AM 67-14

AN EVALUATION OF POTENTIAL DECOMPRESSION HAZARDS IN SMALL PRESSURIZED AIRCRAFT

John J. Swearingen, M.S.

Approved by

J. Robert Dille, M.D.
Chief, Civil Aeromedical Institute

Released by

P. V. Siegel, M.D.
Federal Air Surgeon

June 1967

FEDERAL AVIATION ADMINISTRATION
Office of Aviation Medicine

ACKNOWLEDGEMENTS

The author acknowledges the diligent assistance of Mr. Gary E. Wullenwaber, FAA Flight Standards, and the staff of the Protection and Survival Laboratory of the Civil Aeromedical Institute.

Qualified requestors may obtain Aviation Medical Reports from Defense Documentation Center. The general public may purchase from Clearinghouse for Federal Scientific and Technical Information, U.S. Dept. of Commerce, Springfield, Va. 22151

AN EVALUATION OF POTENTIAL DECOMPRESSION HAZARDS IN SMALL PRESSURIZED AIRCRAFT

I. Introduction.

Military records of World War II bomber flights list numerous examples of ejection of crew members from these large volume pressurized aircraft caused by wind blast during decompression following a blister or window failure. Also, a few ejections of passengers from early pressurized commercial aircraft before the advent of double windows and plug-type exits have been reported. All United States pressurized civil transports and U.S. business jets now have double (or multiple load element) windows and most have plug-type doors. This type of construction has been shown to be very reliable. Decompression tests were conducted in the late 1940's[2,3] to establish danger areas around various size windows of large aircraft and to develop and prove the safety values of the double-pane window. On the other hand, fighter pilots in very small aircraft have lost their entire canopy without being ejected. These experiences would lead one to theorize that there is a break-over point somewhere on the safety curve as the volume of the aircraft is decreased. The number of small business type pressurized aircraft with volumes ranging from about 150 to 900 cubic feet (some with single-pane windows) is rapidly increasing in the United States. The Flight Standards Service Washington Office requested a study be made to answer the question, "Would wind blast effects be sufficient to eject passengers or cause serious injury following a window failure in these small volume aircraft?"

The injurious effects of decompression wind blast depend on a number of variables: (1) cabin volume, (2) area of the opening, (3) cabin pressure differential, (4) the distance a passenger is sitting from the opening, (5) weight and body size of the passenger, and (6) type of clothing being worn.

The study was conducted to attempt to answer the above question and to provide design engineers with information which will aid them in designing safe configurations.

II. Procedure and Discussion.

Decompression tests were conducted in a low pressure chamber equipped with the usual lock and main chamber and an unusually large accumulator tank (15,000 cu. ft.) connected to the main chamber by a 3-foot diameter tube. A specially designed door was constructed to hold a thin sheet of plastic representing the various simulated window and other openings and secured to the lock wall to separate the lock from the main chamber and accumulator. Aircraft cabin volumes and pressures were simulated in the lock while the remaining portions of the system were evacuated to simulate ambient external air pressures. This arrangement of a small lock volume compared with a large accumulator volume (ratio=approximately 1/100 for the small aircraft) allowed decompression testing with very little drop in cabin flight altitude, simulating closely actual flight conditions. Accumulator volumes (16,700 cu. ft.) were held constant for all tests while variations in cabin volumes (190 to 700 cu. ft.) were made by adding fill materials to reduce the volume for simulating smaller aircraft. Rupture of the simulated window membrane was accomplished at the desired time by a simple swinging knife released by an electromagnetic solenoid.

Instrumentation and recording equipment consisted of triaxial Statham accelerometers mounted in the dummy heads along with appropriate amplifiers and recorders for recording head impact forces, motion picture coverage from both sides of the window of wind blast effects on the dummies during decompression, and closed circuit television monitoring of all tests.

In all, three hundred and thirty-eight tests were conducted to determine danger areas around windows of small volume aircraft in terms of ejection and head impact injuries. Four anthropomorphic dummies (a 13-pound infant, a 31-pound 3-year-old child, a 47-pound 6-year-old child, and a 180-pound adult) were placed various distances from each size window under different test conditions and relative danger determined from accelerometer readings and study of the motion pictures. Cabin volumes were varied from 100 to 700 cu. ft. to cover the range of the present fleet of small pressurized aircraft. Aircraft with volumes larger than 700 cu. ft. are probably regulated by Federal Aviation Regulations, Part 25, and required to have double-pane windows. Window areas tested ranged from 100 to 900 sq. in. The largest windows in present use have areas of 350 to 500 sq. in. However, most windows in present use have areas of 250 sq. in. or less, but larger areas were evaluated to determine effects of exit, door, and windshield failures.

