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THE DESIGN AND EVALUATION OF AN IMPROVEMENT TO THE TYPE III EXIT OPERATING MECHANISM

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THE DESIGN AND EVALUATION OF AN IMPROVEMENT TO THE TYPE III EXIT OPERATING MECHANISM

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Abstract

In 1994 the UK Civil Aviation Authority (CAA) commissioned the Department of Aerospace Technology at Cranfield University to investigate the operating mechanism of Type III exits in order to consider ways of improving the ease of operation and hence the speed at which these types of exits could be made available. A concept study was first carried out, considering methods by which support and constraint of motion of the hatch could be provided. Following assessment of a range of possibilities, a single concept was chosen and developed to show its engineering practicality for application to the Type III exit locations of both narrow and wide-bodied aircraft. An operational prototype of this concept was then constructed using the Type III exit location in the Cranfield Cabin simulator.

Following the construction of the exit prototype the CAA commissioned the Department of Applied Psychology at Cranfield University to conduct a programme of tests to determine the influence of the modified operating mechanism on the ease with which members of the public were able to open the exit and evacuate through the aperture. An assessment was also made of the influence of changes to the seating configuration adjacent to the exit on the ability to operate the Type III exit, using both the conventional design and the modified operating mechanism. The seating configurations tested involved the two options specified in the Airworthiness Notice No 79 (Ref. 1). One involved a thirteen inch vertical projection passageway between seat rows adjacent to the exit and the other two six inch vertical projection passageways between the seat rows combined with the removal of the outboard seat. The tests involving the thirteen inch vertical projection passageway between the seat rows also included a 50th percentile male dummy seated adjacent to the exit in order to simulate the presence of an incapacitated passenger.

The tests were conducted in a narrow-bodied cabin simulator. The test protocol involved a standard pre-flight briefing procedure followed by a simulated emergency at the end of which the participants were given the evacuation command. The participants were directed to immediately open the exit and evacuated onto the wing. Ninety six participants (48 males and 48 females) from the lower 50th percentile of the population took part in the test programme. Participants were required to operate the exit on three separate occasions in order to assess the influence of practice on the ability of members of the public. The performance of participants was documented using video cameras with internal time bases and questionnaires.

The research demonstrated the feasibility of improvements to the Type III exit design. Comparative tests between the conventional Type III exit and the modified Type III exit proved that the modified exit provided a significant reduction in the amount of time to make the exit available.

Contents

ABBREVIATIONS AND DEFINITIONS

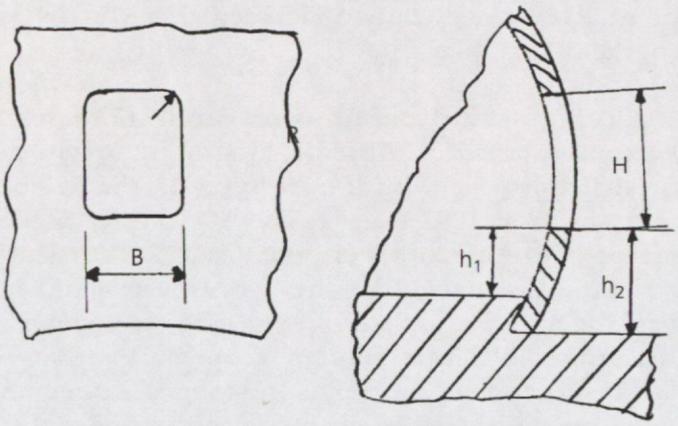
BAe	British Aerospace
CAA	Civil Aviation Authority
CAD	Computer Aided Design

For the purposes of this report, the following definitions apply:

'aperture'	the hole in the aircraft fuselage side made available by opening the exit
'hatch'	the physical item moved to reveal the aperture of the exit
'exit'	the aperture, hatch and any additional items directly connected to operation of the exit

1 INTRODUCTION

Type III exits are used on a large range of sizes and types of civil aircraft. They differ from airframe main doors in not being supported or having their motion constrained by a mechanism. The dimensions of these exits and restrictions are given in Figure 1 and a simplified representation of their operation is shown in Figure 2.



B (min) 508 mm (20 in)

H (min) 915 mm (36 in)

R (max) ⅓ B

h_1 (max) 508 mm (20 in)

h_2 (max) 686 mm (27 in)

Figure 1 Type III exit dimensions

Figure 2 Simplified representation of the operation of a conventional Type III exit

Once released from the aperture, the weight of the exit hatch must be supported by the person operating the exit who should then rotate the hatch and jettison it through the opening. This method of operation has a number of possible disadvantages in an emergency situation. Firstly the hatch can be very heavy, for example 30.4kg (67 lbs) on a specific wide-bodied aircraft. Added to this there is limited space between seats and other obstructions, contrary to the impression given by Figure 2, a situation potentially made worse by passengers crowding into the space available to escape through the opening. Finally, the operation of the exit is not common in everyday life. This is compounded by the fact that the operator is a passenger not a member of the cabin crew, as would normally be the case for larger exits, and passengers, unlike cabin crew, do not have the benefit of training.

CAA Publication CAP 360, Part One, Chapter 6 page 6/19 Paragraph 3.1 (ref. 3) requires that for Type III exit seat rows 'Seats which form the access route from the cabin aisle to these exits should only be allocated to passengers who appear capable of operating and/or assisting with the operation of the exit'. According to this requirement, passengers may not occupy these seats if they are persons of reduced mobility, children or infants, frail, elderly or obese, deportees or prisoners in custody, as they may in an emergency evacuation cause a delay or obstruction. Unfortunately, these requirements do not guarantee the speedy operation of these exits, passengers may fail to make the exit available quickly due to incapacitation from physical injuries or as a result of psychological trauma (Ref. 2).

Evidence from aircraft accidents and previous research indicates that many passengers do in fact experience great difficulty operating a Type III exit and evacuating through the exit onto the wing for example in the accidents which occurred at King Salmon, Alaska in 1982 (Ref. 4) and Manchester in 1985 (Ref. 5) passengers seated adjacent to these exits were confused and unclear about the method of operation. In the Alaska accident the overwing exit did not become operational until the passengers were assisted by the aircraft commander. In the Manchester accident a passenger initially attempted to operate the exit by using the armrest on the exit hatch. Subsequently the person sat next to her operated the release handle trapping the person seated adjacent to the exit under the exit hatch. The man behind her had to then manoeuvre the hatch and place it on a seat in his row. These delays led to the exit not being fully operational until 45 seconds after the aircraft came to a halt.

Work by Fennell & Muir 1993, (also commissioned by the CAA (Ref. 6)) on the influence of hatch weight and seating configuration on the operation of a Type III exit, illustrated the difficulties that members of the public can experience when operating this type of exit. Indeed some participants in this experiment took over 50 seconds to operate the exit and evacuate onto the wing. This research also highlighted the difficulty some passengers experience with the correct disposal of the hatch (many participants left it inside the aircraft, thus potentially causing an obstruction).

The recognition of these problems led the CAA to commission work from the Department of Aerospace Technology at Cranfield University, to investigate ways of improving the operation of the Type III exit. Following the selection of a preferred design and the development of this new concept as an operational prototype in the Cranfield Boeing 737 cabin simulator, the Department of Applied Psychology at Cranfield University, was commissioned by the CAA to conduct a programme of tests in order that an assessment could be made of the potential benefits of the modified operating mechanism.

2 OBJECTIVES

The objectives of the design phase of work were as follows:

(i) To identify and develop feasible concepts for the support and constraint of the motion of hatches of Type III dimensions.

(ii) To demonstrate, through a simplified full-scale prototype, the concept selected as most suitable.

It should be noted that at the outset the demonstration prototype was only intended to be very basic, simulating only the motion and not for use in evacuation trials.

The objectives of the experimental test phase were as follows:

(i) To compare ease of operational performance of the modified Type III exit with the conventional Type III exit with current seating configurations around the exit

(ii) To study the effects of test participants practice on their ability to operate either of the Type III exits

3 TYPE III EXIT OPERATING MECHANISM DESIGN PHASE

3.1 Concept generation and selection

A sensible step in any design process is consideration of designs for the same or similar applications which already exist. Thus, present methods of motion and support of exits on aircraft were surveyed. In practice these are quite limited, if consideration is restricted to exits that must be available in emergency situations for egress. However, other doors on aircraft, such as those for cargo and baggage, use further methods of support, motion and latching which are acceptable due to their not being required to be made available during emergencies.

Simply restricting the study to existing concepts was not thought acceptable. Therefore, a whole range of concepts for the basic motion(s) of the Type III hatch were generated, beginning with the simplest translations/rotations and progressing through combinations of these to novel or unusual concepts.

In all some 22 basic concepts were identified for the motion along with support and actuation methods. This number of concepts was too large to consider each in detail within the limitations of the study. However, by consideration of the basic advantages and disadvantages of each and their ability to meet selection criteria below, as required by CAA, it was possible to select a short list of concepts for motion of the exit. The selection criteria were as follows:

(a) Must meet all current regulations in particular FAR/JAR 25.783, 25.809 as well as all relevant ACJs and AMJs.

(b) Must not result in reduction of the number of passenger seats in the aircraft.

(c) Must not become an internal loose item when opened.

(d) Must meet crashworthiness requirements (JAR 25.783).

(e) Operation must not be affect by icing.

(f) Must be simple and obvious to operate.

(g) Operation must be achieved with a minimum of effort.

(h) Ideally, the exit should only have one possible method of operation.

(i) Must be operable from both inside and outside the aircraft.

(j) There must be an indication of the latch state.

(k) There must be potential for easy retrofit to existing aircraft.

It was also stressed that the exit hatch must be positively closed by internal cabin pressure, requiring a 'plug' type closure with the first motion inwards and not relying on latches to withstand pressure loads. This criterion was to retain the structural integrity benefit of the conventional Type III exit design.

In addition, other factors to be taken into account were;

(i) Complexity of support, sealing and actuation.

(ii) Alterations to exit hatch and/or aperture structure.

(iii) Requirements for maintenance.

(iv) Any increase in drag through external protrusions.

(v) Needs for stored energy devices.

(vi) Possibility of retaining a window in the exit hatch.

(vii) Possibility of use of exit in non-emergency situations e.g. during maintenance.

Details of the procedure used to arrive at a short-list of concepts are provided in Appendix A.

The five concepts shown in Figure 3 were short-listed for more detailed consideration in terms of consequences of their application to the Type III exit locations in versions of the Boeing 767. This aircraft was chosen due to the large mass of the present exit 30.4 kg (67 lbs), which was used as an example for this evaluation, and the close proximity of Cranfield to an operator of such aircraft. Appendix B provides further details of the consideration of the five concepts.

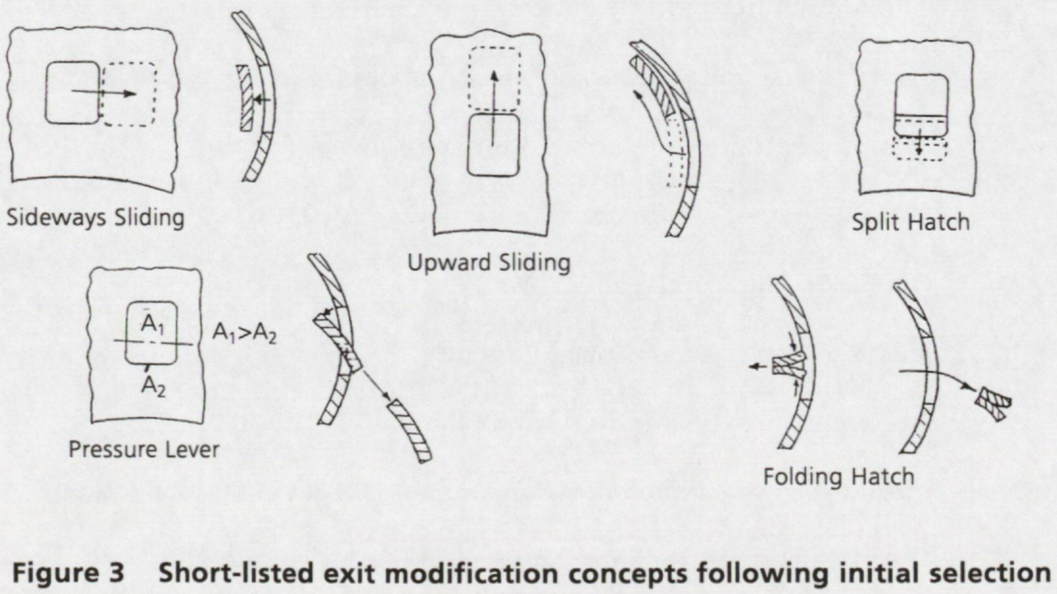


Figure 3 Short-listed exit modification concepts following initial selection

The sideways sliding concept, shown in Figure 3 was found to be likely to cause loss of seats, particularly with the twin Type III exit configuration. Split exit hatch and folding exit hatch concepts, although in theory possible, were found to be complex and not user-friendly. Therefore, the 'upward sliding' and 'pressure lever' concepts in Figure 3 were selected for consideration in terms of design detail. In addition, CAA specified that the concept of motion used on Type I emergency exits present on some Boeing 757 and 767 aircraft (Door 3) Fig 3A, and previously eliminated, should be again considered.

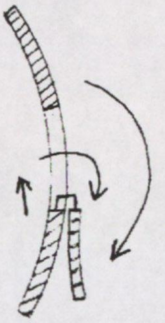


Figure 3A Additional concept

From the final short-list of three concepts the 'pressure lever' concept was seen as having significant potential for application to new aircraft. As it would sensibly require alteration to the present fuselage aperture shape, implying significant expense in a retrofit application, it was seen as less desirable under the selection criteria for this study. In addition, development of seal designs for the exit were required. The concept based on present Type I exits, where the exit hatch moves in then up and drops out (eg Boeing 757 door 3), rotating about the lower sill, was also found to be difficult and/or costly to apply in a retrofit application. Position of the exit hatch outside the fuselage in an over-wing location was also found to be a problem.

As a result of the above, the inward then upward sliding exit concept was finally selected as the most suitable. In fact, this concept is used on the main doors of wide bodied aircraft such as the Boeing 767 and even older aircraft such as the Hawker Siddeley Trident. Due to the need to raise the doors, power and/or counterbalancing is required and has been provided by a range of methods from bungee to electric or hydraulic motors.

Because the hatch in a Type III application would only initially need to move inwards at the top before sliding up into the overhead region, there is no problem with interference with seats. However, the concept does imply some loss of overhead bin space for the exit hatch and tracking to pass through the area.

Further details of the considerations leading to final concept selection are presented in Appendix C.

3.2 Selected concept development and demonstration

Having selected a single concept, development work was then undertaken using hand drawings, computer modelling and finally a full scale prototype in the cabin simulator at Cranfield to prove its practicality. Initially the design work was based on the Boeing 767 Type III exit location. The cabin simulator was configured to represent a Boeing 737, thus, work progressed to this application for the experimental prototype.

Using information on the Boeing 767 dimensions, the Engineering Unit of the College of Aeronautics produced a scheme for motion and support of exit hatch in this application. Figure 4 outlines this scheme showing the exit hatch in closed, transitory and fully open locations.

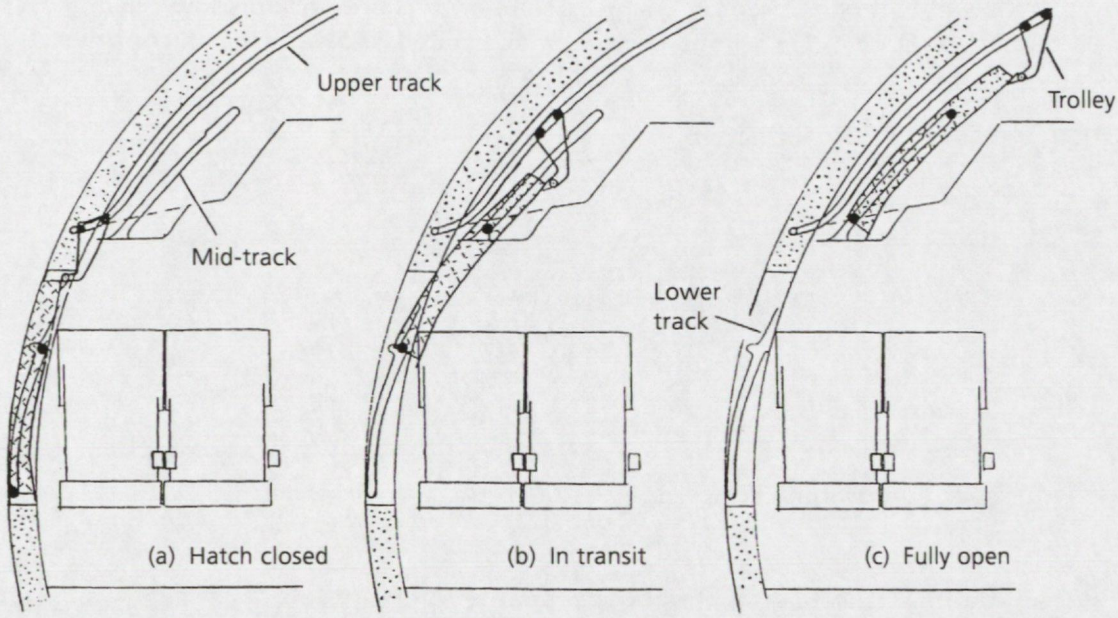


Figure 4 Proposal for improved Type III exit in a Boeing 767 application

The hatch is supported at the upper end by a trolley running on tracks in the overhead roof space whilst its lower end is initially supported by rollers in lower tracks at the sides of the aperture. To limit incursions into the cabin these lower tracks do not support the exit hatch for the later part of its travel. Thus, mid-tracks which engage rollers around the centre of the exit hatch are required. Assistance in lifting the exit hatch is provided by a cable, attached to the trolley, being pulled by a spring mounted in the overhead space.

