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EMERGENCY EVACUATION TESTS OF THE C-9A AEROMEDICAL AIRCRAFT

BURTON P. CHESTERFIELD, FIRST LIEUTENANT, USAF

TECHNICAL REPORT ASD-TR-69-4

MARCH 1969

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EMERGENCY EVACUATION TESTS OF THE C-9A AEROMEDICAL AIRCRAFT

BURTON P. CHESTERFIELD, FIRST LIEUTENANT, USAF

FOREWORD

This report is the final summary of work conducted by the Deputy for Engineering of the Aeronautical Systems Division (ASD), Air Force Systems Command, during the week of 9-14 September 1968 at Scott Air Force Base, Illinois. Under Program 412A, a full-scale series of emergency evacuation tests was conducted on the C-9A Aeromedical Aircraft. Lt Burton P. Chesterfield, ASD Escape Systems Project Engineer, who was in charge of the study and test program, was assisted by A1C David Steinberg, Personnel Subsystems technical assistant.

Without the able assistance of many persons behind the scene, who gave time and manpower, these tests could not have been run smoothly. Special thanks go to the following:

Mr. James D. Garner, Federal Aviation Administration, for his technical assistance and the loan of FAA timing equipment;

Mr. O. K. Stampley, Federal Aviation Administration, Western Regional Headquarters, for his technical assistance at the test site;

Mr. Gary E. Wullenwaber, Federal Aviation Administration, Flight Standards Division, for his technical assistance at the test site;

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Mr. Richard L. Peterson of Air Force Flight Dynamics Laboratory and Maj Gary B. McIntire of the Deputy for Engineering, ASD, for their valuable contributions and technical assistance.

This report was submitted by the author 21 January 1969.

This technical report has been reviewed and is approved.

GINO P. SANTI
Chief, Crew Support Division
Directorate of Crew and AGE Subsystems Engineering

ABSTRACT

The series of tests reported herein had two primary objectives -- a) to gather technical data needed to evaluate the ground and ditching characteristics of the C-9A aeromedical aircraft; and b) to obtain data necessary for revising and updating specifications and the new AFSC Design Handbook, System Safety, DH 1-6, to provide better emergency escape potential for future aircraft. An important secondary benefit realized from these tests was the development of better medical training procedures for handling the wounded during ground and ditching emergencies.

The C-9A aircraft was used in the tests which were conducted under cover of darkness to simulate the worst possible survivable crash condition -- that of darkness or fire and smoke. Six tests were made, using a different combination of exits each time. Exits that would be available during a survivable ground crash were used during five of the tests, and exits available during a water ditching were used during the sixth test. It is important to note that no more than half of the exits were made available during each test as prescribed by MIL-STD-872, which assumes that one half of the exits will be blocked by fire or structural damage. The C-9A has seven exits available, but the assumption that half the exits were blocked permitted the use of no more than three exits at a time. The exception to this rule was the ditching test in which the aircraft was assumed to have ditched at sea and come to rest, floating at wing level, with all four overwing exits available for use. The average evacuation time was 128 seconds, which is 68 seconds more than time permitted by current standards. The 128-second average was computed without considering Test No. 4, which was not conducted in accordance with MIL-STD-872.

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SECTION I

INTRODUCTION

Why conduct emergency evacuation tests?

Because virtually all survivable aircraft accidents occur with little or no warning, during takeoff or landing; and in a panic situation, egress routes must be so obvious that ambulatory patients will require little or no assistance to escape (Figure 2), and nonambulatory patients can be evacuated easily and quickly. Therefore, it is important to test and evaluate the characteristics of the airframe, such as the number of exits, their size and location, escape equipment, and interior configurations, including emergency lighting, seating density, environmental factors, and crew capability (Figures 3, 4, and 5). Passenger briefings on emergency evacuation procedures and the proper operation of emergency escape equipment are of special importance during testing to ensure their adequacy and system compatibility should emergency evacuation be necessary.

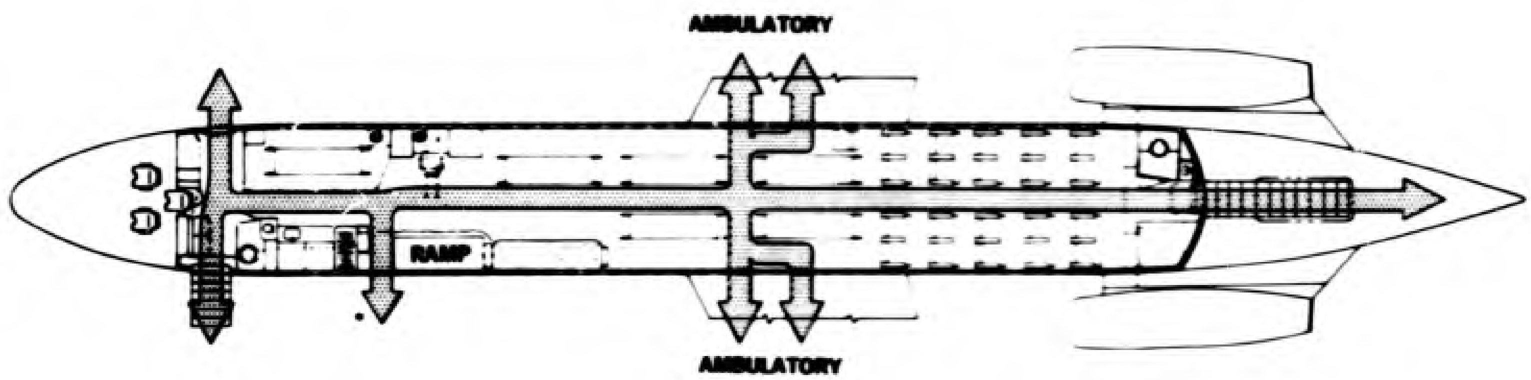
There is little doubt that future USAF aircraft can be designed and built safer if the deficiencies of the current aircraft are better understood. The six egress test series conducted on the C-9A and questionnaires filled out by evacuees, crewmen, and medical personnel offer valuable data necessary to develop higher standards for aircraft design. In addition, the series of tests has demonstrated that the C-9A can be evacuated within a reasonable elapsed time in the event of an emergency. However, this elapsed time could be lessened. Recommendations for obtaining this improved egress rate are found in Sections IV and V, Conclusions and Recommendations. The evaluation of the responses to the special questionnaire given to each patient is presented in Appendix II.

To understand the need for emergency evacuations, emergency situations must be examined as they exist. They are really three major types of aircraft accidents: aborted takeoffs, enroute accidents, and approach and landing accidents. Aborted takeoff emergencies occur after starting takeoff roll. Approximately 20 percent of all jet cargo, cargo/transport, and passenger type aircraft accidents fall into this category. Enroute accidents, including many of

Figure 1. C-9A Aeromedical Aircraft

the nonsurvivable type, occur during flight and include such accidents as collision with rising terrain, engine failure and/or tearaway, and wing failure. Midair collisions are included in this group. Approximately 30 percent of all the jet cargo, cargo/transport, and passenger type aircraft accidents fall into the enroute accident category. Approach and landing emergencies are those in which the pilot either lands short of the runway, skids off the runway, stalls, or otherwise loses control. Approximately 50 percent of all jet cargo, cargo/transport, and passenger type aircraft accidents are of the approach-or-landing type.

Certain accidents are considered survivable if the landing forces are not above human endurance or intensity limitations. It is possible that an accident can be 100 percent fatal and still be considered survivable, if lives could have been saved by the proper use of escape equipment and/or proper crew training.