Because of the great number of tests required to evaluate all variables in combination, only two pressure differentials were evaluated: 5.2 psi (270mm Hg) simulating aircraft flying at 24,000 ft. with cabins pressurized to 8,000 ft., and 8.55 psi (442mm Hg) simulating flight altitudes of 43,000 ft. with cabins pressurized to 8,000 ft. Some small jets are presently certified to fly at 45,000 ft.

In addition, flow tests were conducted for all test conditions to determine decompression times without the dummies in place to serve as a basis for determining time available for donning protective oxygen equipment and possible harmful effects of R.G.E. (Relative Gas Expansion).

III. Results.

As might be expected, small light-weight individuals were affected more by a given wind blast situation than heavy adults. Figures 1 and 2 summarize the results of all decompression tests in terms of safe and unsafe distances from the "window." The test condition was considered unsafe if the vectored force of head impact read from the triaxial accelerometers exceeded 80g[4] and/or the dummy was completely ejected from the aircraft. Danger areas are shown to the left of each of the family of volume curves for two pressure differentials with area of the opening plotted on the ordinate and distance from the opening on the abscissa. Danger areas for the 180-pound dummy *only* are plotted in Figure 1 while Figure 2 shows the additional distances necessary to protect infants and small children. From Figure 1 it may be determined that adults would not expect to receive fatal injuries sitting next to a "window" during decompression if the volume of the aircraft is not in excess of 350 cu. ft. and the pressure differential is less than 5.2 psi. Also, the same protection may be afforded for up to 5.2 psi differential pressure in 500 cu. ft. and 700 cu. ft. aircraft by designing opening sizes with areas less than 500 sq. in. and 250 sq. in. respectively.

As previously stated, most present window opening areas are below 250 sq. in. and the larger openings are most applicable to emergency exits, doors, and windshields. Referring again to Figure 1, safe distances for adults in a 700 cu. ft. aircraft flying with 5.2 psi cabin pressure differential are 5 inches for a 500 sq. in. opening and 8 inches for a 900 sq. in. opening. Since it is not a general practice to place seats within these distances of doors and windshields, only failure of emergency exits (area of approximately 500 sq. in.) would probably be hazardous to *large adults* in small volume aircraft limited to altitudes of 24,000 ft.

However, as the pressure differential is increased to 8.5 psi, as shown on the right of Figure 1, adults will be in danger of fatal head impacts and/or ejection even in very small aircraft (190 cu. ft.) with very small windows (100 sq. in.). Figure 2 shows that infants and small children will be ejected from and/or receive fatal head injuries in any aircraft with a volume of 190 cu. ft. or greater equipped with windows in excess of 100 sq. in. area and flying with cabin pressure differentials of 5 psi or more. Also, as might be expected, the critically safe distances from the window increase as window area, volume, or pressure differential are increased. A previous study[2] has shown that the proper use of seat belts will prevent ejection from aircraft but will not prevent head injury during a decompression.

Decompression or flow times are plotted for all test conditions in Figures 3 and 4. According to Luft and Bancroft[1] a pressure change of slightly over 400mm Hg in 4/10 of a second or less will produce possible lung rupture. This danger area has been indicated on Figure 4 for the test conditions studied. In addition, these decompression time tables should serve as a basis for selecting oxygen equipment for passengers and crew flying in small pressurized aircraft.

Figures 5 through 7 present sequence pictures of representative ejections of the four sizes of dummies.

IV. Conclusions.

In view of the data presented in this study, it is obvious that the volumes of even small pressurized aircraft are sufficient to cause ejections from aircraft, fatal injuries from head impact, concussion and unconsciousness, and in some cases even lung rupture.

For these reasons considerations should be given to equipping all pressurized aircraft, large or small, with double-pane windows and plug-type exits.