A possible concern was noted in that the hatch could interfere with the shoulder and/or head of a passenger located in the seat next to the exit. To investigate this and optimise track positions the CATIA Computer Aided Design (CAD) system was used to build a 3-dimensional model including seats and a simple representation of a large passenger. As a result, the clash of exit hatch and passenger was found only to be significant in a rather unusual position of the passenger, neither sitting up-right nor fully slumped forward.

Having shown a feasible scheme for the Boeing 767, interest then moved to the Boeing 737 to which it was hoped that the Boeing 767 scheme could simply be transferred. Unfortunately, this was not entirely the case. Whilst the method of assistance in lifting and the use of a trolley attached to the upper centre of the exit hatch was possible, it was not sensibly possible to use the same system of support for the lower end of the exit hatch. To overcome this problem the lower tracks were continued up into the overhead space, to support the exit hatch through its full travel. However, when not in use, the tracks are held up against the inside of the fuselage structure. Only when the exit hatch is released from the aperture do they rotate out to allow the exit hatch to clear structure above the aperture.

The College of Aeronautics Engineering Unit produced a design scheme, on which Figure 5 is based, and a CATIA model was used to investigate clashes with passengers and fuselage structure and systems. In this case a further complication arose due to the fact that, whilst the Cranfield cabin simulator is configured to represent Boeing narrow-bodied aircraft such as the B737, its dimensions do not exactly match these and the structure is different. Thus, although initial modelling was based on true Boeing 737 installation, it had to be modified to the dimensions of the cabin simulator and its structure.

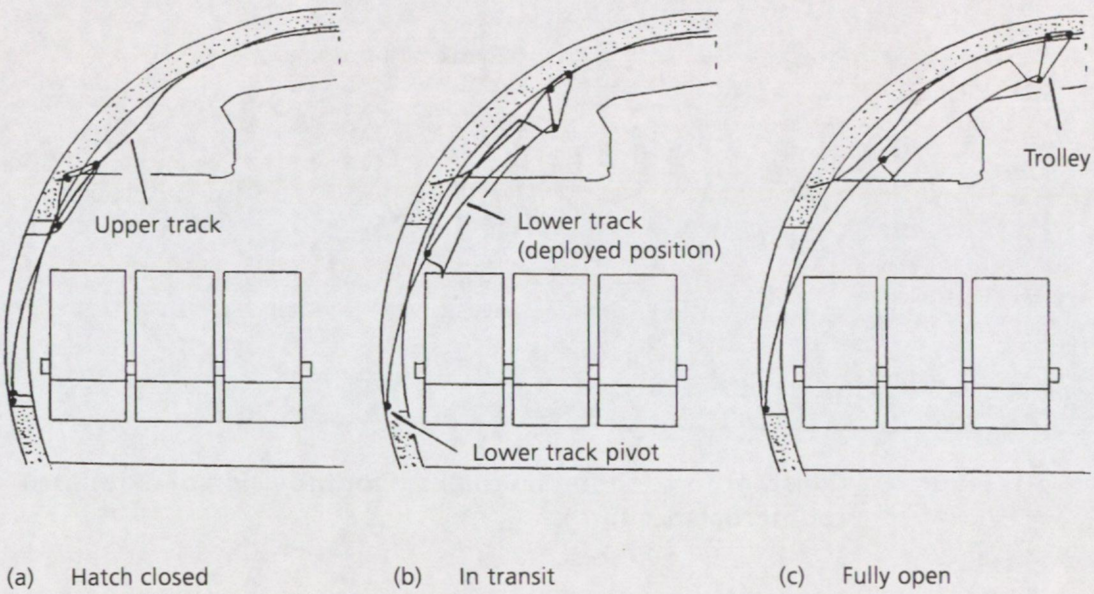


Figure 5 Proposal for improved Type III exit in a Boeing 737 application

A full design for an experimental prototype in the cabin simulator was produced by the Engineering Unit on a second CAD system, AUTOCAD, which produced most of the manufacturing and assembly drawings directly.

It should be noted that by this stage the objectives of the experimental prototype had been increased beyond the original intent of simply demonstrating motion. As the real proof of the concept would be in its ability to provide exit availability more quickly and easily than the conventional Type III exit, it was clear that the prototype should be useable at least in ease of operation trials if not evacuation trials. However, the limits of the first phase of work required that the design had to be produced in a very cost effective fashion and not attempt to use techniques suitable for a true aircraft installation. Therefore, the initial prototype was produced by using the cabin simulator's original Type III exit hatch, stripped down to minimum weight, with simply addition of tracks, rollers, upper support trolley and an assistance device based on a constant force spring.

Provision of a device to assist in raising the door based on a bungee was initially thought to be the most cost effective and simplest approach but the length required and its strength was found to pose a possible safety hazard in the cabin simulator. The spring assistance mechanism is shown in Figure 6 and provides an almost constant output force through the length of the cable's travel. It was decided that the assistance provided should be just less than the pull of the exit hatch, due to its weight, when just released from the aperture. This required that the door be assisted up in its initial motion but once moving it continued to the end of its travel.

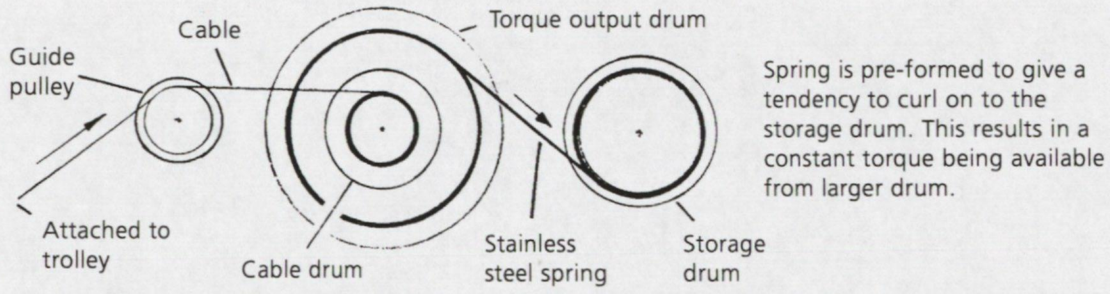


Figure 6 Constant force spring mechanism for provision of exit hatch counterbalance force

Initially the installation was not trimmed nor was there a latching mechanism and handles to release the exit hatch. Whilst the objectives of the initial phase of work had been fulfilled, enhancements were necessary to use the installation in trials.

The installation was tidied-up and trim added where it could simply be placed. The exit hatch mass was increased to 21.5 kg (47.4lbs), which is comparable with in-service Boeing 737s, and this required installation of a second constant force spring to the assistance mechanism, to counter the extra weight. A more difficult design decision concerned the placement of the release handle.

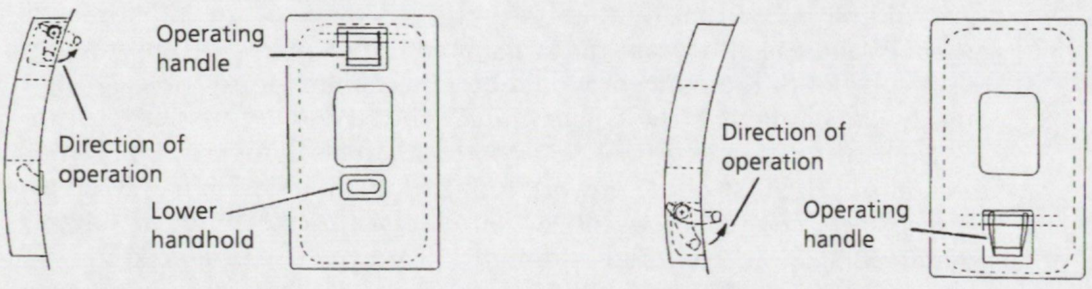


Figure 7 Alternative handle/handhold configurations tested in preliminary operation trials

Two handle positions, as shown in Figure 7, were assessed in preliminary operation trials. Whilst there appeared little difference in operation times, subjects found the option with release handle below the window easier to use. Thus, this configuration was used along with a very simple latching mechanism as shown in Figure 8. At this stage the mock-up was considered ready for full scale operation trials.

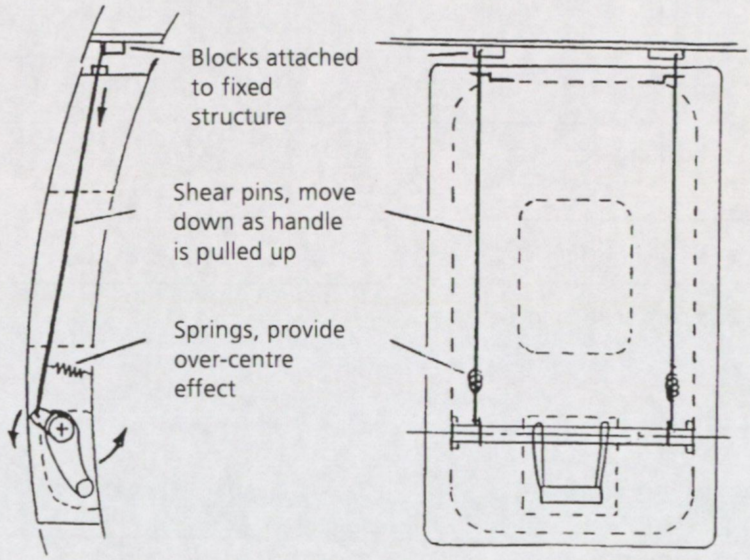


Figure 8 Release mechanism for handle configuration adopted for main operation trials

4 COMPARATIVE TESTING OF THE CONVENTIONAL AND THE MODIFIED EXIT

4.1 Research Design

The operation of the modified exit was investigated and compared with the conventional exit. Members of the public were recruited to take part in a research programme in which each participant was required to operate a Type III exit on three occasions. Half of the participants operated the exit with the conventional mechanism and half operated the exit with the modified mechanism. All of the participants operated the Type III exit on three occasions. The influence of changes to the seating configuration adjacent to the exit on the ability to operate the exit using both the conventional and modified Type III exits was also assessed. The seating configurations tested involved the two options specified in the Airworthiness Notice No 79 (Ref. 1). One used a thirteen inch vertical projection passageway between the seat rows adjacent to the exit and the other two six inch vertical projection passageways between the seat rows combined with the removal of the outboard seat. The tests involving the thirteen inch vertical projection passageway between the seat rows were repeated with a 50th percentile male dummy, simulating a incapacitated passenger unable to operate the exit. During the test the hatch weight was kept constant at 21.5kg (47.4lb) (similar to a Boeing 737 hatch).

In Table 1 the number of participants in each of the experimental conditions are shown. A total of 96 participants took part (48 operating the modified exit and 48 operating the conventional exit) with equal numbers of left and right handed males and females in each test configuration.

Table 1: The numbers of participants in each of the experimental test conditions

Seating Configuration	*Modified Type III exit design*				*Conventional Type III exit design*			
	Left handed		*Right handed*		*Left handed*		*Right handed*	
	M	*F*	*M*	*F*	*M*	*F*	*M*	*F*
13" Vertical projection	4	4	4	4	4	4	4	4
13" Vertical projection – Dummy	4	4	4	4	4	4	4	4
OSR 6" vertical projection	4	4	4	4	4	4	4	4

OSR = Outboard seat removed

4.2 Equipment

4.2.1 *The cabin mock-up*

The experimental tests took place on board the single-aisle cabin simulator in the College of Aeronautics at Cranfield. Ten rows of triple seats were located on both sides of the cabin fuselage. A fully functioning Type III exit of either the modified or conventional design was fitted half way down the side of the fuselage(see Appendix D for modified exit details). The seat rows adjacent to the Type III exit were arranged in accordance with AN79 1989 (Ref. 1), either paragraph 4.1.1 or 4.1.2 (see Appendix E for diagrams) which state respectively that:

'Where all forward facing or all aft facing seats are arranged such that there is a single access route between seat rows from the aisle to a Type III exit, the access shall be of sufficient width and be 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 seat rows vertically projected, shall not be less than half the exit hatch width including any trim, or 10 inches, whichever is greater.'

and

'Seats may only be located beyond the centre line of a Type III exit provided there is 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 aircraft cabin simulator, when there were rows of triple seats forming the exit aisle the seats fore and aft of the Type III exit were at a seat pitch of approximately 38 inches (97 cm) with a vertical projection between the seats of 13 inches (33 cm) This vertical projection was used so the exit seat row did not extend beyond the exit centre line thus complying with paragraph 4.1.1 in AN79 (see Appendix E). When the outboard seat removed configuration was used the seats fore and aft of the Type III exit were at a seat pitch of approximately 29 inches (78 cm) with a vertical projection of 6 inches (15 cm). The seat back of each seat which formed the boundary of the access route to the Type III exit was restricted in its movement in accordance with AN79 1989 paragraph 4.3 (Ref. 1).

Figure 9 The cabin simulator

4.2.2 *The Type III exits*

The dimensions of both the modified and conventional Type III exit hatch in the cabin simulator were representative of those on a narrow-bodied aircraft. The vertical step-up from the floor to the bottom of each exit inside the cabin was 13.5 inches (34.4cms), identical to that of a Boeing 737 aircraft. The step-down height from the bottom of each door onto the wing was 15 inches (38cms) which although identical to a Boeing 737, is considerably less than the maximum 23 inches (58.5cms) allowed (Ref. 7).

The handle mechanism of the conventional Type III exit operated in the standard manner. In accordance with the Type III exit operating instruction requirements (Ref. 8), the word 'PULL' was written in white on this handle mechanism. Additionally, at the top of the exit there was a red arrow pointing downwards on either side of the handle. The handle mechanism and operating instructions for the modified Type III exit had 'PULL' written in white on the operating handle and red arrows either side of the handle.

In accordance with AN79 requirements, safety placards illustrating the operating method for the conventional and modified Type III exits were located on the back of each seat in the row forming the access to the exit. The illustration depicting the operating method of the conventional exit was based on those currently used on Boeing 737 aircraft. A new safety placard was designed for use with the modified Type III exit design (both of these can be found in Appendix F).

4.3 *Data Acquisition*

Video cameras were located inside and outside the cabin, in order to record the manner in which participants opened and disposed of the Type III hatch. The cameras were fitted with a time base function and microphones to provide the information required for the data analysis.

A short questionnaire was used to identify any problems experienced by participants when opening the exit and evacuating onto the wing. In this questionnaire participants were asked to assess the ease with which they considered they were able to open the exit and evacuate from the cabin and to indicate the nature of any difficulties experienced in completing the task (see Appendix G).

As all the participants operated a Type III exit three times, a shortened version of the questionnaire was completed by participants after the second and third time they operated the exit. In the shortened version of the questionnaire, participants were asked if their experience in operating the exit in the first and second tests affected the manner in which they subsequently operated the exit.

4.4 **Participants**

A total of 96 participants took part in the study, 48 in each phase. Exactly equal numbers of left and right handed males and females operated each design of Type III exit. The participants were recruited by campus advertising and through the use of the Department of Applied Psychology's participant database. In order for the participants to be representative of those individuals in the population who were expected to encounter most difficulties in completing the task, the maximum height and weight of participants recruited for these tests was decided using the criteria for fiftieth percentile UK males and females, as indicated in Table 2. None of the participants had previously operated a Type III exit.

Table 2: Fiftieth percentile height and weight for males and females

	50th Percentile Height	*50th Percentile Weight*
Males	175cm	70kg
Females	161cm	64kg

4.5 **Procedure**

The 48 male and 48 female participants were each assigned to one of the experimental conditions in Table 1, such that there were eight males and eight females in each. A member of the research team, trained and dressed as a cabin crew member, briefed each participant about the nature of the test upon his/her arrival at the College of Aeronautics. In order to maximise the realism, the participants were not told about the precise nature of the test but were forewarned that they might be required to lift a weight equivalent to that of a heavy suitcase (potential participants with health problems were screened out during recruitment). Participants were then asked to complete a consent form indicating that they understood the general nature of the study and that they believed they were physically able to take part in the test.