•NOT FAA CERTIFIED FOR EMERGENCY EGRESS
AVAILABLE UNDER CERTAIN CONDITIONS

Figure 2. C-9A Emergency Egress

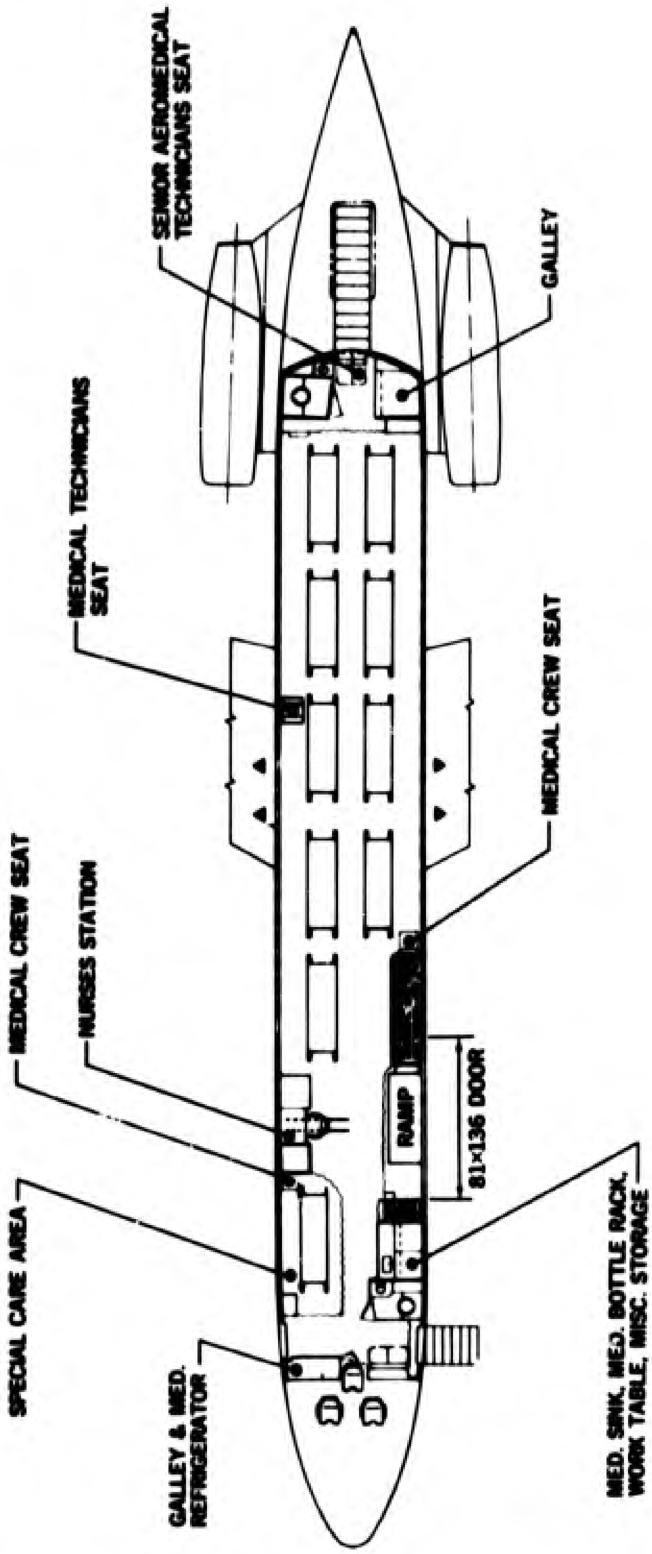


Figure 3. C-9A Litter Configuration

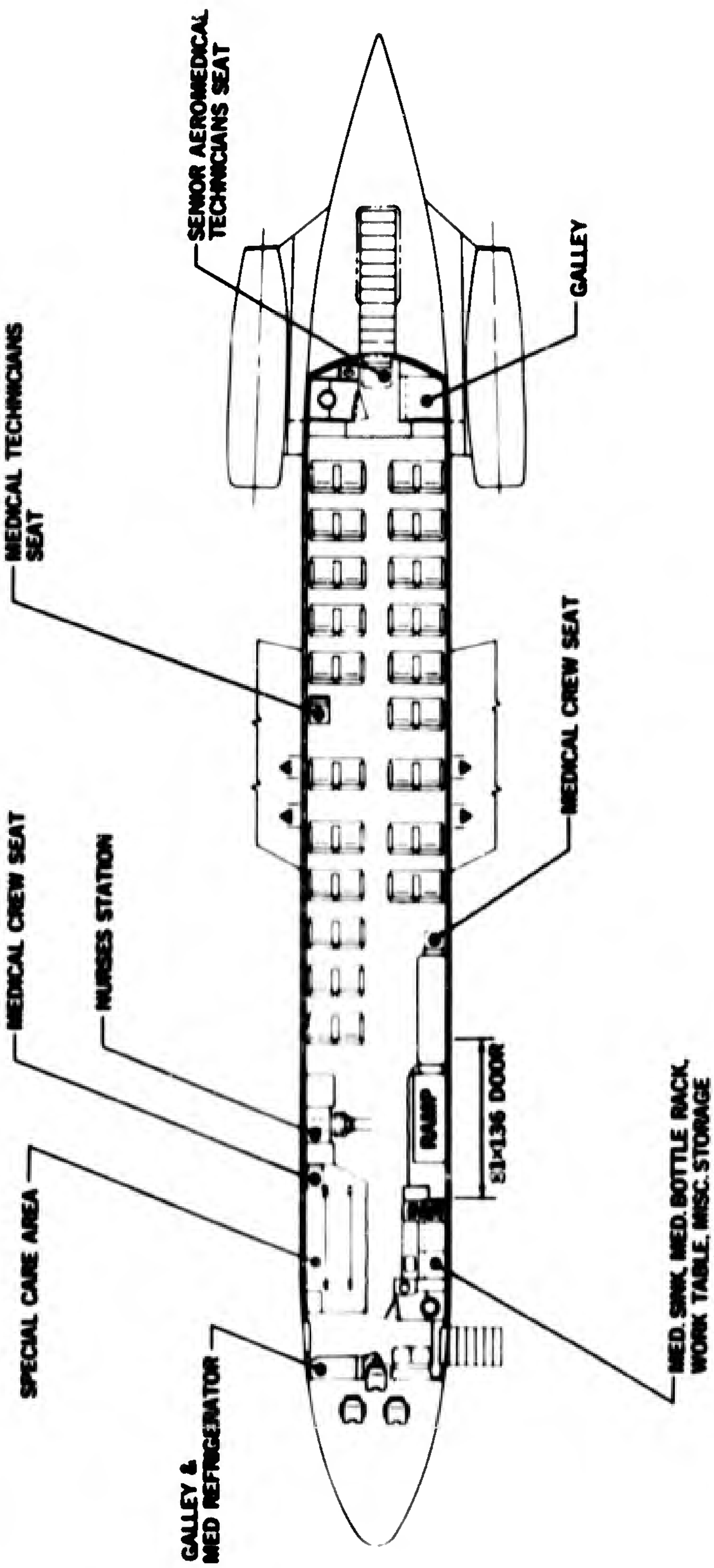


Figure 4. C-9A Ambulatory Configuration

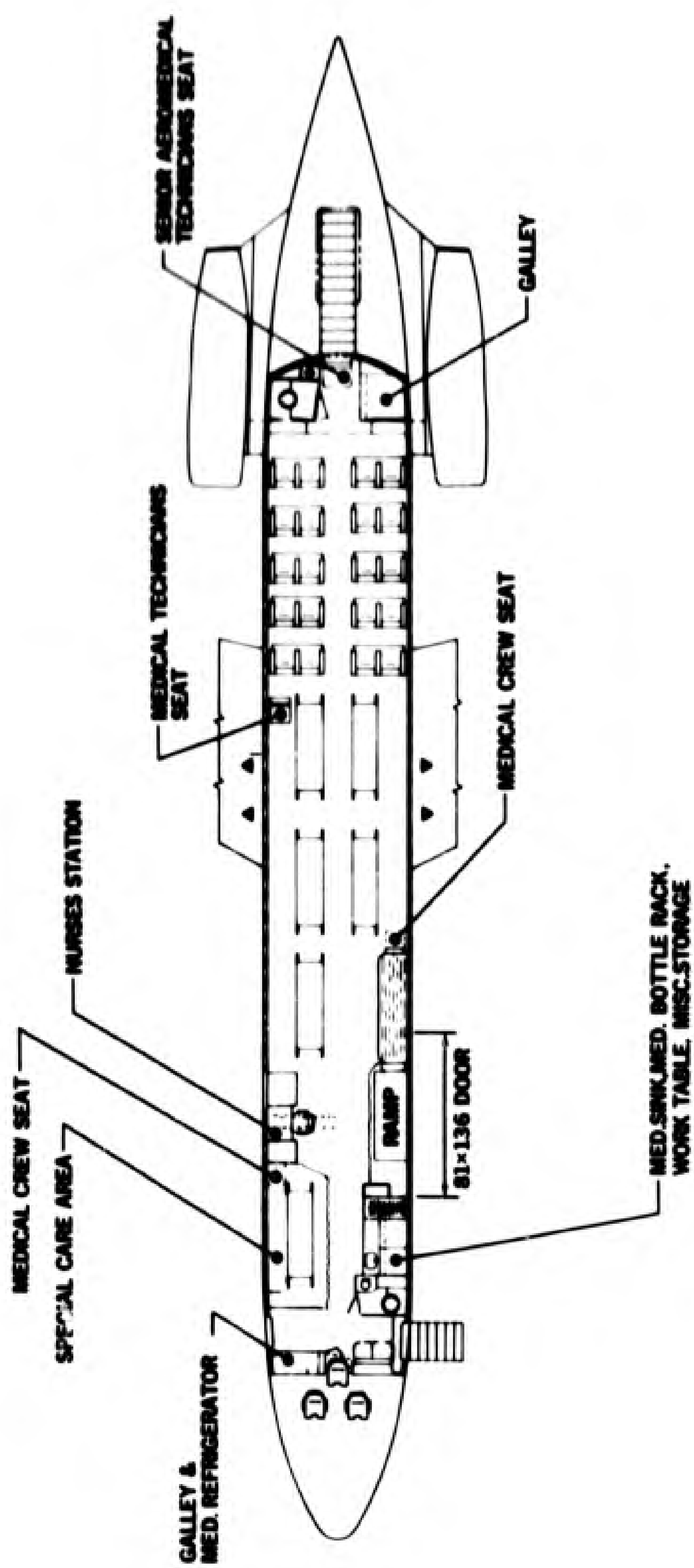


Figure 5. C-9A Mixed Configuration

Thus, some accidents, where it may have been possible to survive, should be classed as survivable. On the other hand, nonsurvivable accidents are classed as accidents in which crew and passenger areas have been so badly deformed that there was little chance of survival.

