 39 inches
Vertical projection – 13 inches
Equivalent to An 79 requirements

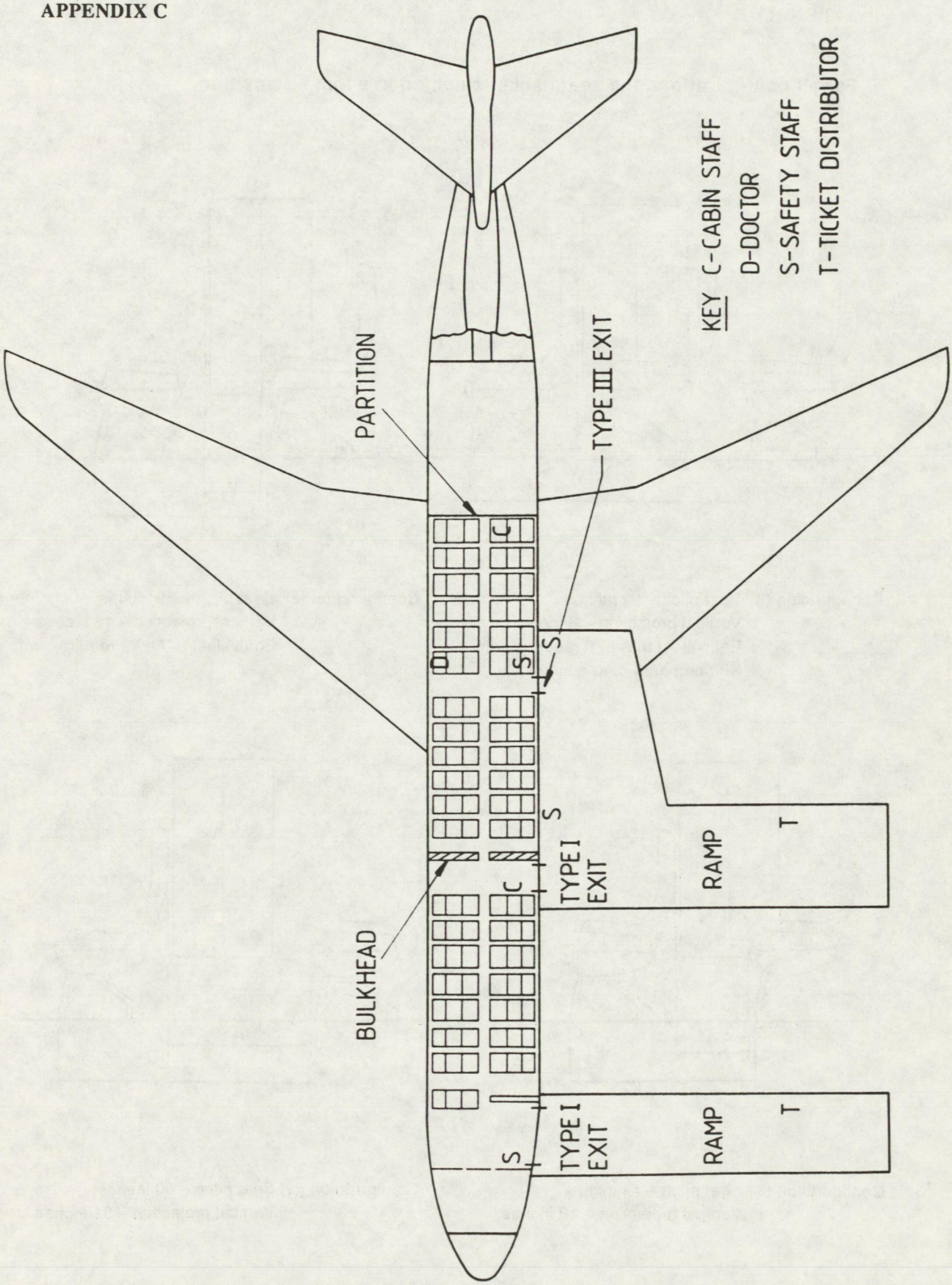


Configuration (iii) Seat pitch – 44 inches
Vertical projection – 18 inches



Configuration (iv) Seat pitch – 60 inches
Vertical projection – 34 inches

APPENDIX C


PARTITION
TYPE III EXIT
KEY C-CABIN STAFF
D-DOCTOR
S-SAFETY STAFF
T-TICKET DISTRIBUTOR
C
D
S
S
S
C
BULKHEAD
TYPE I EXIT
RAMP
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APPENDIX D

Evacuations through the Bulkhead Aperture
Post hoc comparison at the 0.05 level (Newman-Keuls)

Bulkhead Aperture	24″	30″	36″	PGR
24″				
30″				
36″				
PGR	*	*	*	

PGR = Port galley removed