In the experimental conditions when a dummy was not present, the participant was sat in the seat adjacent to the Type III exit. In the experimental conditions when the dummy was present, the dummy was positioned, with the seat belt fastened, in the seat adjacent to the Type III exit and the participant sat next to the dummy (see Appendix E).

Once seated inside the cabin, each participant was given an abbreviated pre-flight safety briefing by a member of the research team (a transcript of this can be found in Appendix H). The safety briefing included a demonstration of the method of operation of the seat belt and oxygen mask, as well as the location of the Type III and other exits. This briefing also drew the participants attention to the safety briefing card situated in seat pocket of the seat in front of them. In accordance with recommended procedure in CAP 360, Part One, Chapter 6 Page 6/21 Paragraph 1.3 (Ref. 9) the following statement was used 'I would like to draw your attention to the fact that you are sat by an emergency exit, should there be an emergency you would be expected to operate this exit. Instructions showing the method of operation can be found on the safety briefing card in the seat pocket in front of you and on the safety placard on the back of the seat, here'.

The member of the research team then checked that the participant's seat belt was fastened securely and positioned him/herself at the rear of the cabin. The participants heard one of three different engine noise scenarios (see Appendix I), before being issued with the instruction to *'Undo your seat belt and get out'*. If the participants were hesitant in moving towards the exit (that is, if they had not begun to open the exit after five seconds) the researcher shouted the instruction 'Overwing exit' in order to hurry the participant. The test continued until the participant had successfully opened the Type III exit and evacuated onto the wing, or had given up on the task voluntarily. After this first test had been completed each participant was asked to fill in a short questionnaire in order to identify any problems they had experienced in carrying out the task.

The test procedure was then repeated twice more with each participant. On each occasion the participant was given a modified pre-flight safety briefing and seated in the same position as before. A different engine noise scenario was used with each trial in order that participants did not anticipate the call to evacuate. After completing the third test and questionnaire the participant was debriefed and thanked for taking part in the test, before being paid his/her attendance fee.

5 RESULTS

5.1 Individual characteristics of the participants

5.1.1 *Modified Type III exit*

The mean age of all of the participants was 33.85 years; 34.67 years for males (with ages ranging between 20 and 48 years) and 33 years for females (with ages ranging between 20 and 48 years). The male participants had a mean height and weight of 172.29cm and 69.17kg. The female participants had a mean height and weight of 160.70cm and 59.46kg respectively. The median frequency of exercise for males and females was once or twice a week. All but three participants had previously flown on an aircraft before and the median category on the questionnaire for total number of return flights taken by the participants was 6-10 flights.

5.1.2 *Conventional Type III exit*

The mean age of all of the participants was 31.17 years; 31.08 years for males (with ages ranging between 21 and 49 years) and 31.25 years for females (with ages ranging between 20 and 48 years). The male participants had a mean height and weight of 173.58cm and 71.67kg. The female participants had a mean height and weight of 161.83cm and 59.13kg respectively. The median frequency of exercise for males and females was once or twice a week. All but three participants had previously flown on an aircraft before and the median category on the questionnaire for total number of return flights taken by the participants was 11-15 flights.

There were no significant differences between the age, height, weight and frequency of exercise taken by participants in the two types of exit mechanisms.

5.2 **The operation of the Type III exit**

The participant's times to evacuate were obtained from the video recordings. The camera's internal time base and audio recordings provided information on the time it took for each evacuation and the way in which the participant opened and disposed of the Type III hatch. The evacuation time was calculated from the point at which the participant's hand touched the operating handle, to when he or she had put one foot onto the wing. This particular starting point was taken so that any variation in the delay of participants responding to the call to evacuate was not included in the analysis. The mean reaction time of participants to respond to the call to evacuate (from the call 'Undo your seat belt and get out' to when their hand was on the operating handle) was 4.94 seconds for the conventional Type III exit and 4.14 seconds for the modified exit.

5.2.1 *The influence of the Type III exit operation mechanism*

The mean times taken by participants to open the modified and conventional Type III exits in the first test conducted by each participant in the three test configurations are shown in Table 3. This is graphically represented in Figure 2. The raw data giving demographic details for each participant and the times taken by each participant to operate the Type III exit in each of the three tests they performed can be found in Appendix J. The data from the previous Type III exit operation research carried out at Cranfield University (Ref. 6) involving the conventional Type III exit is also included in Table 3.

The mean times taken by participants to operate the Type III exit, in all of the conditions in the recent research were consistently quicker than those recorded in the previous testing (Ref. 6). A number of factors could have contributed to these differences, they include improved Type III exit operation diagrams and alterations in the cabin simulator improving realism. The data from the previous test programme is not included in the subsequent analyses.

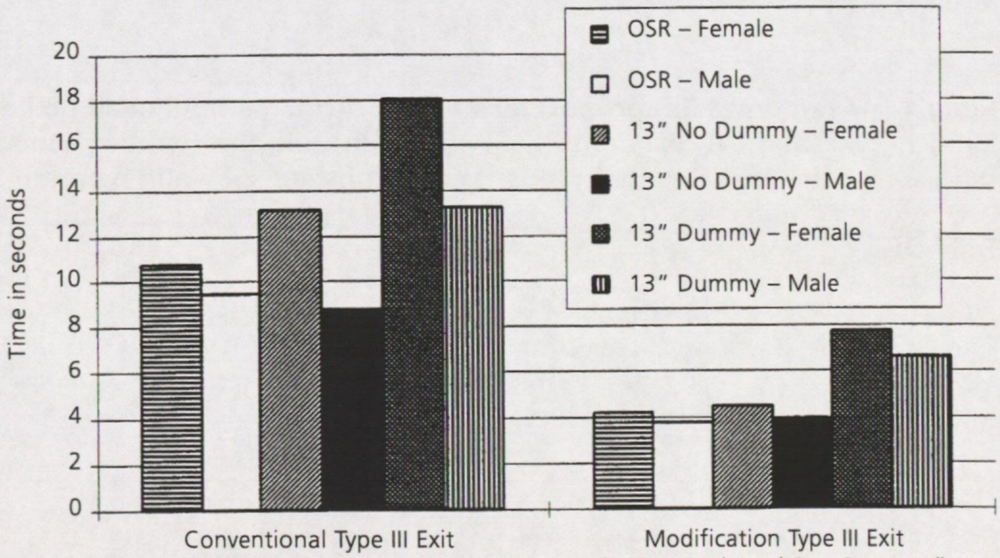
Table 3 Mean times (in seconds) taken by participants from hand on handle to exit and evacuate onto the wing (standard deviations are shown in parentheses)

TEST ONE

	Outboard seat removed 6" Vertical Projection		*13" Vertical Projection No Dummy Present*		*13" Vertical Projection Dummy Present*	
	Female	*Male*	*Female*	*Male*	*Female*	*Male*
Modified Type III	4.17 (0.97)	3.76 (1.43)	4.47 (1.83)	3.90 (1.00)	7.73 (3.74)	6.61 (2.93)
Conventional Type III	10.76 (4.28)	9.45 (3.32)	13.15 (4.78)	8.78 (1.28)	18.04 (7.33)	13.26 (7.79)
Previous testing[1]	N/T	N/T	19.63 (7.12)	9.96 (2.10)	31.87 (14.11)	21.95 (11.48)

N/T – Configuration Not tested

It can be seen from Table 3 that the mean times for each experimental condition in test one of the recent research ranged from 3.76 seconds for males operating the modified Type III exit with the outboard seat removed, to 18.04 seconds for females operating the conventional Type III exit with the dummy present. The mean time of 12.24 seconds for all participants operating the conventional Type III exit regardless of seating configuration was significantly slower than the time of 5.11 seconds for the modified Type III exit ($F_{1,72} = 78.69$, $p=0.0001$)[2]. This data is graphically represented in figure 10.



TEST ONE

Figure 10 Graphical representation of mean times (in seconds) taken by participants from hand on handle to exit and evacuate onto the wing

1 Previous testing data for a conventional Type III exit weight 25Kg (Ref. 6)

2 The F ratio is obtained by performing the technique of analysis of variance in order to establish whether any statistically significant differences exist between the data from a number of conditions. Whether the F ratio is sufficiently large to achieve significance will be influenced by the variability in the data and also by the number of conditions and replications of the test.

5.2.2 *The influence of seating configuration on the operation of the Type III exit*

In the situation with an able bodied passenger seated adjacent to the exit for both the conventional and modified Type III exit, changes to the seating configuration adjacent to the exit did not significantly influence the time taken for participants to operate the exit and evacuate onto the wing ($F_{1,60}$= 0.544 NS).

5.2.3 *The influence of an incapacitated passenger on the operation of the Type III exit*

When an incapacitated passenger (dummy) was seated adjacent to the exit for both the conventional and modified exit mechanisms, there was a significant increase in the time taken by participants to operate the exit and evacuate onto the wing in comparison to when participants were sat in the seat adjacent to the exit ($F_{1,60}$= 10.57 p=0.002).

5.2.4 *The influence of participants gender on operation of the Type III exit*

The mean operation time of 7.63 seconds for male participants was significantly faster than the time of 9.72 seconds for female participants indicating that women found the operation of a Type III exit regardless of the type of mechanism more difficult ($F_{1,95}$ = 6.78 p=0.011). The mean times shown in Table 3 suggested that the differences between the operating times for males and females were reduced for the modified Type III exit. However this difference failed to reach significance ($F_{1,72}$ = 3.01 p=0.087).

5.2.5 *The influence of participants handedness on the operation of the Type III exit*

Table 4 below, clearly indicates that mean times for participants to operate either exit type, were not effected by an individuals handedness. Statistical treatment of the data supported this as the effect of handedness was found to have a non-significant result ($F_{1,72}$ = 1.62 p=0.207).

Table 4 Mean times (in seconds) taken by participants from hand on handle to exit and evacuate onto the wing, indicating the effect of handedness of the participants (standard deviations are shown in parentheses).

TEST ONE

	Outboard seat removed 6" Vertical Projection		*13" Vertical Projection No Dummy Present*		*13" Vertical Projection Dummy Present*	
	Right	*Left*	*Right*	*Left*	*Right*	*Left*
Modified Type III	3.93 (1.31)	3.99 (1.12)	4.04 (1.32)	4.34 (1.65)	7.19 (3.14)	7.15 (3.65)
Conventional Type III	10.06 (3.53)	10.15 (4.24)	11.71 (4.98)	10.21 (3.06)	12.04 (6.53)	19.26 (7.42)

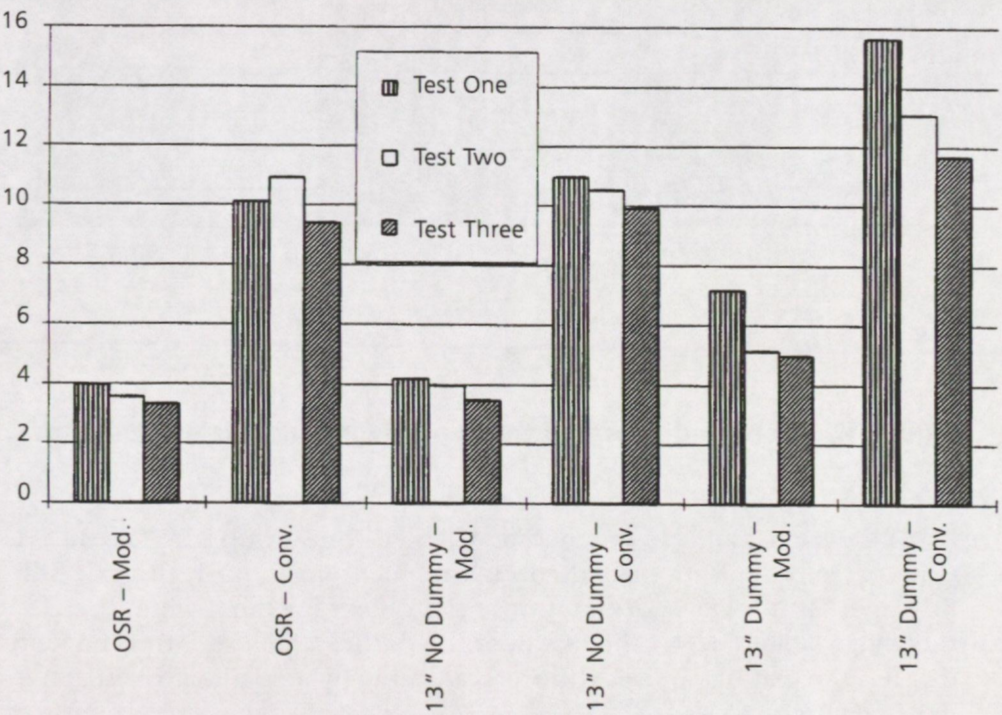
5.3 The influence of practice on the operation of the Type III exit

Table 5 below, shows the mean evacuation times for all three tests by each participant and the data can be seen graphically represented in Figure 11.

Table 5 Mean times (in seconds) taken by participants from hand on handle to exit and evacuate onto the wing. operate the exit and evacuate onto the wing (standard deviations are shown in parentheses)

ALL TESTS

	Outboard seat removed		*13" Vertical Projection No Dummy Present*		*13" Vertical Projection Dummy Present*	
	Mod. Type III	*Conv. Type III*	*Mod. Type III*	*Conv. Type III*	*Mod. I Type III*	*Conv. Type III*
Test One	3.96 (1.2)	10.11 (3.77)	4.19 (1.45)	10.96 (4.07)	7.17 (3.29)	15.65 (7.71)
Test Two	3.54 (0.74)	10.91 (5.38)	3.95 (1.27)	10.54 (3.23)	5.14 (1.91)	13.09 (5.71)
Test Three	3.31 (0.68)	9.41 (2.83)	3.48 (1.00)	9.92 (3.44)	4.99 (2.02)	11.67 (5.64)



Mod. = Modified Type III exit Conv. = Conventional Type III exit OSR = Outboard Seat Removed

ALL TESTS

Figure 11 Graphical Representation of mean times (in seconds) to operate the exit and evacuate onto the wing

Figure 11 shows the effect of practice upon the mean operation times. The statistical treatment of the data indicated that overall the effect of practice, in the majority of cases, led to a decrease in mean evacuation time and improved performance ($F_{2,180}$ = 9.87 P=0.0001). The increase in mean operation time in test two taken by participants operating the conventional Type III exit when the outboard seat was removed can be explained by the increase in the number of participants trying to correctly dispose of the exit hatch onto the wing of the cabin simulator. Individual participant's mean times for all three tests are tabulated in Appendix J.

5.3.1 *Placement of exit and the effect of practice*

Figure 12 below shows the number of participants correctly disposing of the exit hatch for both designs of Type III exit mechanism. In order for the exit hatch to have been 'correctly disposed' the conventional exit hatch had to be placed out onto the wing and the modified exit hatch had to be pushed fully up into the fuselage. Figure 12 clearly shows that the numbers of participants correctly disposing of the exit hatch in the first test, were greater with the modified exit (94% as opposed to 40% with the conventional exit). The number of participants correctly disposing of the conventional exit hatch did increase in tests two and three, however 29% were still leaving the exit inside the aircraft in test three.

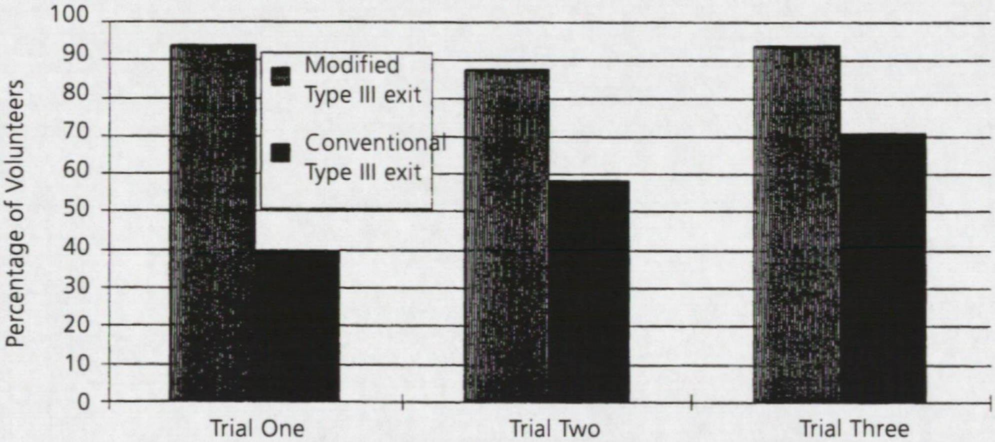


Figure 12 Correct disposal of the Type III exit and the effects of practice

All of the participants in the modified Type III exit group who failed to dispose of the exit correctly, had not gained enough momentum to push the exit fully up into the fuselage. This however, did not pose a problem for them when they evacuated onto the wing. Table 6 below shows where the participants using the conventional Type III exit left the exit hatch inside the aircraft cabin, when failing to jettison it through the exit aperture.