Because many cargo and cargo/transport accidents occur at relatively low airspeeds, and near airfields with fire suppression and rescue equipment, the chances of survival are high. The chances of survival are especially high through proper understanding of, and education and training in emergency evacuation procedures. Evacuation tests such as the ones conducted on the C-9A aid in this education, training, and overall understanding.

To completely understand this series of tests, some general terms connected with the tests must be understood. The definition for the terms follow.

a. Simulated Ground Evacuation Tests - Simulated ground evacuation tests are those tests conducted to demonstrate that a sufficient number of doors, hatches and normal emergency exits, as well as sufficient emergency escape equipment are provided to permit complete evacuation of personnel from the aircraft on the ground within a reasonable time period.

b. Simulated Ditching Escape Tests - Simulated ditching escape tests are those tests conducted to demonstrate that a sufficient number of ditching escape hatches and equipment, and adequate flotation and survival gear are provided to permit all personnel to evacuate the aircraft within a reasonable time.

c. Total Test Time - The time necessary to completely evacuate the patients, medical personnel, and crew without endangering their lives.

d. Starting Time - The time at which the test is started. All times were measured from this reference. The starting time is referred to as "Time T = 0" in the tables that appear in Appendix II.

e. Exit Opening Time - The time required to open and/or remove a hatch or door so that personnel may pass through the opening.

f. Total Ground Evacuation Time - The time required for all evacuees to clear the aircraft and reach the ground.

g. Total Ditching Time - The time required for all evacuees to reach the simulated water level.

h. Inflatable Emergency Escape Slide - Escape slides which provide a means of descending to the ground from exits of cargo and cargo/transport aircraft. Slides are inflated manually or can be designed to open automatically when the exit is opened during an emergency.

i. Girth Bar - The metal bar attached to the escape slide which, when snapped into place in the doorsill, allows the slide to be deployed from the doorsill.

SECTION II

TEST PARAMETERS AND VARIABLES

In order to simulate the worst emergency condition possible without resorting to real smoke, the tests were conducted at night, using only the normal battery-powered emergency exit lighting. This system provided 0.05 footcandles of light from the cabin ceiling, measured at seat armrest level up and down the aisle. The emergency exits were lighted by FAA standard-type emergency exit wall and ceiling mounted signs and lights.

Motion pictures were made to capture the action of both the exterior views during egress and the interior of the cabin showing actions of crew and patients during the simulated crash landings, ditchings, and aborted takeoffs. Motion pictures of the action inside the aircraft during each test were taken using infrared floodlights, thus providing no illumination which would aid egress. The exterior cameras used a fast film -- black and white Tri-X -- during the first three tests, which were conducted at dusk. Later in the evening, when the test environment became sufficiently dark, the exterior cameras were loaded with infrared film and all white light was turned off to provide complete darkness on the aircraft exterior. Infrared floodlight provided invisible light at each exit to aid in photo coverage without offering illumination that would have been beneficial to patients and crew during egress.

Accurate elapsed times for each test were recorded by a series of four full-sweep second hand clocks which were started simultaneously at the moment each test started. These clocks were placed within view of each camera during the tests Thus, the record of the elapsed time for egress through each exit and total test time are recorded on film. As a backup, two-man observer-timer teams, equipped with stopwatches and observer-timer scorecards, recorded observed elapsed times at the particular exits to which they were assigned.

Two flight nurses and three medical technicians were aboard during each test. The number of crew members is critical as the elapsed total time is dependent upon the number of persons who are able to assist in the litter evacuation. Thus, the persons most directly responsible for the rapid egress of all ambulatory and litter patients are the medical and flight crewmembers. This is the one largest variable which affects the egress time. When removing litter patients through the exits, it is necessary to remove each patient from his litter and direct him, drag him, or carry him to the nearest exit. The final responsibility of the flight and medical crews is to ensure that all patients reach an exit.

During all of the tests, except Test No. 3, the situation simulated was that the aircraft, shortly after takeoff, had come to rest on its gear, and that there were no injuries to the passengers or crew. The situation simulated in Test No. 3 was that the aircraft ditched at sea with little or no external structural damage, and it came to rest floating at wing level, with no ensuing fire. The configuration of each test is given in Table I.

TABLE I

CONFIGURATION OF EACH TEST

Test No.	No. Litters	No. Seats	Exits to be Used	Inflatable Evacuation Slides Deployed
1	20	20 seats, 10 per side	Left forward door and left overwing exit only	Left forward door slide only (Fig. 6)
2	24	10 seats on one side, 4 on other	Right forward door and right overwing exit only	Right forward door slide only (Fig. 7)
3	28	10 seats on one side	Overwing exits only (Fig. 8)	None - ditching capability test
4	36	4 seats on one side	Tail cone exit only	Tail cone exit slide only
5	40	0	Tail cone exit and both forward doors	All slides available
6	40	0	Both forward doors	Left and right forward door slides only

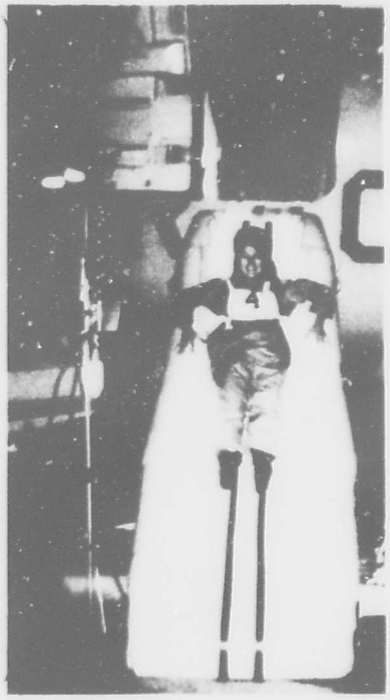


Figure 6. Left Forward Exit and Inflated Escape Slide

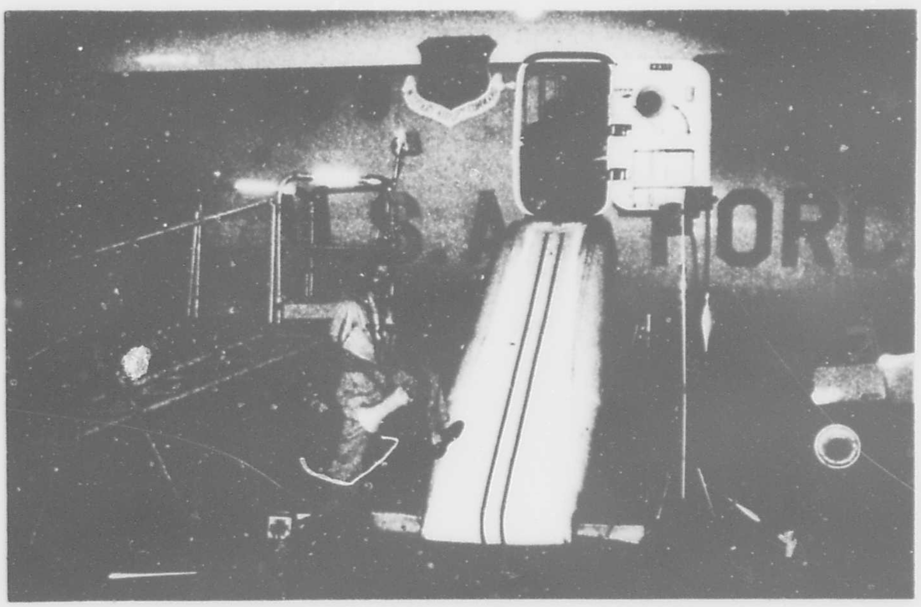


Figure 7. Right Forward Exit and Inflated Escape Slide

SECTION III

TEST RESULTS AND DATA EVALUATION

1. ELAPSED TIME

The average time recorded was 128 seconds, which was considered fair for litter patients aboard the C-9A. This average does not include the 224-second time required for the tailcone egress test which was not in accordance with MIL-STD-872. The elapsed times obtained from the film and those observed by the observer-timer teams correlated very closely upon final comparison. All of the times recorded for individual events are gathered together in tables in Appendix II. Each table deals with one important event and compares the results of this event during each test. The tables are arranged in the sequence in which the events occurred during the tests. Table VII is the analysis of the actual time available for escape after the time periods necessary for exit opening and slide deployment have been substracted. The time necessary for opening each of the various exits is recorded in Table II. Table III shows the various emergency escape slide inflation times, and Table IV shows at what point during the tests the slides became fully deployed. The amount of time it took the first man to reach the ground from each exit is shown in Table V and the time it took the last man to reach the ground and which exit he used is shown in Table VI. This last recorded time is also the total test time.

2. LIGHTING

The emergency lighting, which provided 0.05 footcandles of light measured up and down the aisle at seat armrest level, was found to be very adequate. Each emergency exit was well lighted and provided adequate light for egress. Also, the aisle leading through the tail of the aircraft to the tailcone exit was well lighted.