References

1. LUFT, ULRICH C. and BANCROFT, RICHARD W.: Transthoracic Pressure in Man During Rapid Decompression. USAF School of Aviation Medicine, Randolph AFB, Texas. Report 56-67, August 1956.
2. SWEARINGEN, JOHN J.: Protection of Passengers and Air Crew from Air Blast Effects of Explosive Decompression. Civil Aeronautics Medical Research Laboratory, Aeronautical Center, Oklahoma City, Oklahoma. Project No. 50-516, Report No. 1, August 1950.
3. SWEARINGEN, JOHN J. and MCFADDEN, E. B.: Studies of Air Loads on Man. Civil Aeromedical Research Institute, Aeronautical Center, Oklahoma City, Oklahoma. Report No. 63-9, May 1963.
4. SWEARINGEN, JOHN J.: Tolerances of the Human Face to Crash Impact. Civil Aeromedical Research Institute, Aeronautical Center, Oklahoma City, Oklahoma. Report No. AM 65-20, July 1965.

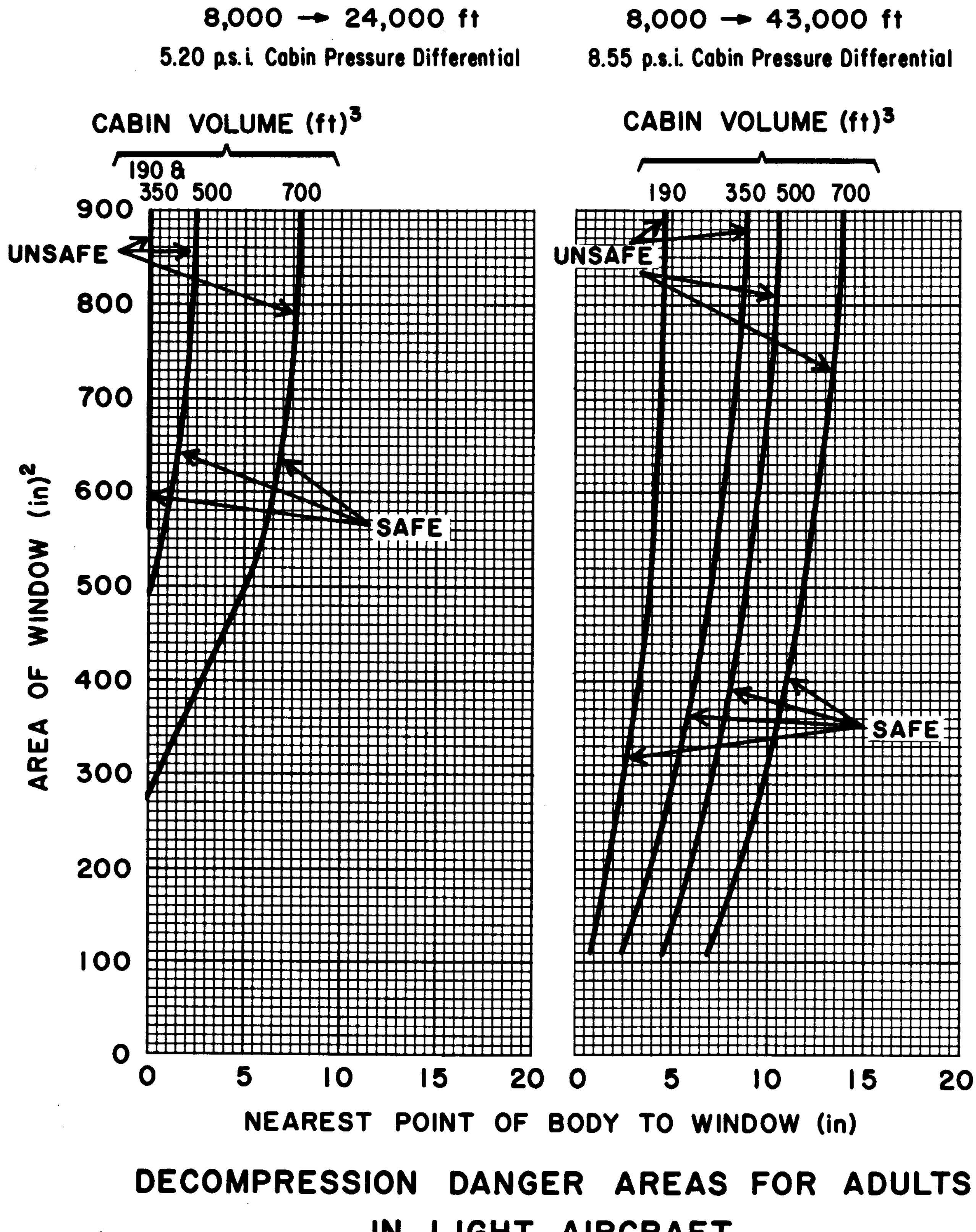

FIGURE 1. Safe and danger areas for a *180-lb. adult* in decompressions of small volume aircraft.