Table 6 Placement of hatch by participants using the conventional Type III exit in Trials One, Two and Three (figures indicate the number of participants placing hatch in each location)

	Trial One	*Trial Two*	*Trial Three*
On floor in exit row	8	3	2
On seat in exit row	5	4	4
Across Dummy's lap	5	4	3
Where the outboard seat had been removed	8	5	2
On the floor behind the exit row (in OSR condition)	3	4	3
Correct disposal onto wing	19	28	34

OSR – Outboard seat removed

5.5 Participants perceived ease of operation and the effect of practice

Participants were asked to rate subjectively (on a seven point scale with 1 indicating 'very easy' and 7 indicating 'very difficult') the difficulty of various actions which were related to the operation of the Type III exit. Statistical analysis was used to assess the degree to which the perceived level of difficulty changed during the three trials that participants carried out. Regardless of the design of the exit, with practice, participant's ratings for the ease of using the operating handle, clarity of exit operating instructions, opening the exit and clarity of instructions for disposing of the exit hatch all became significantly lower. This indicates that participants perceived these to become easier over the three trials ($F_{2,148} = 3.48 < 0.033$, $F_{2,178} = 6.90 < 0.001$, $F_{2,178} = 3.09 < 0.048$ and $F_{2,158} = 24.95 < 0.0001$ respectively). Participants ratings for the weight and size of the exit and exiting on to the wing did not change significantly during the three trials.

5.6 Problems experienced by participants in operating the type III exit and the effects of practice

The percentage of participants reporting difficulties in operating the Type III exit was far greater with the conventional exit mechanism than with the modified exit mechanism. During trial one, 31% of those participants operating the modified exit experienced some difficulties in comparison to 88% of those participants operating the conventional Type III exit. Tables 7 and 8 below show the difficulties experienced by participants during the three trials for the modified and conventional Type III exits respectively.

Table 7 shows the frequency with which problems were occurring with the modified exit mechanism. Problems such as the size of the exit aperture and stepping over the exit ledge onto the wing, remained stable with practice and did not effect the initial operation or disposal of the exit itself. During the three trials the number of participants reporting that they did not translate the exit fully in to the fuselage increased. The participants explained that due to the ease of the first operation they had not opened the exit with the same amount of force in the subsequent trials, this led to their difficulties in movement of the exit hatch into the fuselage.

Table 7 Problems experienced by participants in operating the modified Type III exit mechanism during the three trials (figures indicate percentage of participants experiencing each difficulty)

	Trial One	*Trial Two*	*Trial Three*
Size of Type III exit aperture	25	25	23
Stepping over exit ledge	8.3	8.3	8.3
Hit head on exit	2.1	4.2	2.1
Unsure where to put exit	8.3	2.1	–
Exit didn't retract all the way into fuselage	2.1	4.2	6.25
Dummy obstructed participant in some way*	6.25	12.5	12.5
Seats were in the way	–	–	2.1

*percentage refers only to 16 participants in the 'dummy present' trials

Table 8 Problems experienced by participants in operating the conventional Type III exit during the three trials (figures indicate percentage of participants experiencing each difficulty)

	Trial One	*Trial Two*	*Trial Three*
Size of exit hatch and therefore the disposal	37.5	58.3	58.3
Unsure where to put exit hatch	16.6	10.42	2.1
Seats were in the way	8.3	4.2	12.5
Surprise of weight and exit hatch coming free	16.6	6.25	–
Stepping over exit ledge	2.1	–	2.1
Exit hatch hit their head	2.1	2.1	2.1
Dummy obstructed participant in some way*	12.5		18.75

*percentage refers only to 16 participants with the dummy present

Table 8 clearly shows the problem participants experienced with the size of the exit hatch and consequently its disposal. The frequency of this problem increased as participants practised opening the conventional Type III exit. This increase was accompanied by a decrease in the number of participants who were unsure where to put the exit hatch. Figure 12 above, clearly shows that as participants practised opening the exit there was an increase in the probability of a correct disposal of the conventional Type III exit and therefore a similar increase in those participants encountering difficulty in trying to place the exit hatch onto the wing.

6 DISCUSSION

The work on this study led to the selection of a concept for the support and motion of the Type III exit hatch. In making this choice, application to medium to large civil aircraft was given greatest consideration due to the greater numbers of passengers travelling in these types of aircraft. However, Type III exits are used on a wide range of aircraft types.

This section considers the basic acceptability of the selected concept and its suitability for application to a range of aircraft before the trials data, including questionnaire results, are discussed.

6.1 Acceptability of the concept in general

The concept of a Type III exit in which the hatch moves in and then upwards was selected from many other possibilities on the basis that it met the statutory airworthiness requirements and best met the selection criteria defined in Section 3.1.

In application to medium to large civil aircraft the concept does not result in loss of passenger seats though it would cause loss of some luggage storage space. The hatch is supported and, with the correct assistance, requires minimum effort to operate. The method of operation is also reasonably familiar and simple.

Addition of tracks, rollers and a trolley beyond what is required for a conventional Type III exit is necessary and it is therefore more complex. However, support and sealing is relatively simple in comparison to many types of main door. Thus, the increase in maintenance requirement may not be significant. In fact some maintenance personnel find the 'up and over' type of main doors to be considerably less vulnerable to damage than the outward opening types. It should, however, be said that much of this results from very minor damage caused during ground operations.

As intended, the concept does not require the outer skin and surrounding fuselage structure to be modified. Alterations to the fuselage should be limited to addition of track supports and redesign of pressure supports and hatch fittings. Hatch structure would require more extensive modifications but this would be much less costly than fuselage modifications. Therefore, it is thought that the cost of the modifications themselves would not present too great a barrier to adoption of the concept in retrofit applications.

It is accepted that trim alterations and re-routing of cables and some pipes could be required. Alterations to large air distribution ducts may be avoidable on the Boeing 767 and should be on the Boeing 737 but this may not be the case on other narrow-bodied aircraft.

In summary, the concept provides the desired features for an improved Type III exit with the penalties minimised to the greatest extent sensibly possible on larger diameter fuselage applications. Smaller fuselage diameters may present greater problems and for this reason the considerations covered in the following two sections were undertaken.

6.2 Application to smaller aircraft

A number of executive jets have Type III exits with a small fuselage diameter. As there was concern with the difficulties in applying the chosen concept to such aircraft a preliminary investigation was performed.

The British Aerospace (BAe) 125 executive jet has a single Type III exit positioned over the starboard wing. Although it is possible to provide the necessary tracks etc to obtain the motion for application of the up and over concept, it would be difficult without obtrusive fairings in the trim inside the fuselage. In addition, the hatch in its open position presents a substantial obstruction to movement along the cabin at head height.

Perhaps a more difficult application still is that of the Jetstream 41 regional turboprop aircraft which has two exits which, though not immediately opposite each other do overlap. With a fuselage diameter similar to that of the BAe 125, it is difficult to conceive of an 'up and over' scheme which would allow both hatches to be fully open at the same time.

A similar problem exists with an application such as the Cessna Citation II series of executive jets which have an even smaller fuselage diameter with a Type III exit opposite the main door. Again it is not possible to have both fully open and the apertures clear at the same time quite apart from the difficulties in providing the necessary tracks etc.

A general conclusion from the above is that application of the selected concept becomes increasingly difficult as fuselage diameter reduces. However, for such aircraft hatch weights are normally lower and hence potentially more easily operated. Therefore, it is probably acceptable to allow continued use in such aircraft.

6.3 Application to narrow-bodied civil transports

In considering the Boeing 737 application it was found that a large air-conditioning air distribution duct along the roof of the aircraft presented some problems for installation of the selected concept. These can probably just be overcome without alterations to the duct but similar problems may exist on other narrow-bodied civil transports.

Preliminary investigations showed that the Fokker F-100/F-70, the McDonnell Douglas MD-80/MD-90 and Boeing 757 all have ducts along the roof centre-line. The Airbus A-320 and BAe ATP have twin ducts along each side of the roof space.

Due to the smaller fuselage diameters of the Fokker, McDonnell and BAe aircraft, it is expected that some re-routing or at least reshaping of the air-distribution ducts in the local area of the over wing exits may be necessary. The nature of the flows in these ducts is such that, unless direction or cross-section changes are particularly violent, undue pressure losses should not result. However, there would be an inevitable cost penalty due to the alterations.

6.4 The operation of the Type III exit

The research programme illustrated many of the difficulties that members of the public can have in operating Type III exits. The participants were not briefed about the exact nature of the test prior to taking part, so the experimental situation simulated the ambiguity which may occur in an emergency.

The differences in the mean operation and evacuation times from previous Type III exit tests may have been due to such factors as improvements to the Type III exit operation diagrams or improved realism in the aircraft cabin simulator.

The participants were also advised that passenger safety briefing cards in the seat pockets and safety placards on the seat backs in front of them detailed how the exit operated. However, the results should not be taken to indicate that all passengers would be equally prepared in an aircraft emergency, indeed a few participants during the research programme initially started to move towards the exits at the rear of the cabin as they believed that cabin crew would be stationed there and that these exits would be easier to evacuate from, thus disregarded the instructions given to them in the pre-flight briefing.

6.4.1 *The influence of the Type III exit operation mechanism*

The mean evacuation time for each participant on the first test, regardless of seating configuration, clearly indicated that the modifications to the Type III exit operating mechanism significantly increased the speed at which participants could open the exit and evacuate onto the wing of the simulator. The difficulties participants found in manoeuvring and disposing of the exit due to its size and weight were removed or lessened when operating the modified exit mechanism. This finding demonstrates the benefits which could be gained from the adoption of the modified Type III exit mechanism. These tests were undertaken with a 21.5kg (47.4lb) hatch weight, some aircraft are fitted with heavier hatches thus even more benefits may be available.

6.4.2 *The influence of seating configuration on the operation of the Type III exit*

The evacuation times from both types of exit mechanisms showed that the seating configuration did not affect the speed at which participants opened the exit and evacuated onto the wing. However, exit operation times were significantly slower when a dummy representing an incapacitated passenger was present. Participants found that their access to the exit was restricted and therefore the operation of the exit more difficult. The restricted space caused by the presence of the dummy was a particular hindrance when participants were trying to dispose of the conventional Type III hatch. The dummy was less of a hindrance when participants were operating the modified hatch. In some cases using the conventional hatch, as the participant tried to manoeuvre the exit through the exit aperture it became wedged against the dummy and seat row in front. Due to the weight and size of the exit hatch they decided to leave the exit lying across the dummy's lap rather than continuing in their efforts to place the exit onto the wing.

6.4.3 *The influence of participants gender on the operation of the Type III exit*

Male participants operated the Type III exit significantly quicker than female participants. Women found the operation of both Type III exit mechanisms more difficult than male participants, although the mean evacuation times suggested that these differences were reduced when participants were operating the modified exit mechanism. It appeared that the female participants who found the size and weight of the conventional exit particularly difficult to manage were not at such a disadvantage when operating the modified exit mechanism. This mechanism did not require them to support and manoeuvre the heavy hatch, a task which the female participants had found particularly difficult. The results of changes in exit mechanism on male and female participants ability to operate a Type III exit suggest that the benefits of adopting the modified design of Type III mechanism would be greater for female passengers.

6.4.4 *The influence of participants handedness on the operation of the Type III exit*

The mean times taken to operate both exit mechanisms showed that an individuals handedness did not affect their ability to operate a Type III exit.

6.5 **The influence of practice on the operation of the Type III exit**

Practising the task three times significantly reduced the times taken by the participants to operate the exit and evacuate onto the wing. The effects of practice between the two exit mechanisms were not found to be significantly different, however the benefits of reduction in evacuation times appeared to be greater with the conventional exit mechanism. Although practising the operation of the conventional Type III exit mechanism improved participants ability to operate the exit, it failed to the increase it to the speed of operation of the modified exit mechanism.

The reduction in operating time and benefits due to practice were greatest when the dummy was present. This demonstrates the effect an incapacitated person could have on an evacuation of this type and the importance of including this configuration in future testing.

6.5.1 *Placement of exit and the effect of practice*

The number of participants correctly disposing of the Type III exit was greater in all three trials when participants were operating the modified exit mechanism in comparison to the conventional exit mechanism. In the first test only 40% participants correctly disposed of the conventional exit correctly where as 94% participants fully pushed the modified exit up into the fuselage. The numbers of participants correctly disposing of the conventional Type III exit did increase in tests two and three, however 29% were still leaving the exit inside the cabin simulator in test three.

The participants who failed to dispose of the conventional Type III exit onto the wing did so because they found that either the size and weight of the exit was too difficult to manoeuvre or because they failed to understand the diagrams on the passenger safety briefing cards and placards. Many of the participants felt that improvements could be made to the diagrams indicating the operation of the conventional Type III exit for example they felt that the pictures could be clarified, showing exactly where to place the exit. They also commented that it would be useful to give an indication of the weight of the exit and to verbally explain how to use the exit.

This result demonstrates the difficulty that participants can experience when operating the conventional Type III exit. The failure to correctly dispose of the conventional Type III exit could lead to it becoming an obstruction to passengers in their attempt to evacuate from an exit of this type. As the testing showed, the modified exit removed the problem of passengers leaving the exit inside the aircraft and therefore creating any subsequent obstruction. Even when participants had failed to read or were not clear about the operating instructions for the modified exit, when they released the operating handle, the movement of the exit encouraged them to correctly push it up into the fuselage.

6.6 Participants perceived ease of operation and the effect of practice

Participants subjective ratings indicated that regardless of the Type III exit operation mechanism, they felt that the ease of using the operating handle, clarity of exit instructions, opening the exit and disposing of the exit all became easier with practice. This suggests that the diagrams used in this study became easier to understand with practice and the information they impart could in fact be clarified and improved. The participants subjective ratings for the hatch weight and size and exiting on to the wing did not change significantly during the three trials, indicating that the difficulty of these factors remained constant.

6.7 Problems experienced by participants in operating the Type III exit and the effect of practice

The percentage of participants reporting difficulties in operating the Type III exit was far greater with the conventional Type III exit mechanism than with the modified exit mechanism. The type of difficulties encountered by participants were dependent on the exit mechanism being used. In the conventional Type III exit trials more participants reported difficulties relating to the operation and disposal of the exit. In comparison, difficulties reported in the modified Type III exit trials were linked to the size of the exit aperture and height of the exit ledge, which caused problems when participants were evacuating onto the wing.

7 CONCLUSIONS

7.1 Whilst conventional Type III exits have the advantage of simplicity they have a number of limitations which have led to problems in the operation of the exit, demonstrated by service experience.

7.2 The limitations of conventional Type III exits could be eliminated by provision of a system of support and constraint which facilitates operation of the exit and disposal of the hatch.

7.3 Although a single concept was selected for development and demonstration during this study, other concepts may have particular advantages in certain Type III exit applications.

7.4 The selected concept uses the same motion principles as the floor level exits (eg main doors) on a number of wide-bodied aircraft. This concept may provide a relatively simple solution which would not require substantial fuselage modification or loss of seating capacity.

7.5 Application of the selected concept to larger diameter aircraft in an over-wing location is likely to present few problems. However, on smaller diameter aircraft and/or where Type III exits are placed below wings an alternative concept might need to be developed due to space limitations.*

7.6 The time taken by participants to operate a Type III exit and evacuate onto the wing of a cabin simulator was significantly quicker when using the modified Type III exit mechanism.**

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* These hatches however are of minimal size and weight and operation by passengers should not present a problem.

** The test results show that the modified exit can be made available significantly faster than the (21.5kg, 47.4lb) hatch used in the study. With heavier hatches an increased benefit may be available.

7.7 The two seating configurations specified in AN79 paragraphs 4.1.1 and 4.1.2 1989 (Ref. 1), did not significantly influence the time taken by participants to operate either type of Type III exit mechanism and evacuate onto the wing.

7.8 The presence of the dummy (simulated incapacitated person) seated adjacent to the Type III exit significantly increased the time taken by participants to make the exit available and evacuate onto the wing. The dummy was less of a hindrance in the case of the modified exit.

7.9 Female participants found the operation of both types of Type III exit mechanism more difficult than male participants. The benefits of installing the modified Type III mechanism would be greater for females than for males (although still significant for males).

7.10 Participants handedness did not affect participants ability to operate either Type III exit mechanism.

7.11 Providing participants with the opportunity to practice the task three times led to a reduction in the times taken to operate both types of Type III exit mechanisms and evacuate onto the wing.

7.12 Practising the operation of the conventional Type III exit failed to improve participants speed of operation to the speed achieved by participants when operating the modified Type III exit without practice.