3. MEDICAL CONFIGURATION

Many of the patients were wearing braces and bandages (Figure 9) of one form or another. These bandages made handling the patient awkward and

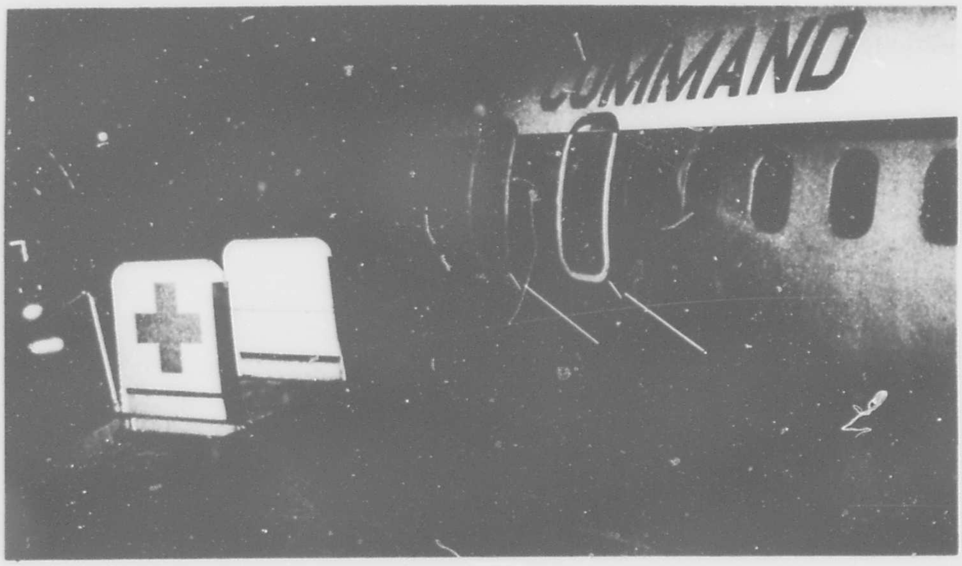


Figure 8. Exterior View of Overwing Exits Closed

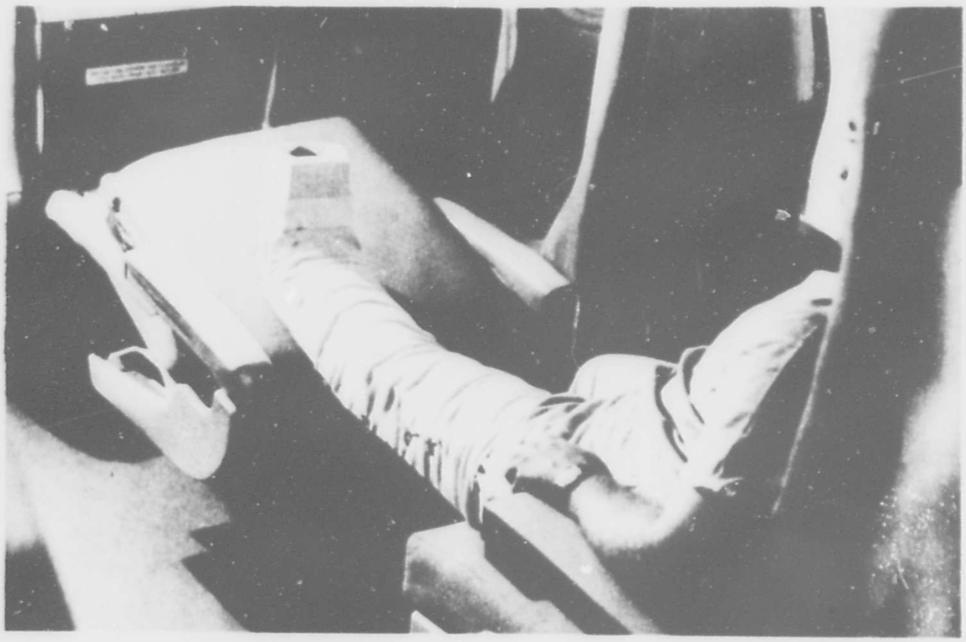


Figure 9. Typical Leg Bandage Which Made Egress Difficult

probably contributed to the total elapsed test time on each test. Also, in each test, a configuration was used which included patients on four-high litter tiers, the maximum for the C-9A. (Normal patient placement configuration is three-high litter tiers, which would be quicker to evacuate.) Therefore, the bandages and the configuration, along with the fact that these tests were conducted at night, created the worst crash condition that could be simulated. Thus, it is felt that, if any one of these conditions were improved the elapsed times on similar tests would be even lower.

4. EVALUATION OF INDIVIDUAL TESTS

a. Test No. 3

The time recorded for Test No. 3, the ditching test using the four overwing exits, took the least time for total evacuation (see Table VI). This fact is significant, because it is an indication that the four overwing exits (Figures 8 and 10) will provide the quickest route for escape. It is important to note that of the four overwing exits available, only 17 percent used the two aft exits while 83 percent used the two forward exits. Thus, these two aft exits provide only a slightly improved egress capability. One major factor contributing to this was that the aft exits were located behind tiers of litters which tended to impede rapid egress. This is especially true of the aft overwing exit on the right side because passengers cannot walk around one end of the litter to reach the exit since the medical technician's forward-facing seat (Figures 11 and 12) blocks the passageway. To a lesser extent, this problem exists on the left-hand side also with the nurse's aft-facing station. See Figure 13 showing the nurse's seat and Table VII showing the time wasted at the aft overwing exits. Although Test No. 3 was a ditching test in that only the ditching exits (overwing) were used, it was not a test of life rafts or their prepacked survival gear, thus no life rafts were deployed. The patients were, however, instructed to wear life jackets, and the test was conducted to determine if wearing a life jacket would interfere with egress through a small 20 inch by 36 inch exit. It is significant to note that the life jackets posed less of a problem to patients during egress than did their bandages.