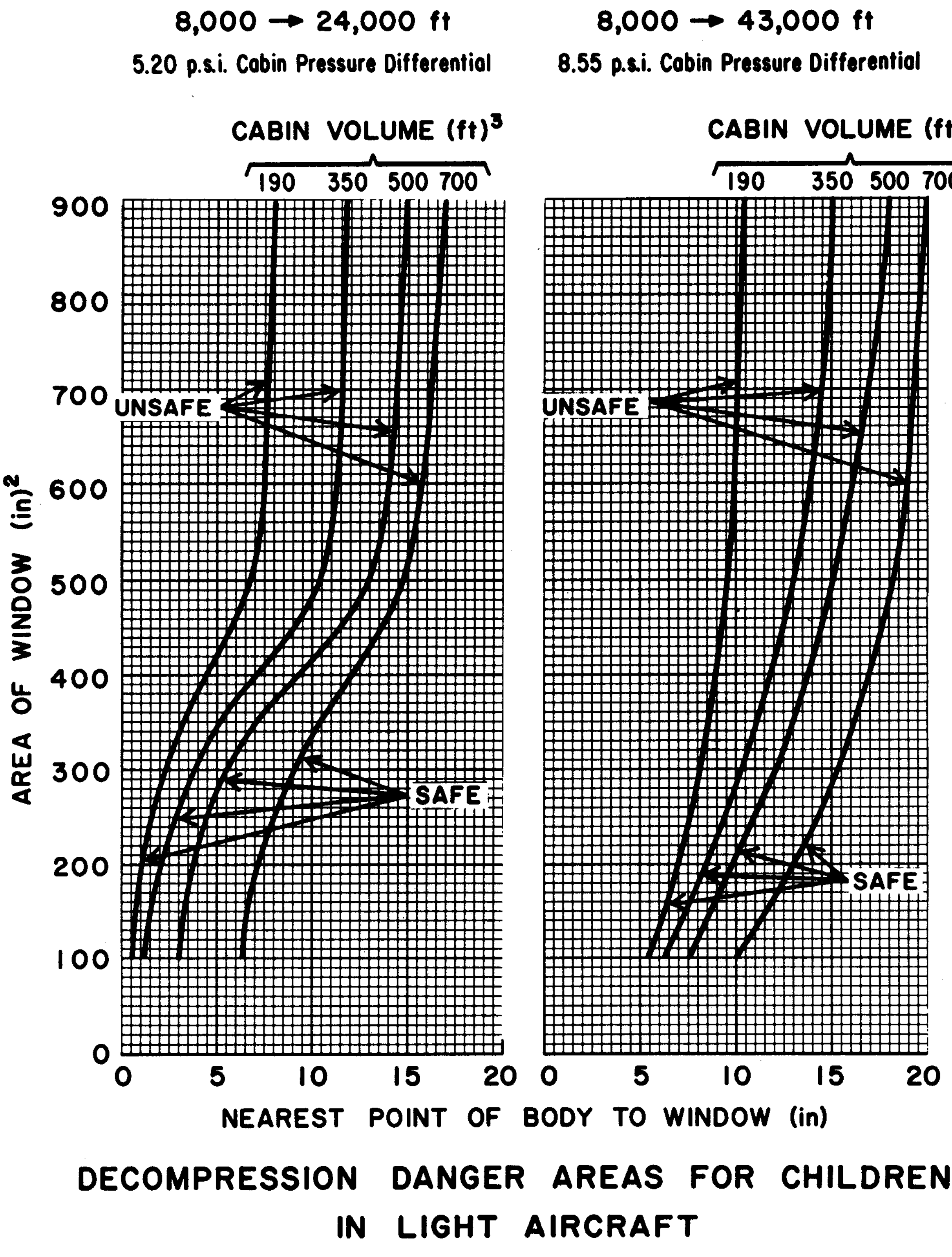

FIGURE 2. Safe and danger areas for infants, children, and adults in decompressions of small volume aircraft.