7.13 The effect of practice was greatest in conditions with the dummy present.

7.14 Practice provided participants with the opportunity to find more effective methods of opening and manoeuvring the conventional Type III exit. Practice also led to a greater number of participants correctly disposing of the conventional Type III exit.

7.15 The difficulties that naive participants encountered in trying to understand the exit operating instructions of the conventional Type III exit indicated the need to clearly communicate the method of operation and disposal of such exits.

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Appendix A Procedure for selection of short listed concepts

Initial consideration of the advantages and disadvantages of concepts led to elimination of some four concepts from the original twenty two. These do not meet the requirement of having initial motion inwards leaving those concepts listed on the left of Table A.1.

Using the basic criteria in Section 3.1, a further 10 concepts were eliminated for the reasons indicated in Table A.1.

The remaining concepts cannot easily be eliminated by simple application of the basic criteria and thus a more detailed consideration of the concepts was necessary. This was performed by considering each concept against possible cost increasing or other undesirable features. Table A.2 gives the negative features considered and the resulting assessments for the nine remaining concepts. In some cases possible, rather than obviously, negative features for a concept are indicated by a single slash rather than a full cross.

Although it would not be appropriate to total the negative factors for each concept to rank them, it can be seen that the following concepts have more negative factors than the others:-

4a + d
4b + d
4c + d
5a

As a result, these four concepts were initially eliminated from further investigation. However, it was recognised that they could, particularly 4c+d, be reinstated should all remaining concepts prove unworkable.

Table A1

Concept		Elimination with Reason
1a	Translate, In	X As used at present
2a	Rotation, Vertical Hinge, In	X Loss of seat
2c	Rotation, Horizontal Hinge At Bottom, In	X Loss of seats
2e	Rotation, Horizontal Hinge At Top, In	X Requires power, problems with crowding
3a	Translate In, Slide Sideways	
3b	Translate In, Slide Upwards	
3c	Translate In, Slide Down	X Major structural problems
4a+d	Translate In, Tilt, Hinge Out, Disconnect Mech.	
4a+e	Translate In, Tilt, Hinge Out, External Hinge	X Aerodynamic penalty
4b+d	Translate In, Shorten, Hinge Out, Disconnect Mech.	
4b+e	Translate In, Shorten, Hinge Out, External Hinge.	X Aerodynamic penalty
4c+d	Translate In, Drop, Hinge Out At Bottom, Disconnect	
4c+e	Translate In, Drop, External Hinge Out at Bottom	X Aerodynamic penalty most cases
5a	Multiple Sections, Hinged At Sides	
5b	Multiple Sections, Sliding	X No advantage over 3a or 3b
5c	Multiple Sections, Rotating In Plane	X Large complexity
5d	Multiple Sections, Upper Section As 1a, Lower Retained	
5e	Pressure Lever	
5f	Hinged Hatch	

Table A2 Consideration of negative features of concepts (Concept designations are as given on Table A1) (Cross indicates strong negative feature, slash indicates less strong feature)

Negative Feature / *Concept*	*3a*	*3b*	*4a+d*	*4b+d*	*4c+d*	*5a*	*5d*	*5e*	*5f*
Possible seat loss	X		X	X	X	X	X		
Complex support mechanism	/	/	X	X	X	/	/		
Complex sealing required				X		/		X	/
Complex for single motion			X	X	/	X	/		
Major hatch alterations			X	X	/	X	/		X
Major surround alterations			X	X	/	/	/	/	/
Significant maintenance	/	X	/	/	/	/			
Requires 'power'	/	/							
Unfamiliar operation					/	/		X	X
Loss of window						X	/		/
Non-Emergency use difficult			X	X	X			/	X

Appendix B Consideration of five short listed concepts

For the five short-listed concepts remaining following initial selection, there were a number of questions and concerns that had been identified. These are summarised alongside sketches of the concepts in Figure B.1. Work to address some of these concerns was performed to allow further concept elimination to occur.

B1 FURTHER CONCEPT ELIMINATION

Through further qualitative and some quantitative consideration, information was provided on each of the five concepts shown in Figure B.1.

Some of the consideration at this stage was based on application of each concept to the Boeing 767 situation. The geometry for this was gained through a visit to an operator of Boeing 767s with two pairs of Type III exits. Figure B.2 provides a summary of relevant dimensions of exits and seats taken from a Boeing 767 layout.

Using the dimensions of Figure B.2, the sideways sliding concept was shown to have significant problems in the Boeing 767 application with two pairs of Type III exits in close proximity. Translation of the hatch sideways inside the fuselage would not be possible without considerable alteration to and/or loss of seats, Figure B.3. This would also be the case in almost any other application.

Figure B.4 shows that, although the upward sliding concept would require loss of overhead locker volume, interference with seats was unlikely. (Note that seats placed in front of exits do not have an outer arm and therefore upward and outward motion of the hatch would not conflict with this.) Considerable room would be available in the space above the cabin ceiling for mechanism and power assistance installation.

The split hatch concept was introduced in order to retain the simplicity of the present Type III exit type and operation but with a lower hatch weight and smaller size to ease passenger handling. However, the parts of the hatch which remain attached to the fuselage would need to move away from the aperture and would require complexity almost equal to that necessary for a fully retained hatch moved in the same fashion, Figure B.5.

One apparently possible position for the retained hatch portion is below the aperture but even this is difficult to achieve as the lower sill may be too close to the floor and the seat lower portion would require substantial modification.

The pressure lever concept has great apparent simplicity in its mechanism and operation. However, questions of the hinge position necessary to give sufficient pressure force retaining it and consequent angular motion of the door before it is able to slide out were voiced.

From analysis performed a ‘hinge’ position approximately one third of the way up the hatch would appear to provide reasonable forces to prevent opening under pressure and should allow rotation of the hatch prior to sliding to be limited to acceptable angles.

A number of possible problems with the folding hatch concept were identified. Two of these are shown in Figure B.6. The necessary hinge position on the outer skin requires that an over centre mechanism is created and in addition would expose the hinge to icing and sealing problems.

It is also difficult to devise an unassisted means by which the folding hatch can fold and be expelled through a single motion of an operator.

On the basis of the above consideration and in consultation with CAA all but the upward sliding hatch and pressure lever hatch concepts were eliminated from further consideration. However, it was felt that one of the concepts previously eliminated, based on that used on present Boeing 757 and 767 Type I emergency exits (Door 3) should be reinstated for further consideration.

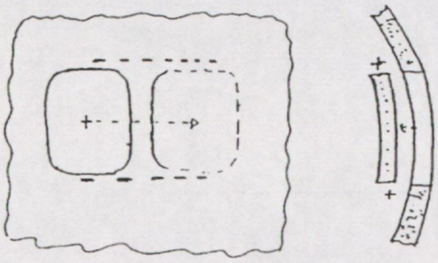
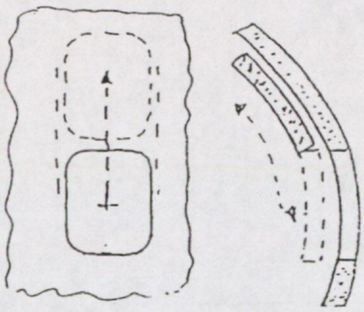
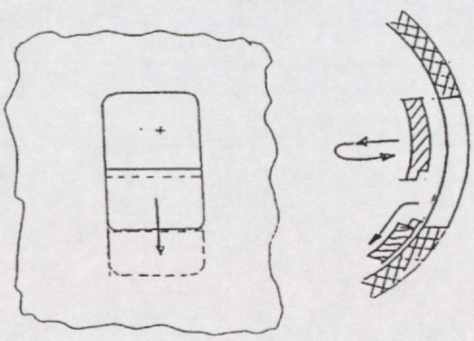
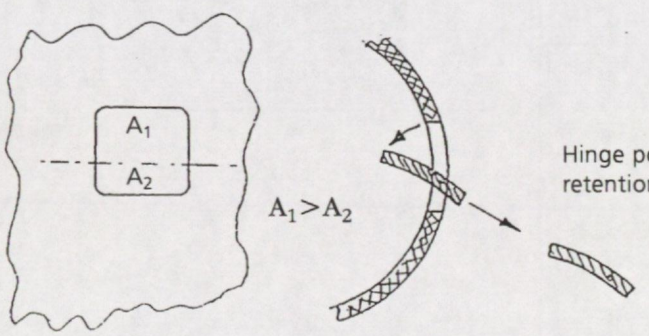
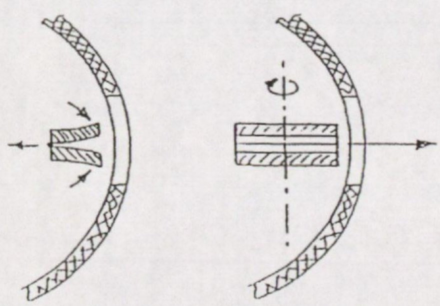
	CONCEPTS REMAINING	Major Questions/Considerations
Sideways Sliding		Interference with seats. Need for actuation and latching in inclined aircraft attitudes.
Upward Sliding		Interference with any overhead systems/equipment. 'Power' assistance device. Need for latching open.
Split Hatch		Ability to initiate necessary motions with a single action. Stowage of retained section.
Pressure Lever		Hinge position to provide acceptable retention force. Sealing of hatch.
Folding Hatch		Actuation to give folding and expulsion from a single action. Sealing of hatch.

Figure B1 Concepts short-listed following initial selection

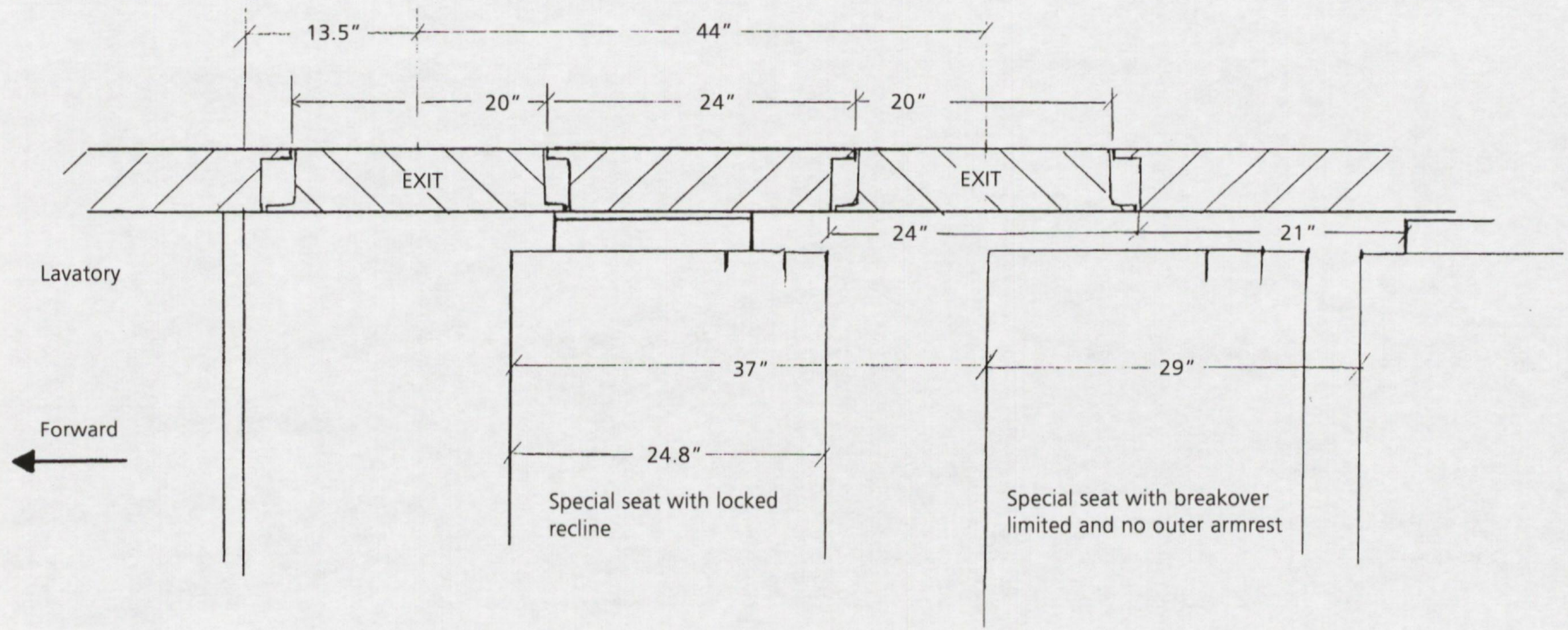


Figure B2 Boeing 767 right-hand side Type III exit arrangement with high density seating configuration

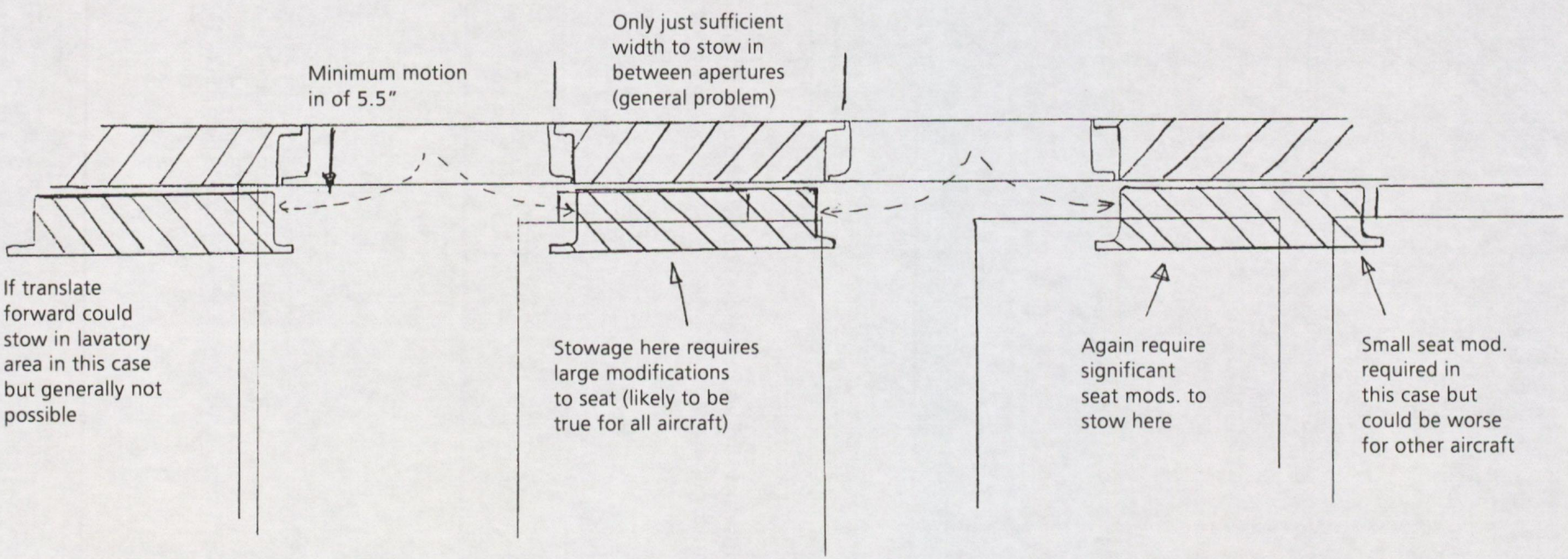


Figure B3 **Sideways sliding hatch concept, considerations for application to a Boeing 767 and generally**

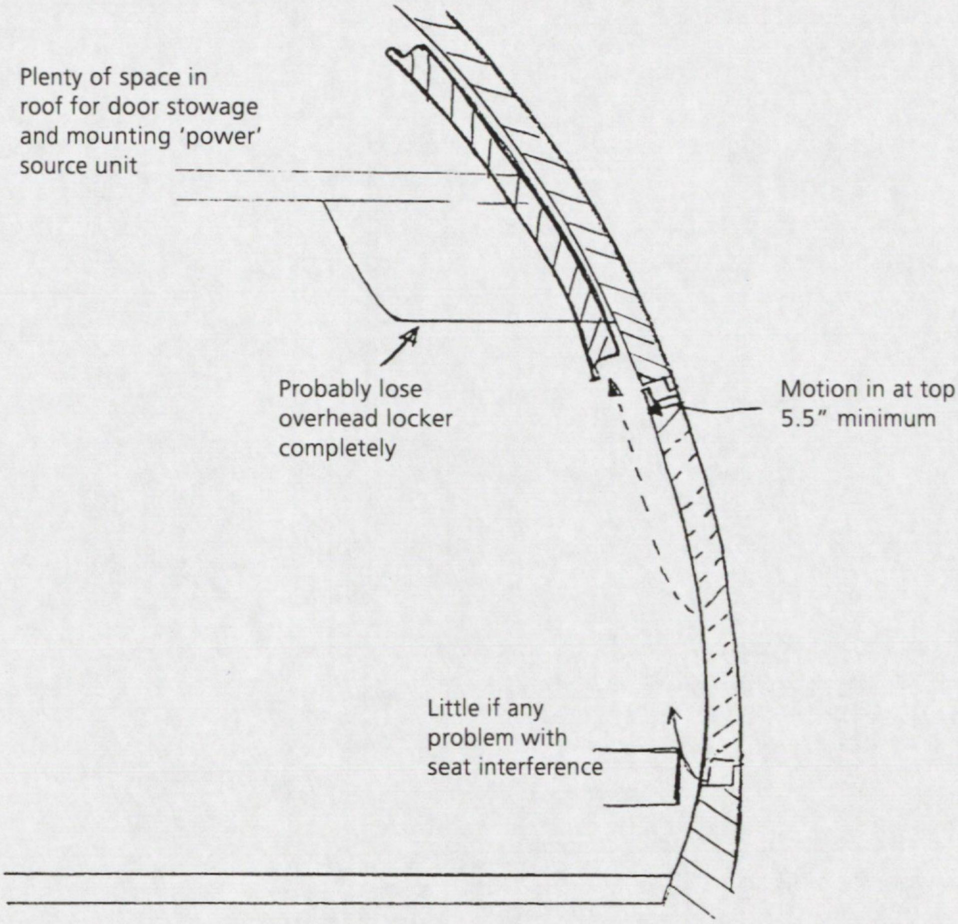


Figure B4 Upward sliding concept, considerations for application to a Boeing 767 and generally