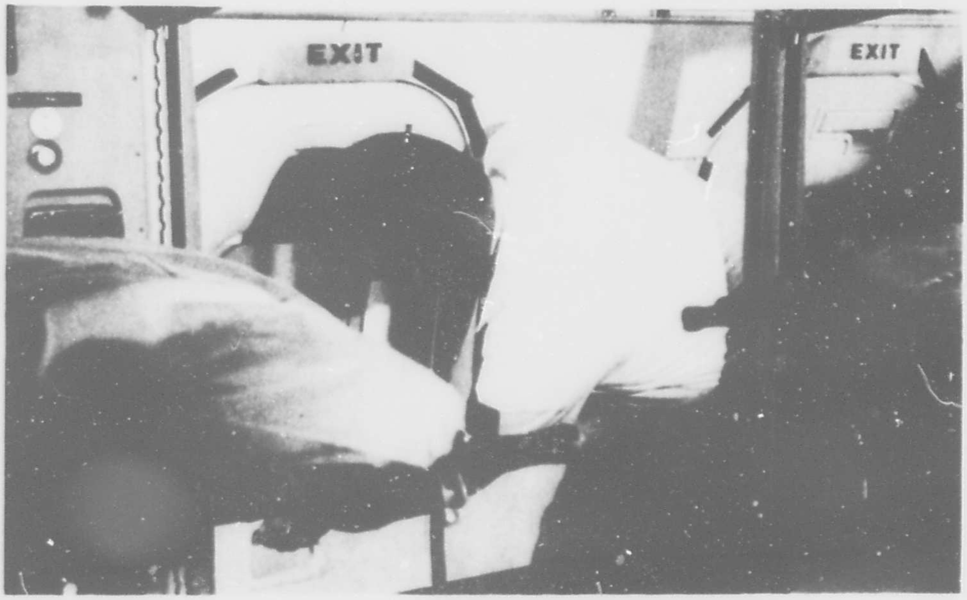


Figure 10. Overwing Exit

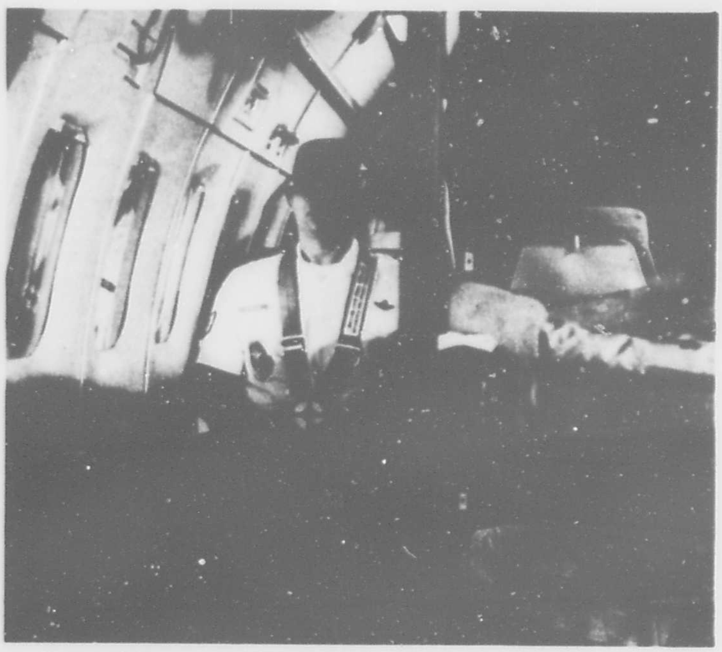


Figure 11. Medical Technician's Seat

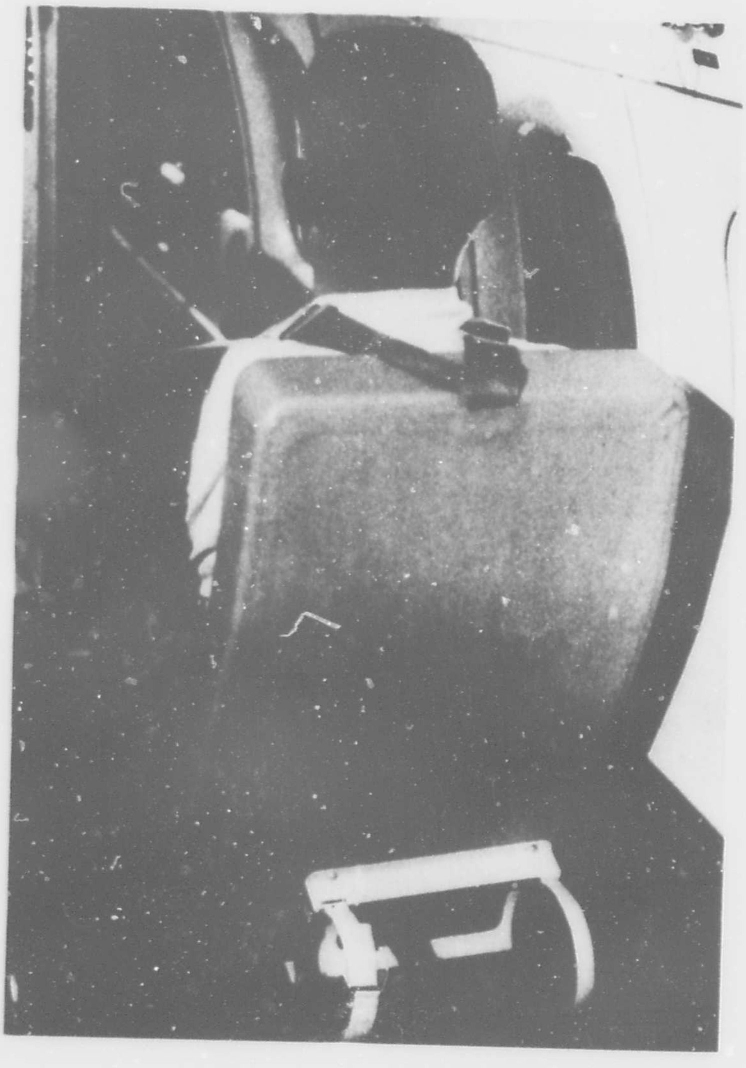


Figure 12. Passageway Blocked by Seat

Figure 13. Nurse's Station

b. Test No. 2

Test No. 2, with total time of 105 seconds, was considered the most realistic and the best test in spite of an error made by a crewmember. The error made by the crew, and it is a typical error, was the failure to attach the inflatable escape slide girth bar to the aircraft floor in front of the door (see Figures 14 and 15). The error wasted 30 valuable seconds at the right forward exit and affected the recorded times of all related events. The failure can be traced throughout Tables II, IV, V, and VII. Because the bar was not properly in place, the inflatable escape slide could not be deployed, thus patients would have had to jump or fall to the ground -- a distance of about eight feet. During an actual emergency, this error could mean the lives of passengers and crewmembers using this exit. Because of the panic involved, people would be pushed through the open door and onto the ground. Recently, a commercial

Figure 14. Packaged Escape Slide

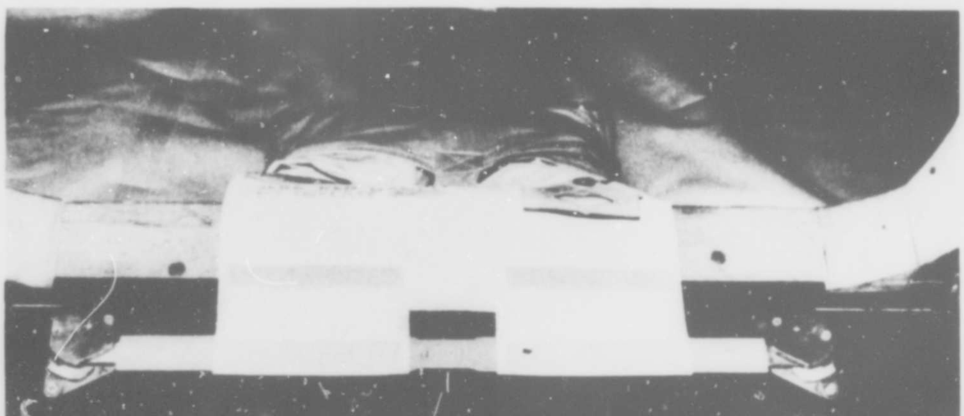


Figure 15. Escape Slide Girth Bar

aviation accident provided a good example of panic which caused two escape slide inflation failures. The aircraft, a TWA Boeing 707, ran off the end of the runway during an aborted takeoff from the Greater Cincinnati Airport, Erlanger, Kentucky, on 6 November 1967. During egress through the two forward exits, the hostesses were unable to manually inflate the ''nonautomatic'' escape slides before being pushed out the exits by panicky passengers. These errors in slide deployment can be avoided by the installation of slides that inflate automatically when exit is opened and the proper positioning of the associated girth bars.

c. Test No. 1

During Test No. 1, left side exits were used. This test required 128 seconds, which is 23 seconds worse than time period when the identical exits were used on the right-hand side during Test No. 2. The actual evacuation during Test No. 1, using the forward left side exit and the left overwing exits, is shown in Figure 6. When Test No. 1 is compared to Test No. 2, several interesting points are observed. The briefing given by the medical crew of the second test was much better than that given prior to the first test. In fact, the preflight briefing was practically nonexistent on Test No. 1, which may account for the slow lapsed time obtained. This points to the extreme importance of giving a clear, yet concise preflight briefing that will save a few precious seconds and lives. Crew training in emergency procedures is a very important part of any emergency egress, especially if passengers and patients have never experienced a simulated or actual emergency egress. This fact was shown when interior film coverage of Test Nos. 1 and 2 were compared. Each test used patients and medical crewmembers who had never before participated in such a test and therefore did not know exactly what to do when the signal to evacuate was given. But, the same pilot and copilot participated in both tests, and, because of their training gained in Test No. 1, they worked more effectively in aiding the evacuation of patients in Test No. 2.

d. Test No. 4

Test No. 4, involving only the tailcone exit, was conducted to test the capability of the tailcone. The test was not intended to conform to the MIL-STD-872 requirement that calls for tests to be run using one half of the available exits. The test took 224 seconds, which is considered poor from an elapsed time standpoint. Figures 16a and b show the aircraft tail with the tailcone removed and the escape slide inflated. There is a narrow passageway leading from the aft bulkhead to the tailcone slide. In theory, this exit will provide an excellent path of egress, straight down the aisle and out the tailcone (see Figure 2); but, in actuality, there is some doubt that the tailcone will be a usable exit because of the danger of fire around the tail near the engines.

e. Test No. 5

Test No. 5, which required the average test time of 128 seconds, was a test simulating fire at both wing root locations, thus the overwing exits were considered useless. It was a real test of the capability of the medical crewmembers. The test was conducted with an augmented medical crew consisting of two extra medical technicians in addition to the three normal medical technicians and two flight nurses. This test was one of the most difficult as there were no ambulatory patients on board, which meant that there were more litters requiring individual attention. It is important to note that the two extra medical technicians played an important part in the evacuation.

f. Test No. 6

In Test No. 6, fire was simulated at each overwing exit and the tailcone; only the two forward exits were available for escape. The test required 175 seconds which is considerably more than should be necessary for these two exits. In this test, as in Test No. 5, there were no ambulatory patients on board, thus each patient required some attention from members of the medical crew. Two factors helped to increase the total test time of Test No. 6 as compared to Test No. 5 -- the tailcone was not used in Test No. 6 and this test did not use an augmented medical crew as was used on Test No. 5. Throughout all the tests, and especially in Test Nos. 4 and 6, where the number of available exits was limited to one or two, proper medical crewmember training and motivation were important. Figure 17 shows an example of one method of assisting a litter patient, and Figure 18 indicates another example of crew training and teamwork. Crewmembers assisted in every way possible to assure rapid movement of patients down the aisles towards the exits. Figure 19 shows a patient sliding down the emergency escape slide from the forward, left side exit. Note the full