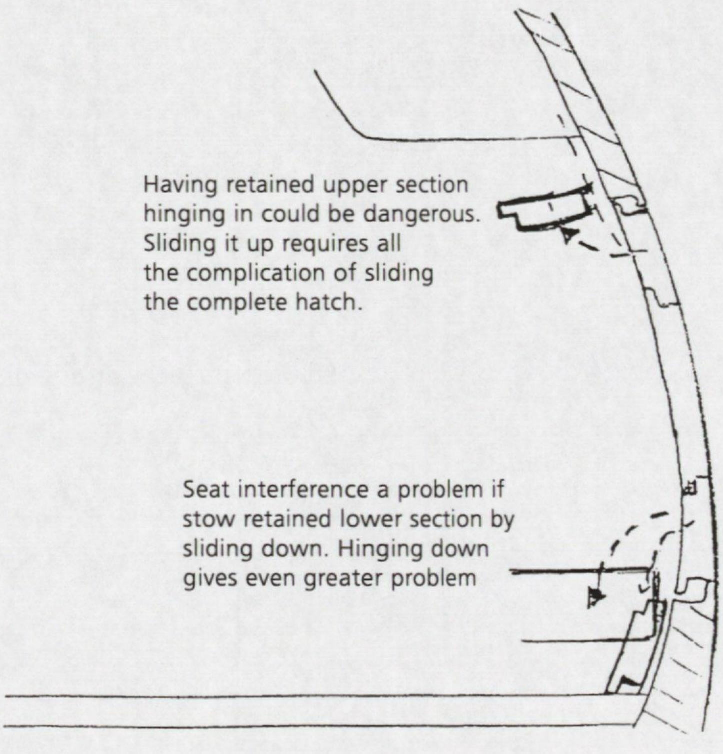


Figure B5 Split hatch concept, considerations for application to a Boeing 767 and generally

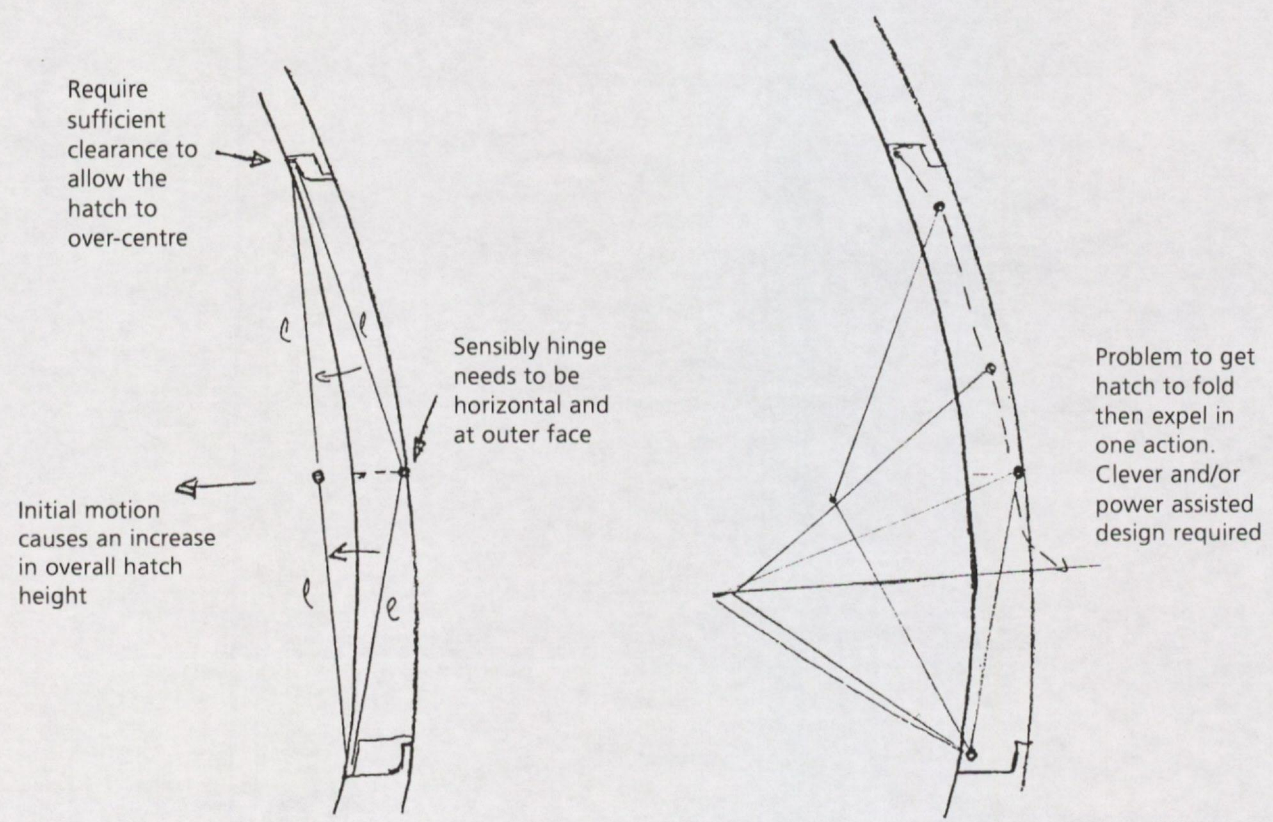


Figure B6 Folding hatch concept, considerations for application to a Boeing 767 and generally

Appendix C Considerations leading to final concept selection

Having Selected the three concepts as follows:

Upward sliding hatch
Pressure lever hatch
Drop-out hatch

each was considered in yet further detail prior to selection of a single concept.

C1 UPWARD SLIDING HATCH

The concept is based on that of the main doors on aircraft such as the B767, DC-10 and L-1011. In theory it is a simple inward and upward sliding of the hatch. However, there are several possibilities for providing the necessary 'power' for the motion and the need to provide latching etc complicates the scheme.

There are a number of ways such doors are 'powered' at present and others are also possible. The 767 uses a large torsion spring device acting on the door through cables and pulleys. Hydraulic and electric power applied through a rack and pinion drive is used in the case of the DC-10. A long bungee and pulley system has previously been produced by Cranfield for a paratroop door installed on a BAe 146.

In addition to powering the motion, it must be guided. In the DC-10 case this is in part performed by the same track as for power but such a scheme requires accurate track/door positioning. The cable operated systems, on the otherhand, are not sensitive to exact door position and tracks can be relatively crude in terms of their design and construction. This also makes them less sensitive to distortion of the fuselage in a crash case.

It is necessary to consider latching of the hatch in both the open and closed positions. Along with the operation handle, their mechanisms and location require careful thought and will probably differ from main door schemes.

Interference of the hatch with the seats, whilst opening, and with overhead items, when stowed, has been a concern. However, in the case of most modern low wing civil transport aircraft, the limited size hatch appears to pose little problem to overhead systems aside from a small loss of overhead bin space. For the situation of a Type III exit below a high wing there is a significant problem for this concept.

The large longitudinal structural members in the fuselage around a hatch are likely to necessitate a significant inward movement prior to upward motion. Whether this is a problem for interference with seats will depend on exact details of seat dimensions and locations but it does not appear so serious that seat removal would be necessary.

C2 THE 'PRESSURE LEVER' HATCH

This concept was retained in the short-list as one which although novel apparently possessed desirable attributes. Some problems, in sealing and ensuring the correct door motion and final expulsion occurred, were recognised at an early stage.

A detailed coverage of work related to the following five issues is provided in Ref.9:

(i) Sealing

(ii) How to pass the hatch through the aperture

(iii) The mechanism

(iv) Support

(v) Release, latching and the ability to close

Only the major points are included below.

Sealing problems result from the top and bottom of the hatch moving in opposite directions (in and out) initially. Schemes which are workable have been devised but they are not simple and may be unreliable.

The simple design and motion can only be retained if the fuselage aperture shape is more complex than at present. This is not a problem for new designs but makes retro-fitting expensive.

Mechanisms issues cover pivot location and motion constraints. A number of approaches are suggested in Ref.9, including a 4-Bar Link solution.

The reaction of the pressurisation forces could pose some problems for the concept though again approaches are suggested and latching and reclosing requirements have been considered.

C3 THE DROP-OUT HATCH

The drop-out hatch concept is based on that used for the Type I floor level exits at Door 3 on the current Boeing 757 and 767. It was re-instated for consideration in the short-list in preference to other novel concepts as a scheme which exists and is simpler than most main doors.

Reference 9 contains some detailed considerations of application of the concept to a Type III exit. However, the major points are outlined below.

It is apparently not too difficult to add an operation mechanism to the present Type III exit hatch on a 767 and, retaining the present pressure supports, acquire the required concept. Unfortunately, the present fuselage skin structure would need to be substantially modified around the aperture. This would be a very expensive modification for a retro-fit though not a real problem for a new design.

An alternative approach, which could allow retention of most of the present hatch and fuselage structure, would 'retract' the pressure load supports on the door prior to passage through the aperture. This requires a complex mechanism with large components due to the need to carry loads. However, it does avoid a further problem with the previous scheme, in that the fuselage pressure supports would not protrude beyond the general line of the aperture side. Protrusion does occur with the present Type I exits but could be considered dangerous in the Type III size exit case.

Once outside, the hatch's final location may become a problem. The present Type I exits hinge down to the vertical out of the way but an overwing Type III exit could not do this. With larger distances down to the wing the hatch should remain attached to the hinge mechanism and have a step extending from it. When the distance down to the wing is small its presence becomes a problem for egress but releasing it would not solve the problem as then it would become an unstable stepping point.

C4 SINGLE CONCEPT SELECTION

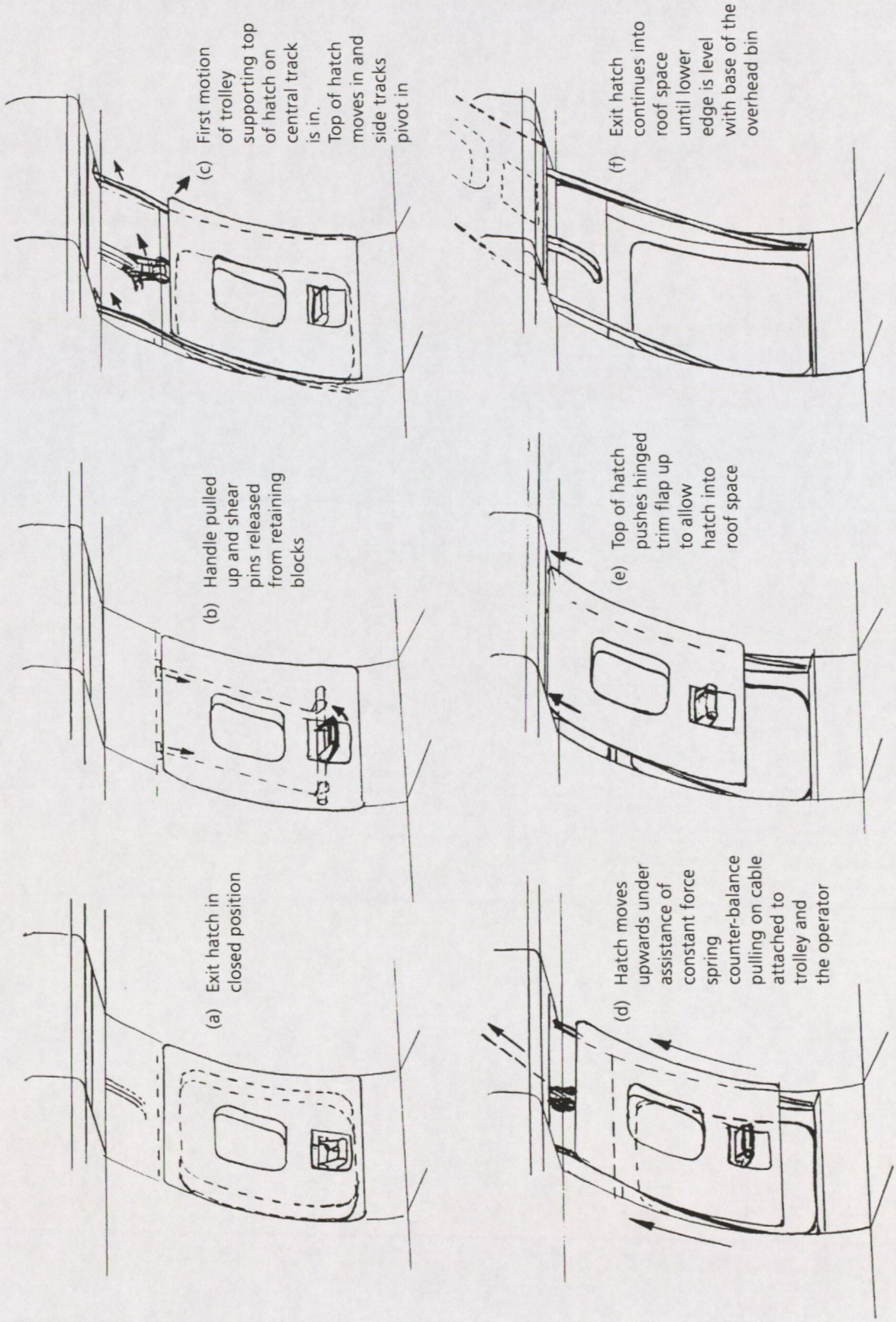
The work performed to this point in the study did not answer all the concerns and questions related to the three remaining concepts. However, sufficient had been done to provide the basis for a supportable single concept selection.

The 'pressure lever' concept is novel and consequently unproven. There appears to be an approach to provide a workable solution but to do so and retain the attraction of the concepts basic simplicity would either require expensive modifications in a retro-fit or application to a new design.

Whilst the drop-out hatch concept is an existing scheme for larger exits, they are not located over wings. The reduction in size to Type III dimensions and overwing location both cause problems for the concept causing it to become both a complex and expensive option particularly in a retro-fit application.

Unlike the other two concepts the upward sliding hatch concept requires 'power' but there are a number of ways this can be provided. Also the necessary modification to the basic fuselage and hatch structure are minimised with this concept, making it a sensible option for retro-fitting as well as new designs. The concept does require further work on mechanism detail aspects, but whilst these may differ from those presently used in main door schemes, there do not appear to be any significant problems to be overcome. Thus, this concept was selected to be further refined, developed and demonstrated during the remainder of the study.

Appendix D Diagram of the modified Type III exit



Appendix E Diagrams of the two Seating Configurations

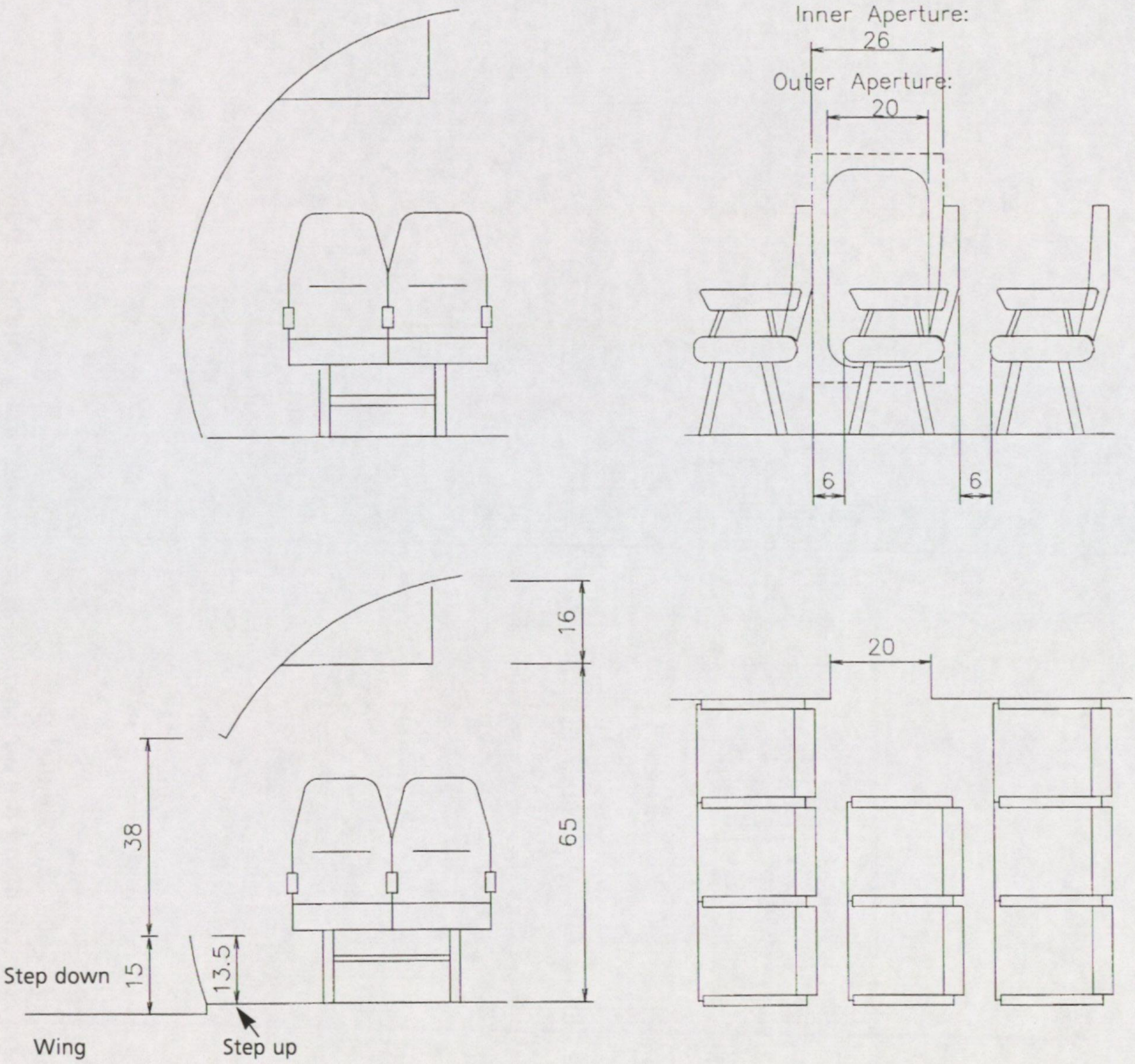


Figure E1 Outboard seat removed Configuration

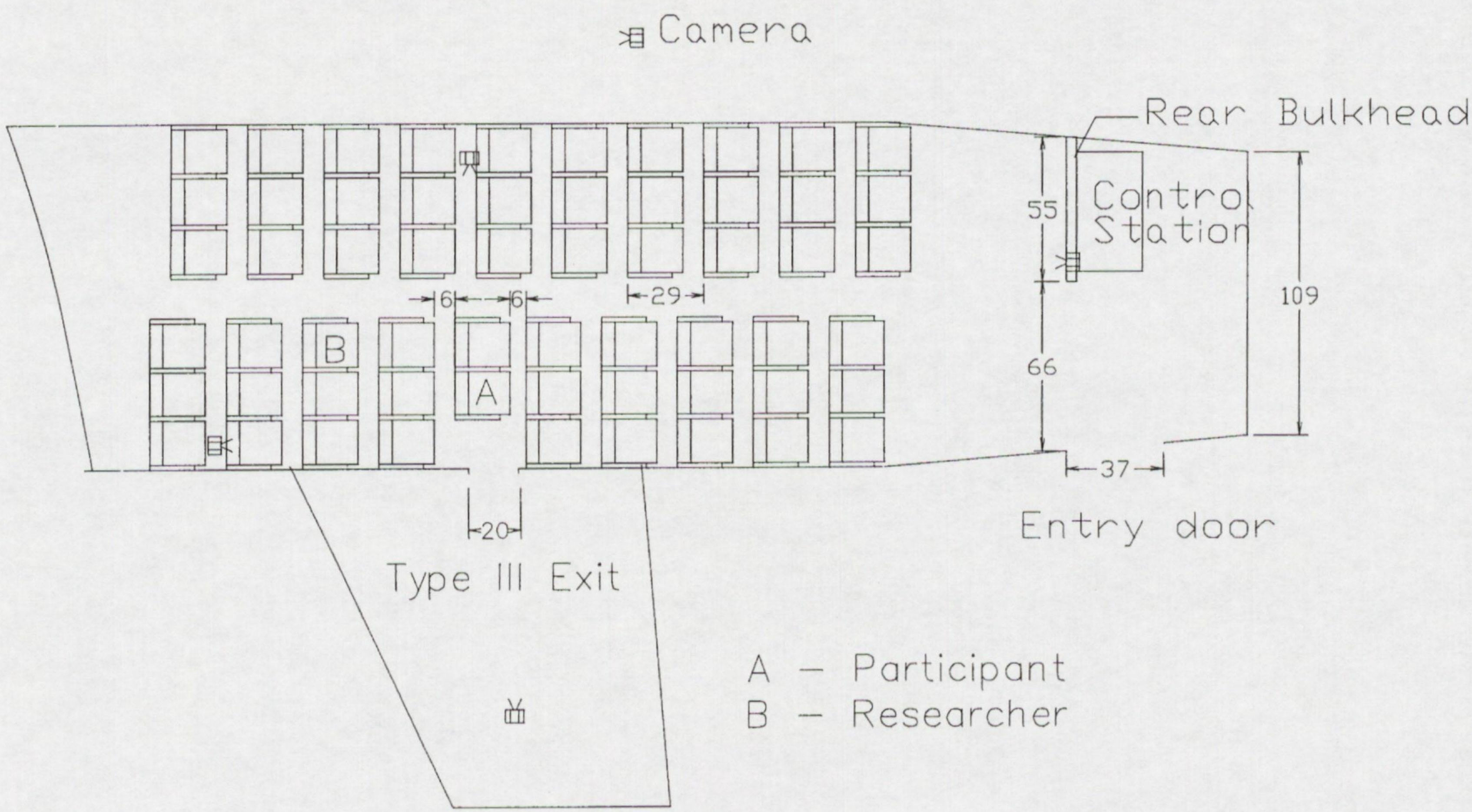


Figure E2 Plan View of Boeing 737-200 Cabin Simulator
Six inch vertical seat projection and the outboard seat removed seating configuration

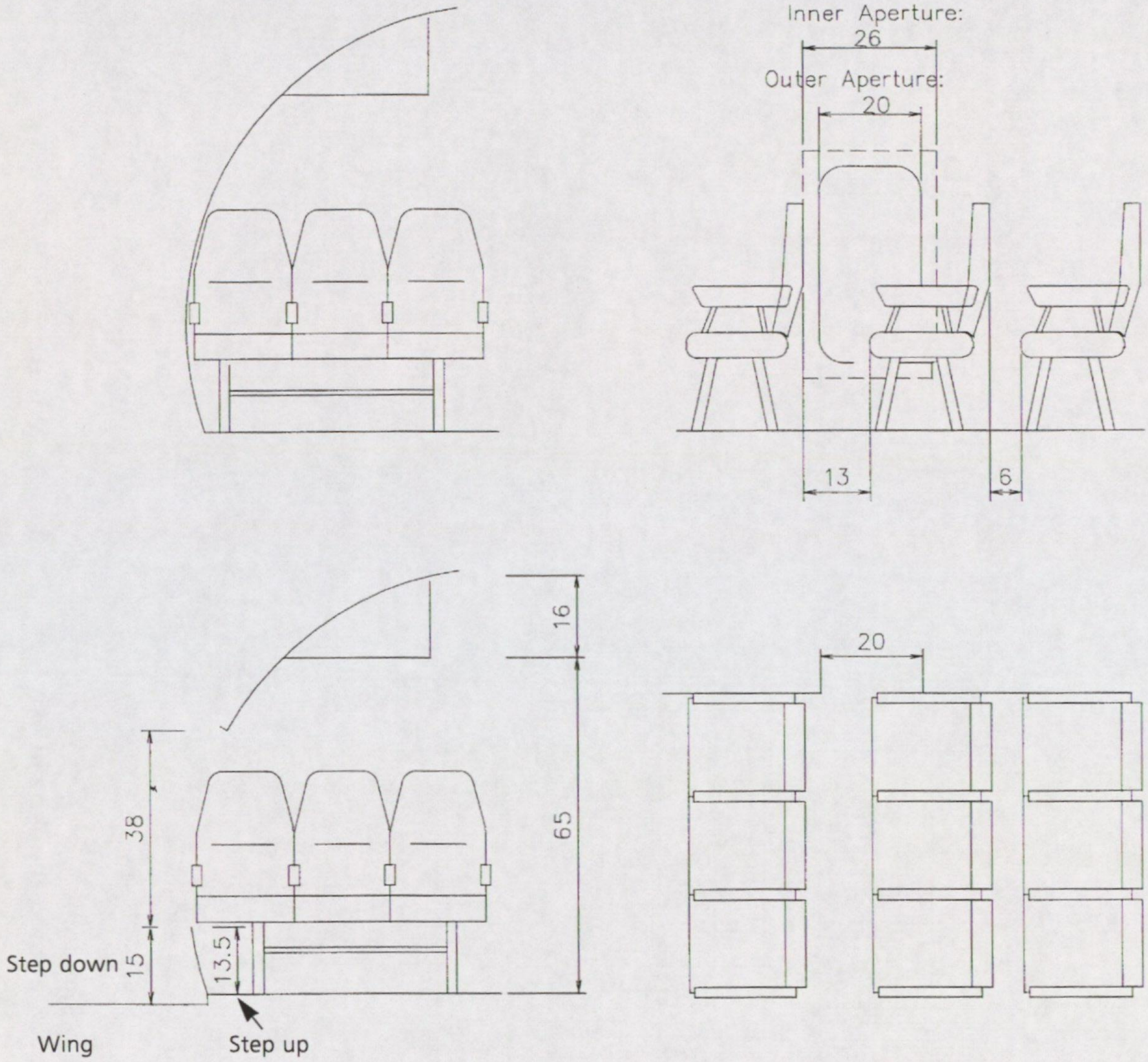


Figure E3 Thirteen inch vertical projection seating configuration

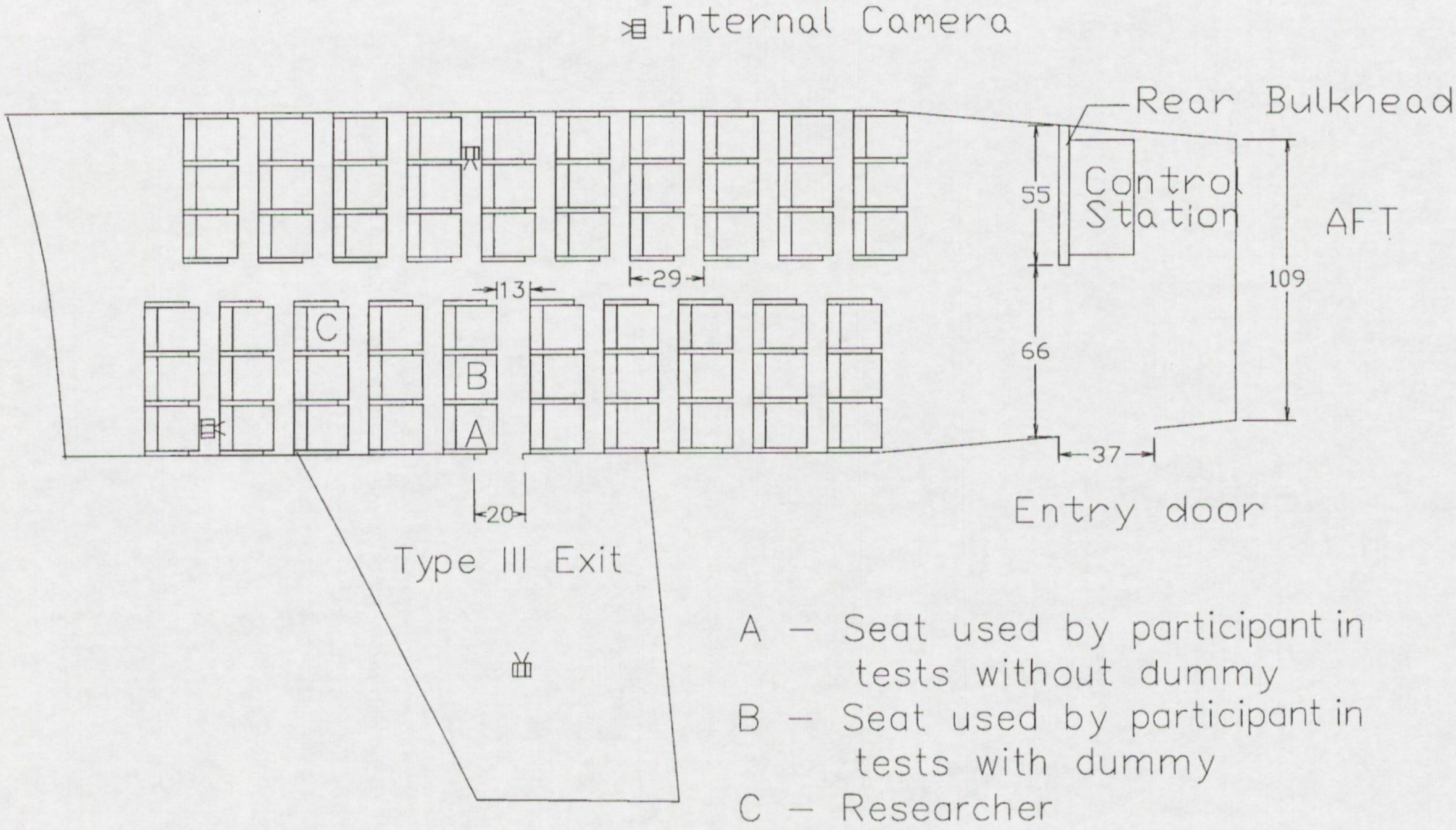


Figure E4 **Plan View of Boeing 737-200 Cabin Simulator**
Thirteen inch vertical seat projection around the Type III exit

Appendix F Safety Placard showing the operation of a conventional Type III exit

Appendix F Safety Placard showing the operation of a conventional Type III exit

Appendix F Safety Placard showing the operation of the modified Type III exit

Appendix G Questionnaire

Cranfield University
Department of Applied Psychology

Questionnaire Number 1

Volunteer Number

Please complete the relevant sections of the questionnaire and return it to the researcher

☐ ✓ Tick as applicable

1. Did you pay close attention to the safety briefing given by the cabin crew member?

Yes ☐
No ☐ → go to Q.2

If yes, did this aid your escape?

Yes ☐
No ☐

If yes, how did it aid your escape? ______________________________

____

____

If no, why didn't it aid your escape? ______________________________

____

____

2. Did you pay close attention to the additional safety briefing given by the cabin crew member, indicating that you were seated next to the overwing exit and might therefore be required to operate it in an emergency situation?

Yes ☐
No ☐ → go to Q.3

If yes, did this aid your escape?

Yes ☐
No ☐

If yes, how did it aid your escape? ______________________________

____

____

____

If no, why didn't it aid your escape? ______________________________

____

____

3. Did you study the safety card in detail?

Yes ☐
No ☐ → go to Q.4

If yes, did this aid your escape?

Yes ☐
No ☐

If yes, how did it aid your escape? ______________________________

____

____

If no, why didn't it aid your escape? ______________________________

____

____

4. Did you study the diagrams on the safety card/placard showing the method of operating the overwing exit in detail?

Yes ☐
No ☐ → go to Q.5

If yes, did this aid your escape?

Yes ☐
No ☐

If yes, how did it aid your escape? ______________________________

____

____

If no, why didn't it aid your escape? ______________________________

____

____

5. If you have any suggestions of ways in which the safety briefing or card/placard could be improved, such that they increase your likelihood of escape in an emergency situation please write them in the space below:

____

____

____

6. Were you hindered in your access to the exit from your seat?

Yes ☐
No ☐ → go to Q.7

If yes, what were you hindered by? ____

____

7. In opening the exit, please rate how easy or difficult you found the following by circling the appropriate number on the scale below:

	Very Easy ... Very Difficult
The location of the exit in relation to your seat	1———2———3———4———5———6———7
Finding the exit's operating handle	1———2———3———4———5———6———7
The clarity of exit operating instructions	1———2———3———4———5———6———7
Using the exit's operating handle	1———2———3———4———5———6———7
Opening the exit	1———2———3———4———5———6———7
The weight of the exit	1———2———3———4———5———6———7
The size of the exit	1———2———3———4———5———6———7
Clarity of instructions for disposing of the door	1———2———3———4———5———6———7
Exiting through the exit onto the wing	1———2———3———4———5———6———7

8. Please describe in detail anything about the overwing exit that caused you difficulty.

____

____

____

9. Did you operate the overwing exit from a seated or standing position?

Seated ☐
Standing ☐

For what reason did you operate the exit from this position?