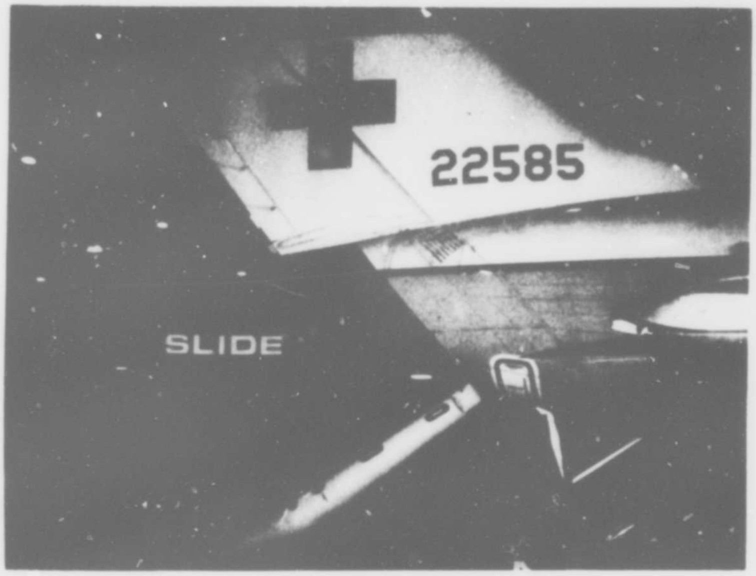


Figure 16a. Tailcone Escape Slide, Side View

Figure 16b. Tailcone Escape Slide, End View

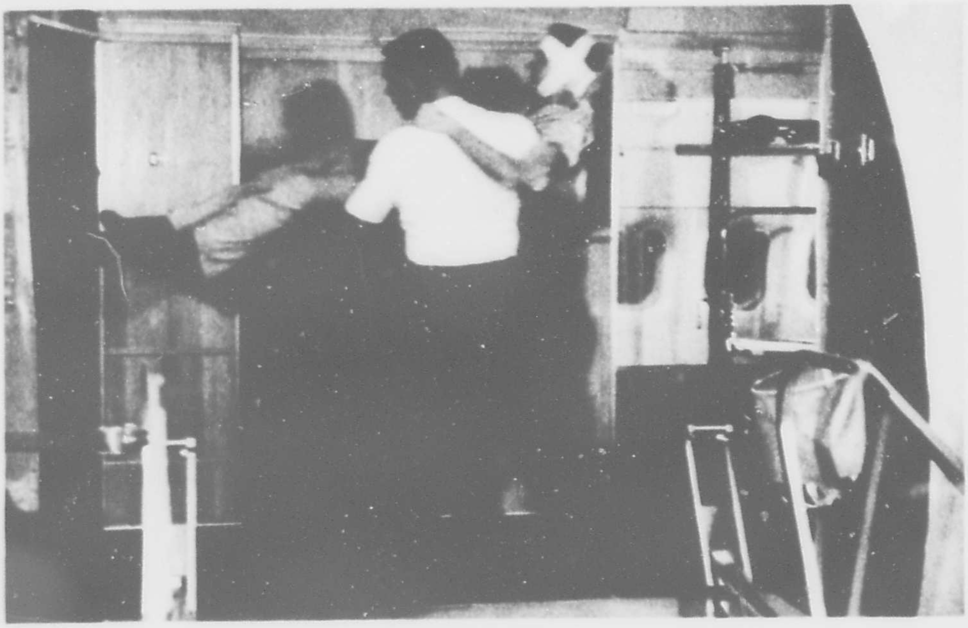


Figure 17. Evacuation of Litter Patient

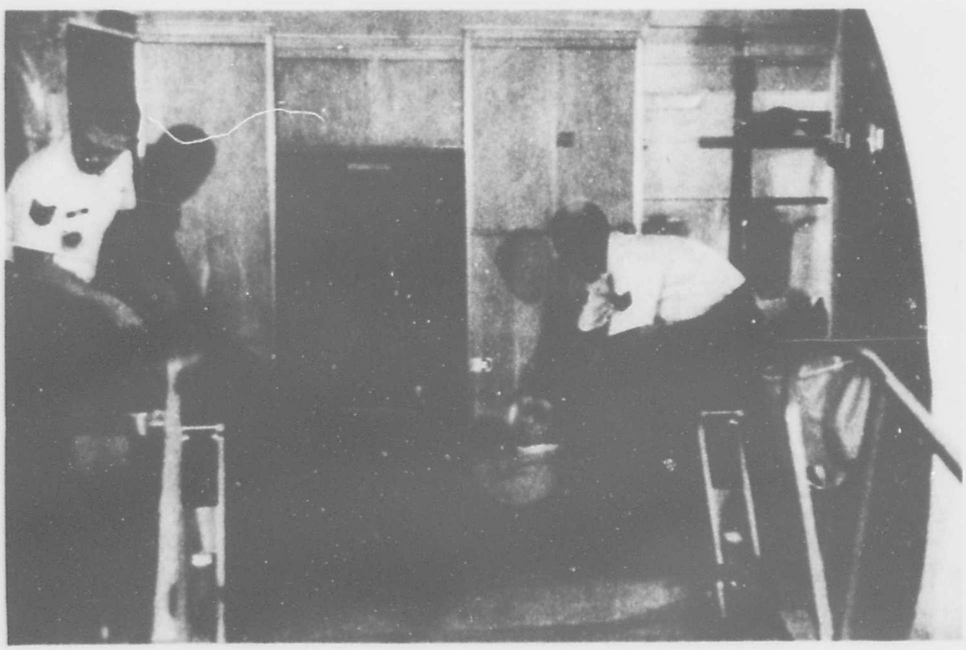


Figure 18. Teamwork During Evacuation

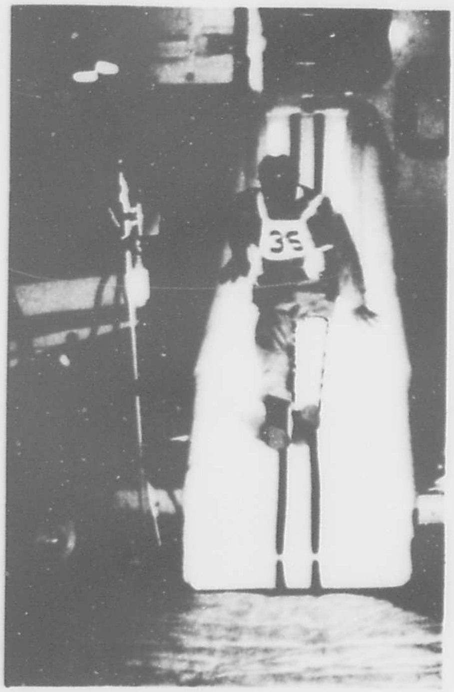


Figure 19. Escape Slide in Use

length leg bandage on the evacuee's left leg, a typical wound dressing worn by many of the patients.

5. FINAL ANALYSIS OF ELAPSED TIME DATA

Table VII lists the amount of time that was actually available for escape; that is, the number of seconds each exit was available for use after the door was opened and until the total test was concluded. The last two columns in the table list the amounts of time the individual exits were used and not used, expressed as a percentage of the amount of time each exit was actually open and available for egress. The exits were open but not in use 53 percent of the time, which is significant when probing into the reasons for lengthy egress times. By careful analysis of the test films, it was found that much of this wasted time was caused by a combination of two factors -- confusion among the patients from lack of information (inadequate emergency preflight briefing) and hesitation on part of evacuees because they were not receiving needed assistance from crewmembers during egress.

From the time observed, plus the evaluation of the rates of evacuation obtained from the films, an approximation can be made as to realistic standard aeromedical evacuation time criteria. A reasonable design objective for cargo/transport aircraft requires that, for every 10 persons expected to occupy a section of aircraft, there should be one exit available. This requirement meets the standard guidelines called for in the new AFSC Design Handbook - System Safety - DH 1-6, Chapter 3, Section 3Q, Design Note 3Q6. Emergencies may occur in which 50 percent of the exits may be blocked by fire or structural damage; therefore, a normal occupant/exit ratio of 10:1 would become 20:1 under these conditions. A reasonable total evacuation time can now be computed based upon 20 persons per exit and an estimated rate of evacuation. It has been determined, from the films of the tests, that an evacuation rate of four seconds per person is as good a rate as can be expected from average litter patients. Thus, if 10 seconds are allowed for the time required to open an exit, a formula for realistic aeromedical evacuation time (T_E) for that exit can be derived.

$$T_E = \frac{\text{(No. persons)}}{\text{exit}} \times \text{evacuation rate in units of} \left(\frac{\text{seconds}}{\text{person}}\right)$$

$$+ \text{ Exit opening time}$$

$$T_E = \frac{\text{(20 persons)}}{\text{exit}} \times \left(\frac{\text{4 seconds}}{\text{person}}\right) + 10 \text{ seconds}$$

$$T_E = 80 + 10 = 90 \text{ seconds}$$

This 90-second evacuation time is an approximation for exits without escape slides. For exits incorporating escape slides, 10 more seconds must be added to the total time above.

$$T_E = \frac{\text{(No. persons)}}{\text{exit}} \times \text{evacuation rate in units of} \left(\frac{\text{seconds}}{\text{person}}\right)$$

$$+ \text{ Exit opening time}$$

$$+ \text{ Slide deployment time}$$

$$T_E = \frac{20 \text{ persons}}{\text{exit}} \times \left(\frac{4 \text{ seconds}}{\text{person}}\right) + 10 \text{ sec.} + 10 \text{ sec.}$$

$$= 80 + 10 + 10 = 100 \text{ seconds}$$

Therefore, if no more than 20 persons go out through each exit, the total aircraft should be abandoned in 100 seconds. In theory, this formula is an accurate approximation of total egress time, no matter how large the aircraft. Thus, the 100-second maximum evacuation time is the estimated time required for complete abandonment of any aeromedical configuration of an aircraft.