____

____

10. How many times have you flown as an airline passenger before? (counting a return flight journey as one flight)

Never ☐
1-5 ☐
6-10 ☐
11-15 ☐
16-20 ☐
21-25 ☐
26-30 ☐
31+ ☐

11. Have you ever experienced an aircraft emergency situation?

Yes ☐
No ☐ → go to Q.12

If yes, what kind of emergency situation was it and what happened?

____
____
____

12. How often do you carry out strenuous physical exercise?

Once a day ☐
3+ times a week ☐
1-2 times a week ☐
1-2 times a month ☐
less than 1-2 times a month ☐

13. If there are any further points you would like to make please use the space provided below:

____
____
____
____

THANK-YOU

Appendix H Transcript of Pre-flight briefing

ON PASSENGER BOARDING

Ladies and gentlemen, Welcome on board. For your personal safety, any light articles which you have brought aboard the aircraft should be placed in the overhead bins or under the seat in front of you. Please ensure that hand luggage does not obstruct the aisles or any emergency exit. Passengers are asked to refrain from smoking until the no smoking signs have been switched off. Portable telephones must not be used at any time. Electronic items such as computers, tape recorders etc. may only be used when the seat belt signs are off.

DIRECTLY TO PARTICIPANT SAT BY THE TYPE III EXIT

I would like to draw your attention to the fact that you are sat by an emergency exit, should there be an emergency you would be expected to operate this exit. Instructions showing the method of operation can be found on the safety briefing card in the seat pocket in front of you and on the safety placard on the back of the seat, here.

AFTER THE DOORS ARE CLOSED

Ladies and Gentlemen, as the safety equipment on this aircraft may differ from that on other aircraft it is in your own best interest to pay attention to this safety briefing. In the seat pocket in front of you there is a safety card which the Captain would like you to read carefully before take-off. This contains details of the demonstration.

The emergency exits are clearly marked and are being pointed out to you. These are the two doors at the rear of the cabin and an additional exit in the centre of the cabin.

For those of you unfamiliar with the operation of the seat belt it is fastened and adjusted as demonstrated and unfastened like this.

We would also like to advise you of the emergency oxygen supply on board. Should additional oxygen be required throughout the cabin, the panel above your head will open automatically and masks like these will drop down. Remain seated, pull the mask towards you, and place over nose and mouth and breathe normally. Adults should fit their own masks before assisting children.

Please now ensure that your seat table is folded away, your seat back is upright with the armrests down, and your seat belt is tightly fastened.

Thank you for your attention. We would like to wish you a pleasant flight.

Appendix I Emergency evacuation scenarios

EVACUATION SCENARIOS

Scenario 1

After pre flight briefing 'Ladies and gentlemen this is your captain speaking. We are currently in a queue of aircraft awaiting take off and should be airborne in a few minutes.'

Engine noise for approximately 20 seconds then the command 'Undo your seat belt and get out'.

Scenario 2

Following the pre flight briefing a cabin check is made.

A short engine noise lasting approximately 15 seconds is heard then the command 'Undo your seat belt and get out'

Scenario 3

Following the pre flight briefing a cabin check is made.

A long engine noise lasting approximately 30 seconds is heard culminating with a large bang is heard then the command 'Undo your seat belt and get out'

Appendix J Raw evacuation times and participant demographics

Evacuation times for the modified Type III exit

* indicates incorrect disposal of the exit hatch.

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
1	13" Vertical	F	21	Right	161	58	13.52	6.36
	Projection						10.02	6.86
	No Dummy						9.12	5.88
2	13" Vertical	M	35	Right	171	73	4.64	2.80
	Projection						4.60	2.92*
	No Dummy						4.64	3.08
3	13" Vertical	M	24	Left	172	70	7.92	4.58
	Projection						5.64	3.36
	No Dummy						5.02	3.20
4	13" Vertical	F	23	Right	162	59	7.28	5.24
	Projection						7.56	4.88
	Dummy present						7.00	5.14
5	13" Vertical	M	39	Right	170	65	15.16	8.16
	Projection						13.48	6.72
	Dummy present						11.44	5.52
6	13" Vertical	F	21	Right	161	62	16.60	10.72
	Projection						10.44	7.12
	Dummy present						10.16	6.88
7	13" Vertical	F	44	Right	157	62	11.00	8.80
	Projection						7.44	4.40
	Dummy present						6.04	3.88
8	13" Vertical	F	28	Left	162	60	26.00	15.32
	Projection						9.80	5.20
	Dummy present						7.80	5.00
9	13" Vertical	M	31	Right	172	81	5.92	3.20
	Projection						5.32	2.00
	Dummy present						5.32	2.72
10	13" Vertical	F	40	Left	161	52	8.24	4.24
	Projection						7.00	3.88
	Dummy present						6.56	3.60

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
11	13" Vertical	M	34	Right	177	75	19.44	11.84
	Projection						16.72	10.60
	Dummy present						16.32	11.40
12	13" Vertical	F	20	Left	161	54	10.36	5.92
	Projection						8.20	4.60
	Dummy present						9.36	5.56
13	13" Vertical	F	21	Left	160	58	9.34	6.60*
	Projection						9.52	6.40
	Dummy present						8.76	5.52
14	13" Vertical	M	34	Left	175	70	13.32	5.92
	Projection						7.12	4.40
	Dummy present						5.92	4.12
15	Outboard seat	F	33	Left	164	63	6.08	2.68
	removed						5.92	2.44
							5.44	2.12
16	Outboard seat	M	25	Left	170	65	11.40	6.48*
	removed						11.84	4.48*
							8.60	4.76*
17	13" Vertical	F	23	Right	157	58	9.92	4.96
	Projection						7.20	3.60
	Dummy present						6.44	2.88
18	13" Vertical	F	34	Left	165	64	6.16	3.24
	Projection						4.16	2.36
	No Dummy						4.52	2.50
19	13" Vertical	M	20	Left	171	62	5.44	2.96
	Projection						5.84	3.60
	No Dummy						3.88	2.56
20	13" Vertical	F	35	Left	161	64	5.98	2.96
	Projection						5.96	3.60
	No Dummy						5.84	3.14
21	13" Vertical	M	36	Right	173	69	7.74	4.60
	Projection						7.40	4.76
	Dummy present						6.60	4.56
22	13" Vertical	M	40	Left	171	63	12.32	9.32
	Projection						7.14	4.28
	Dummy present						7.24	4.52

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
23	13" Vertical	F	43	Left	161	63	10.60	8.08
	Projection						10.84	5.88
	No Dummy						8.56	4.75
24	13" Vertical	M	42	Left	172	70	11.04	5.24
	Projection						9.24	5.10
	Dummy present						9.82	4.84
25	13" Vertical	F	41	Right	160	47	6.56	3.52
	Projection						6.86	3.56
	No Dummy						5.76	2.80
26	13" Vertical	F	48	Left	157	48	10.40	4.48
	Projection						7.40	5.32
	No Dummy						6.88	4.96
27	13" Vertical	M	48	Right	176	70	7.20	2.80*
	Projection						7.16	3.52*
	No Dummy						5.28	2.96*
28	13" Vertical	M	48	Left	165	66	6.00	4.28
	Projection						5.60	3.12
	No Dummy						6.04	3.76
29	13" Vertical	M	38	Left	170	63	9.12	4.16
	Projection						7.14	3.82
	No Dummy						6.88	2.92*
30	13" Vertical	F	42	Right	160	57	9.96	4.08
	Projection						5.66	2.92
	No Dummy						4.80	2.68
31	Outboard seat	M	42	Left	171	70	5.60	3.84
	removed						6.36	3.64
							5.70	3.32
32	13" Vertical	F	43	Right	160	59	7.64	3.08
	Projection						4.68	2.60
	No Dummy						5.05	2.57
33	Outboard seat	M	46	Right	172	66	4.68	2.52
	removed						5.04	2.88
							5.24	3.32
34	Outboard seat	F	43	Right	162	57	6.24	3.96
	removed						6.56	3.20
							5.12	3.28

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
35	13″ Vertical	M	37	Right	172	70	8.40	5.64
	Projection						7.28	5.36
	No Dummy						6.24	4.28
36	Outboard seat	M	28	Left	171	71	8.44	3.72
	removed						8.52	2.84*
							8.20	3.36
37	Outboard seat	F	22	Right	163	64	8.92	5.40
	removed						7.00	4.44*
							7.28	3.88
38	Outboard seat	F	28	Right	162	64	10.12	4.52
	removed						6.48	3.80
							5.16	2.92
39	Outboard seat	M	35	Right	172	67	9.56	4.40
	removed						6.16	3.72*
							6.20	2.88
40	Outboard seat	F	35	Left	161	64	6.16	3.08
	removed						7.98	3.70
							6.04	3.16
41	Outboard seat	F	47	Left	161	60	9.52	3.76
	removed						6.52	4.20
							5.76	3.08
42	Outboard seat	M	38	Right	174	74	6.44	3.96
	removed						7.00	4.56
							6.44	4.28
43	Outboard seat	M	30	Right	175	70	4.84	1.52
	removed						4.44	1.96
							4.08	2.08
44	Outboard seat	F	34	Left	158	66	8.36	4.80
	removed						7.76	3.84
							6.26	3.36
45	Outboard seat	F	23	Right	162	64	8.80	5.16
	removed						6.48	3.56
							5.68	3.72
46	13″ Vertical	M	34	Left	175	70	6.64	4.64
	Projection						6.12	4.28
	Dummy present						6.04	3.68

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
47	Outboard seat	M	25	Left	175	70	9.28	3.60
	removed						7.28	3.40
							6.80	3.44
48	13" Vertical	M	23	Right	173	70	10.16	4.00
	Projection						8.36	4.40
	No Dummy						6.28	3.68

Evacuation times for the Conventional Type III exit
* Indicates incorrect disposal of exit hatch

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
1	13" Vertical	M	21	Right	177	80	14.80	8.88
	Projection						12.32	8.70
	No Dummy						11.44	6.84
2	13" Vertical	F	28	Right	161	59	12.04	9.24*
	Projection						19.84	17.08*
	No Dummy						12.64	10.56
3	13" Vertical	M	24	Left	171	68	12.28	8.52*
	Projection						10.20	6.92*
	No Dummy						10.24	6.92*
4	13" Vertical	M	37	Left	169	65	9.24	6.44*
	Projection						8.76	5.64*
	No Dummy						9.80	6.60
5	13" Vertical	F	29	Right	162	68	23.76	17.72
	Projection						19.40	14.52
	No Dummy						18.36	14.60
6	13" Vertical	M	37	Right	175	70	14.24	9.00*
	Projection						14.56	9.44
	No Dummy						11.68	7.84
7	13" Vertical	F	26	Right	175	64	16.82	10.84*
	Projection						17.88	13.16
	No Dummy						16.64	11.68

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
8	13" Vertical	F	30	Right	156	55	28.56	21.32
	Projection						18.68	12.12
	No Dummy						23.40	15.00
9	13" Vertical	M	32	Left	171	66	12.84	10.72
	Projection						13.04	10.12
	No Dummy						12.80	9.72
10	13" Vertical	M	28	Left	180	70	14.32	9.96
	Projection						10.80	7.00
	No Dummy						9.20	6.20
11	13" Vertical	F	21	Right	165	67	30.92	24.16*
	Projection						18.12	12.92*
	Dummy present						13.40	8.60*
12	13" Vertical	M	22	Right	171	67	29.00	19.28
	Projection						25.00	12.04
	Dummy present						16.56	7.60
13	13" Vertical	F	24	Left	165	57	30.64	26.34
	Projection						28.60	23.56
	Dummy present						19.04	14.76*
14	13" Vertical	M	35	Left	176	83	16.80	14.00*
	Projection						19.48	15.68
	Dummy present						12.92	10.20
15	13" Vertical	M	23	Left	170	65	28.04	7.96*
	Projection						17.28	12.28*
	Dummy present						13.00	8.72*
16	13" Vertical	F	40	Left	155	55	17.32	13.64*
	Projection						10.12	6.92*
	Dummy present						16.34	13.96*
17	13" Vertical	F	45	Left	167	61	29.76	25.28*
	Projection						30.40	23.08
	Dummy present						32.44	26.96
18	13" Vertical	M	49	Right	175	75	11.20	8.52*
	Projection						10.48	8.06*
	Dummy present						8.24	6.04*
19	13" Vertical	M	22	Right	176	64	8.88	6.40
	Projection						9.10	6.36
	Dummy present						8.60	6.16

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
20	13" Vertical	M	23	Left	171	72	32.84	28.48*
	Projection						23.88	19.52*
	Dummy present						14.72	11.96*
21	13" Vertical	M	24	Right	176	79	12.28	7.92
	Projection						10.76	7.04
	No Dummy						9.60	6.60
22	13" Vertical	F	43	Right	168	66	13.84	11.96
	Projection						20.84	18.52
	Dummy present						18.72	16.72
23	13" Vertical	F	46	Right	167	62	14.08	12.24*
	Projection						9.12	7.40
	Dummy present						10.24	8.48
24	13" Vertical	M	23	Right	175	67	11.72	8.76*
	Projection						14.20	11.64
	No Dummy						12.84	10.36
25	Outboard seat	M	33	Right	181	68	15.52	8.04*
	removed						31.72	20.40
							13.56	9.08
26	Outboard seat	F	48	Left	158	63	22.00	18.92
	removed						19.44	14.52
							16.16	11.36
27	Outboard seat	M	38	Left	173	76	11.76	6.84*
	removed						10.20	6.12*
							10.42	6.9
28	Outboard seat	M	35	Right	164	70	23.48	16.16*
	removed						31.40	21.92*
							18.72	10.60*
29	Outboard seat	M	48	Left	175	75	12.80	6.12*
	removed						11.44	5.48*
							14.48	9.72
30	Outboard seat	M	33	Left	172	80	16.12	11.48*
	removed						11.96	6.76*
							14.08	9.76
31	Outboard seat	F	40	Right	164	59	7.40	5.24*
	removed						13.36	7.76
							7.28	5.24*

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
32	Outboard seat	M	37	Right	165	75	17.08	11.28
	removed						11.20	8.36
							11.48	9.00
33	Outboard seat	M	41	Right	174	62	12.52	7.68*
	removed						9.72	7.08
							10.28	7.68
34	Outboard seat	F	31	Right	161	56	18.82	13.76*
	removed						13.20	6.96*
							13.62	7.06*
35	Outboard seat	M	23	Left	176	63	15.08	8.04
	removed						13.80	9.32
							10.80	8.16
36	13" Vertical	F	36	Right	157	60	12.20	7.84*
	Projection						12.12	8.64*
	Dummy present						22.12	18.44
37	13" Vertical	M	32	Right	175	80	7.44	5.92
	Projection						9.62	7.48
	Dummy present						6.88	5.32
38	13" Vertical	M	26	Left	178	80	18.88	15.48
	Projection						15.40	11.48
	Dummy present						13.00	9.40
39	13" Vertical	F	23	Left	159	65	25.60	22.88
	Projection						18.40	15.52
	Dummy present						15.68	13.40
40	13" Vertical	F	24	Left	165	70	9.60	7.04*
	Projection						10.00	8.04
	No Dummy						9.72	7.80
41	13" Vertical	F	43	Left	157	61	19.68	15.96
	Projection						17.52	13.36
	No Dummy						20.68	17.60
42	13" Vertical	F	20	Left	160	47	15.52	10.64*
	Projection						15.24	10.80*
	No Dummy						14.48	8.84*
43	13" Vertical	F	23	Left	157	57	18.52	12.40*
	Projection						20.12	13.04*
	No Dummy						21.08	11.52

Subject Number	*Configuration*	*Sex*	*Age*	*Handedness*	*Height*	*Weight*	*Total evacuation time*	*Evacuation time from handle*
44	Outboard seat	F	26	Left	165	49	14.40	6.88*
	removed						12.56	7.36*
							13.12	7.92*
45	Outboard seat	F	33	Right	165	62	15.96	9.36*
	removed						22.32	17.80*
							21.52	17.84
46	Outboard seat	F	22	Right	155	55	11.80	8.96
	removed						14.88	11.28
							14.84	11.88
47	Outboard seat	F	28	Left	164	44	16.68	12.28*
	removed						11.24	7.88*
							10.44	8.32*
48	Outboard seat	F	21	Left	156	57	19.64	10.66
	removed						15.20	15.52
							14.68	10.04