SECTION IV

CONCLUSIONS

Several important points came out of these tests from which can be drawn conclusions for procedures necessary for rapid emergency egress. The tests were highly successful from both data-gathering and a crew-training standpoints. The C-9A aircraft proved to be equipped with an adequate number of exits, escape equipment, and emergency lighting, but it is always possible, through a better understanding of the problems, more training, and better use of escape equipment, to achieve faster egress rates. The conclusions below represent the findings of this study:

a. Medical and flight crew training is very important and teamwork must be stressed. Crewmembers who worked as a team, assisting and guiding patients during egress, proved to be the most effective. Crewmembers must know how to cope with panic and fear among the patients. They must react to an ever-changing emergency situation and assist as many patients as possible in the time that exists. This crew training requires strict discipline, as well as actual training such as could be simulated on an aircraft mockup. Crewmembers should be especially trained in maintaining a constant flow of patients down the aisles and to the exits. This was the factor that hampered egress the most during these tests. Keeping the patients moving is the most important point in the evacuation plan of the C-9A.

b. The seating placement of flight nurses and medical technicians throughout the cabin is important in that they should be in the most strategic position from which to assist and direct patients during an emergency.

c. The number of medical crewmembers in the C-9A is critical during an emergency egress. The crewmembers are burdened with responsibilities during an emergency and are actually handicapped by the confusion of persons who have not yet received evacuation assistance. Thus, there is a need for an augmented medical crew when the majority of passengers are litter patients.

d. Emergency exit lighting is very important and is considered essential to rapid emergency egress. The C-9A provides a highly adequate emergency lighting system. Egress was not materially hampered when the tests were conducted during darkness and only emergency lighting was used.

e. According to information gained from the questionnaires one of the major factors adding to the confusion aboard the aircraft during each test was the preflight briefing. Questionnaire responses showed overwhelmingly that the briefing was too short, too general, and its importance to the listener was not stressed enough.

f. From the emergency escape slide inflation problem during Test No. 2, it is evident that all emergency escape slides should be checked before flight to ensure that the slide girth bar is correctly positioned in the doorsill of each exit. This will avoid the tragic error of not having slides deployed when the door opens.

g. At the present time, the inflatable escape slides installed in the C-9A at the two forward doors must be inflated manually after each door is opened. There is a high probability that the slides will never be opened because patients will be pushing and shoving to get through the exits, making it impossible for the crewmembers to manually inflate the slides. An analysis of accident reports on this subject has led the FAA to require that all slides be automatically inflated on all commercial airlines. (This FAA requirement can be found in Federal Aviation Regulation, Part 25, Paragraph 25.809.) Currently, the inflation of the C-9A slides at the two forward doors must be accomplished manually. However, the inflation of the C-9A tailcone slide is fully automatic as the tailcone drops away.

h. The procedures for opening the emergency exits on the C-9A are of the currently acceptable design requiring a single motion of one hand.

SECTION V
RECOMMENDATIONS

The following recommendations, if adopted, should greatly reduce total egress times and provide an even greater margin of survivability than the C-9A currently has. Also, these recommendations should serve as a guide to the future development and procurement of aircraft having adequate means of escape in the event of a survivable accident. Specific recommendations for the C-9A are the following.

a. The training received by crewmembers (both flight and medical crews) should be intensified and stressed to a greater extent. This must involve the actual operation of all of the emergency escape provisions on a mockup or on an actual aircraft. Training should be given to each individual and should be repeated at regular intervals. Special emphasis should be placed on the rapid movement of patients down the aisles towards the exits.

b. Flight nurses and medical technicians should be in their assigned positions for every takeoff and landing. These positions must be positions from which such personnel can be of the greatest value in aiding in the evacuation of patients in the event of emergency.

c. The normal crew, consisting of two flight nurses and three medical technicians, should be augmented by two more medical technicians. This is especially true of flights carrying a large number of litter patients.

d. The preflight emergency briefing on emergency procedures should be improved. Briefings should be easy to understand, and clearly enunciated. Patients, even those who are not in pain, will ignore a long, detailed speech. Techniques of presentation should be improved. If the impact of the life-saving information will be greater, combine talk with slides, short film strip(s), etc., but be sure the briefings are accurate, brief, and clear. Stress must be placed on the importance of the briefing for safety sake.

e. The proper positioning of the girth bar in the doorsill attachment points should be checked prior to takeoff and again prior to landing. This should be a checklist item.

f. The inflatable escape slides on both forward doors on the C-9A should be modified to incorporate an automatic inflation system similar to the systems now specified in Section 25.809(f) of Part 25, Airworthiness Standards: Transport Category Airplanes; Federal Aviation Regulations.

The following are general recommendations for all USAF aircraft.

a. All crewmembers should receive intensive training in the use of all of the emergency escape provisions aboard their aircraft. Training should involve at least one emergency egress from a mockup or the actual aircraft and this type of training should be repeated at regular intervals. The training should emphasize the extreme importance of keeping the passengers moving towards the exits to avoid the blockage of passageways.

b. Seats for loadmasters, stewards, and persons in command for takeoff and landing should be located and assigned so that such personnel will be of maximum use in assisting passengers during an emergency egress.

c. Before flight, provisions should be made for certain persons to be in command of the passengers and be familiar with all of the emergency escape provisions on board the aircraft. One of the duties of persons in charge must be to make sure that every passenger sees, hears, and understands the preflight emergency briefing.

d. Designs of future aircraft should follow the lead that the C-9A has set with its highly adequate emergency lighting system. Emergency lighting should consist of adequate aisle lighting, emergency exit signs, and exit flood lights. Nickel-cadmium battery powered lighting is recommended and should be controlled automatically by impact inertia switches and aircraft power failure.

e. Great care must be given to the preparation and presentation of the preflight emergency briefing. The loadmaster, steward, or other persons in command must stress the importance of the briefing and ensure that all persons understand it. Preflight emergency briefings must be kept accurate, brief, and clear and should be effectively supplemented with films or photographs showing the proper procedures for escape.

f. On all aircraft having inflatable emergency escape slides, a check of the proper positioning of the slide girth bar should be mandatory before takeoff and again prior to landing. Checking this positioning should be a checklist item for the person in command. Efforts should be made to investigate and develop a new or better installation method for slides, to avoid future problems in this area.

g. On all aircraft having inflatable emergency escape slides, the installations should incorporate an automatic inflation system in sequence with the single motion of opening the exits.

h. Procedures for opening emergency exits on all aircraft should be standardized. Mechanisms for opening exits should be designed so that they may be operable with one continuous motion using only one hand.

APPENDIX I

QUESTIONNAIRE AND EVALUATION OF RESPONSES TO THE QUESTIONNAIRE BASED ON TESTS

Following each test, the subjects were requested to complete a brief open-ended questionnaire pertaining to their personal experiences during the simulated emergency egress. The following is the questionnaire used.

C-9A Emergency Egress Questionnaire

1. Age:____, Weight:_____, Height:______, Sex:______

2. Length of time in service:____________________

3. Job title: ______________________________

4. Primary duties:________________________________

5. Explain any trouble you encountered or you observed someone else encountering with the following:

   a. Opening doors or escape hatches.

   b. Deploying escape slides.

   c. Using escape slides.

   d. Getting through the hatches.

   e. Sliding down emergency escape slides.

   f. Carrying litter patients inside aircraft.

   g. Hearing the emergency briefing.

   h. Spacing between the seats/litters.

   i. Amount of available light.

6. Have you flown before?

7. Describe how realistic you thought the test was in simulating an actual emergency.

8. Give your opinion on whether or not the emergency preflight briefing was adequate in explaining how to rapidly evacuate the aircraft.

9. Is there a sufficient number of exits?

10. Are the exits large enough?

11. How do you think we could use the available exits more effectively?

12. Did you receive additional evacuation instructions during the test?

13. Who gave you these instructions?

14. Have you ever been involved in an actual emergency which required evacuation?

   a. When?

   b. Where?

   c. Describe circumstances.

15. How much formal evacuation training do you feel would be necessary and/or beneficial for all military personnel to receive?

16. Describe any equipment malfunctions you noticed.

17. If you have any comments or opinions on the briefing, the escape and survival equipment, or any phase of the test, explain below.

Approximately 87 percent of the test subjects responded, although the percentage varied for different items in the questionnaire.

2. SUBJECT DESCRIPTION

The breakdown of the respondents by age, sex, height, weight, and military status is shown below:

AGE

Test No.	Number of Subjects	Oldest	Youngest	Mean
1	39	53	17	30.9
2	36	58	10	27.1
3	31	48	11	24.4
4	36	54	9	22.9
5	39	51	8	22.2
6	25	40	12	23.4
Summary	206	58	8	25.4

SEX

Test No.	Number of Subjects	Male	Female
1	39	26	13
2	26	26	10
3	31	16	15
4	36	27	9
5	39	25	14
6	25	19	6
Totals	206	139	67

HEIGHT IN INCHES

Test No.	Number of Subjects	Tallest	Shortest	Mean
1	37	76	61	68.3
2	36	75	60	66.9
3	31	76	57	66.1
4	36	73	54	65.9
5	39	75	48	67.1
6	35	76	61	69.2
Summary	205	76	48	67.2

WEIGHT

Test No.	Number of Subjects	High	Low	Mean
1	39	210	97	156.7
2	36	220	75	143.0
3	31	190	56	135.0
4	36	201	68	133.2
5	39	220	56	135.7
6	25	235	75	153.2
Summary	206	235	56	142.5

NO. OF MILITARY VS. CIVILIANS

Test No.	Number of Subjects	Military	Civilian
1	38	28	10
2	36	20	16
3	31	14	17
4	36	18	18
5	39	20	19
6	25	14	11
Totals	205	114	91

The subjects for these tests were all volunteers and were permitted to select the hour they wished to participate. The fact that the tests were conducted on a Friday evening may explain the age differences among the test groups.

3. OPEN-ENDED RESPONSES

a. In questionnaire item 5, the subjects were asked to explain any trouble they encountered or observed with regard to nine aspects of the tests. The following breakdown summarizes the responses in terms of the number of respondents who reported encountering or observing such problems.

DIFFICULTIES ENCOUNTERED/OBSERVED

Test number	Opening doors or escape hatches	Deploying escape slides	Using escape slides	Getting through hatches	Sliding down emergency escape slides	Carrying litter patients inside aircraft	Hearing emergency briefing	Spacing between seats/litters	Amount of available light	Number of subjects responding
1	0	0	6	3	3	0	29	8	2	39
2	0	0	1	6	0	0	1	4	3	36
3	0	-	-	3	-	0	10	11	3	31
4	-	0	6	5	0	1	7	11	3	36
5	0	1	1	2	3	1	9	10	0	39
6	0	0	0	0	2	0	2	8	1	25
Totals	0	1	14	19	8	2	58	52	10	206

The most frequent comment concerned the difficulty in hearing the emergency briefing. It would appear that this problem varied considerably from test to test. In Test 1, for example, 74 percent of the respondents stated that <u>no</u>

briefing was heard at all, whereas less than 5 percent of the combined subjects in Tests 2 and 6 failed to hear the briefing. Although several subjects commented on the absence of instructions with regard to operating the escape hatches, no subject encountered or observed any actual problems with deployment of the hatches (Item 5a). Furthermore, only 9 percent of the "patients" had trouble getting through the hatches (Item 5d). These findings were also substantiated by the responses to Items 9 and 10 which follow. The escape slides also appeared to be quite satisfactory, as only 23 of 206 total subjects reported difficulties in using the slides, which were totally new to most subjects.

b. In Item 8, the subjects were asked whether or not the emergency briefing was adequate. The overall adequacy of the briefings was felt to be poor. In only three tests did a majority of the "patients" rate the briefing as "adequate"; across all six tests, only 45 percent responded "adequate".

ADEQUACY OF BRIEFING

Test No.	Number of Subjects	Adequate	Inadequate
1	38	2	36
2	32	15	17
3	26	18	8
4	36	22	14
5	33	14	19
6	15	10	5
Totals	180	81	99

Most respondents felt that the briefings were not detailed enough since they failed to include procedures for removing litter straps, opening hatches, and determining which exit to use. Since each emergency situation is unique, preflight briefings should include instructions which are applicable to all emergency egress situations, such as litter straps and hatch removal.

c. In Item 9, the subjects were asked whether or not there was a sufficient number of exits; and in Item 10, if the exits available were large enough.

EXITS - SUFFICIENT NUMBER?

Test No.	Yes	No	Number of Subjects
1	33	0	33
2	33	0	33
3	26	1	27
4	32	2	34
5	36	0	36
6	18	0	18
Totals	178	3	181

EXIT - LARGE ENOUGH?

Test No.	Yes	No	Number of Subjects
1	34	5	39
2	33	3	36
3	27	2	29
4	33	2	35
5	35	1	36
6	17	0	17
Totals	179	13	192

Overall, 98 and 93 percent answered in the affirmative to Items 9 and 10, respectively.

d. Responses to other items contained in the questionnaire did not contain information of sufficient quantity or quality to be considered useful in this report.

APPENDIX II

EGRESS TIME TABLES

TABLE II

EXIT FULLY OPENED, MEASURED FROM TIME T = 0

Exit	Seconds	Remarks
Left forward	18	Test 1
Right forward (reopened)	16 46	30 seconds lost[1]
Overwing, left, fwd	8	Test 1
"	11	Test 3
Overwing, left, aft	15	Test 1
"	16	Test 3
Overwing, right, fwd	12	Test 2
"	14	Test 3
Overwing, right, aft	19	Test 2
"	26	Test 3
Tailcone	---	Open prior to test
Desired maximum	10	

[1]During test No. 2, the forward, right side exit (galley service door) was opened, closed, and then reopened when it was discovered that the girth bar on the escape slide had not been hooked into its proper place in the doorsill.

TABLE III

SLIDE INFLATION TIME (SECONDS)

Slide	Seconds	Remarks
Forward, left	5	Good
Forward, right	5	Good
Tailcone	6	Good
Standard	10 or less	

TABLE IV

FULL DEPLOYMENT OF SLIDES, MEASURED FROM TIME T = 0

Slide	Seconds	Remarks
Forward, left	29	Slow door opening
Forward, right	51	Excessive delay See Footnote #1, Table II
Tailcone	---	Deployed prior to test
Desired maximum	18-20 sec.	Includes 10 sec. each for door opening and slide deployment

TABLE V

FIRST MAN ON GROUND,

MEASURED FROM TIME T = 0 *

Test No.	Seconds	Exit Used	Remarks
1	33	Forward, left	
	20	Overwing, left, fwd	
	33	Overwing, left, aft	Aft exit used by only one patient
2	55	Forward, right	Excessive delay See Footnote #1, Table II
	29	Overwing, right, fwd	
	---	Overwing, right, aft	Aft exit opened but never used
3	28	Overwing, left, fwd	
	40	Overwing, left, aft	Aft exit used by only six patients
	18	Overwing, right, fwd	
	28	Overwing, right, aft	Aft exit used by only two patients
4	28	Tailcone	
5	27	Forward, left	Forward, right exit not recorded
	22	Tailcone	
6	25	Forward, left	
	22	Forward, right	

* All times include exit opening and slide deployment time.

TABLE VI

LAST MAN ON GROUND,

MEASURED FROM TIME T = 0

Test No.	Seconds	Exit Used
1	128	Forward, left
2	105	Forward, right
3	103	Overwing, left
4	224	Tailcone. See Footnote 3
5	128	Tailcone
6	175	Forward, left
Current standard	60	See Footnote 4
Estimated aero-medical standard	100	See Footnote 5

[3] Test No. 4 was conducted to measure the capability of the tailcone and was not intended to conform to MIL-STD-872 which requires testing using one half of the available exits. Thus, the recorded time of 224 seconds cannot be compared to any previous standard evacuation time.

[4] Currently, MIL-STD-872 and AFSCM 80-1 require complete evacuation within 60 seconds on cargo and cargo/transport aircraft.

[5] The estimated 100-second maximum evacuation time necessary for an aeromedical aircraft is currently under consideration. See Section III, Paragraph 1.

TABLE VII

ANALYSIS OF ACTUAL TIME AVAILABLE FOR ESCAPE AND PERCENT OF TIME UNINTENTIONALLY WASTED

Test No.	Exit	Number of people who used exit	Amount of time exit was open (seconds)	Amount of time exit was used (percent)	Amount of time exit was not used (percent)
1	Forward, left	19	99	56	44
	Overwing, left, fwd	28	120	68	32
	Overwing, left, aft	1	113	3	97
2	Forward, right	15	54	81	19
	Overwing, right, fwd	31	93	97	3
	Overwing, right, aft	00	86	00	100
3	Overwing, left, fwd	14	92	44	56
	Overwing, left, aft	6	87	20	80
	Overwing, right, fwd	24	89	78	22
	Overwing, right, aft	2	77	8	92
4	Tailcone	47	204	67	33
5	Forward, left	16	108	43	57
	Forward, right	14	108	38	62
	Tailcone	20	108	54	46
6	Forward, left	25	155	47	53
	Forward, right	23	155	43	57
	Average	---	109	47	53

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13. ABSTRACT

The series of tests reported herein had two primary objectives -- a) to gather technical data needed to evaluate the ground and ditching characteristics of the C-9A aeromedical aircraft; and b) to obtain data necessary for revising and updating specifications and the new AFSC Design Handbook, System Safety, DH 1-6, to provide better emergency escape potential for future aircraft. An important secondary benefit realized from these tests was the development of better medical training procedures for handling the wounded during ground and ditching emergencies.

The C-9A aircraft was used in the tests which were conducted under cover of darkness to simulate the worst possible survivable crash condition -- that of darkness of fire and smoke. Six tests were made, using a different combination of exits each time. Exits that would be available during a survivable ground crash were used during five of the tests, and exits available during a water ditching were used during the sixth test. It is important to note that no more than half of the exits were made available during each test as prescribed by MIL-STD-872, which assumes that one half of the exits will be blocked by fire or structural damage. The C-9A has seven exits available, but the assumption that half the exits were blocked permitted the use of no more than three exits at a time. The exception to this rule was the ditching test in which the aircraft was assumed to have ditched at sea and come to rest, floating at wing level, with all four overwing exits available for use. The average evacuation time was 128 seconds, which is 68 seconds more than time permitted by current standards. The 128-second average was computed without considering Test No. 4, which was not conducted in accordance with MIL-STD-872.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
C-9A Aeromedical Aircraft Aircraft Emergency Evacuation Emergency Escape Aircraft Safety Egress from Accident-Involved Aircraft Survival following Aircraft Accident Rescue and Survival following Aircraft Accident Safety During Aircraft Accidents						

13. ABSTRACT (Cont)

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