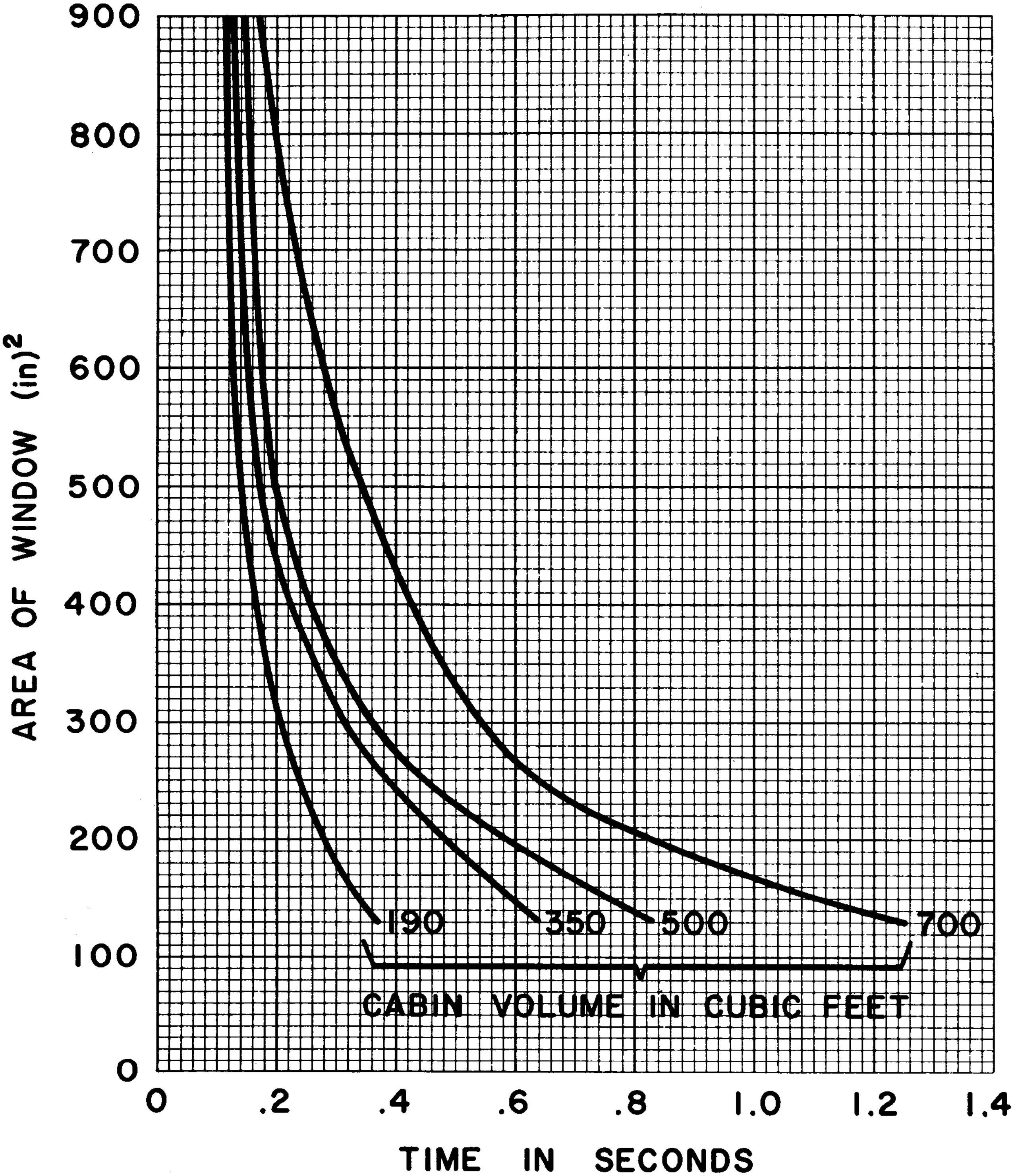

FIGURE 3. Experimental decompression times for 4 volumes of light aircraft with various window sizes (8,000 ft. to 23,500 ft., 263mm Hg differential pressure).

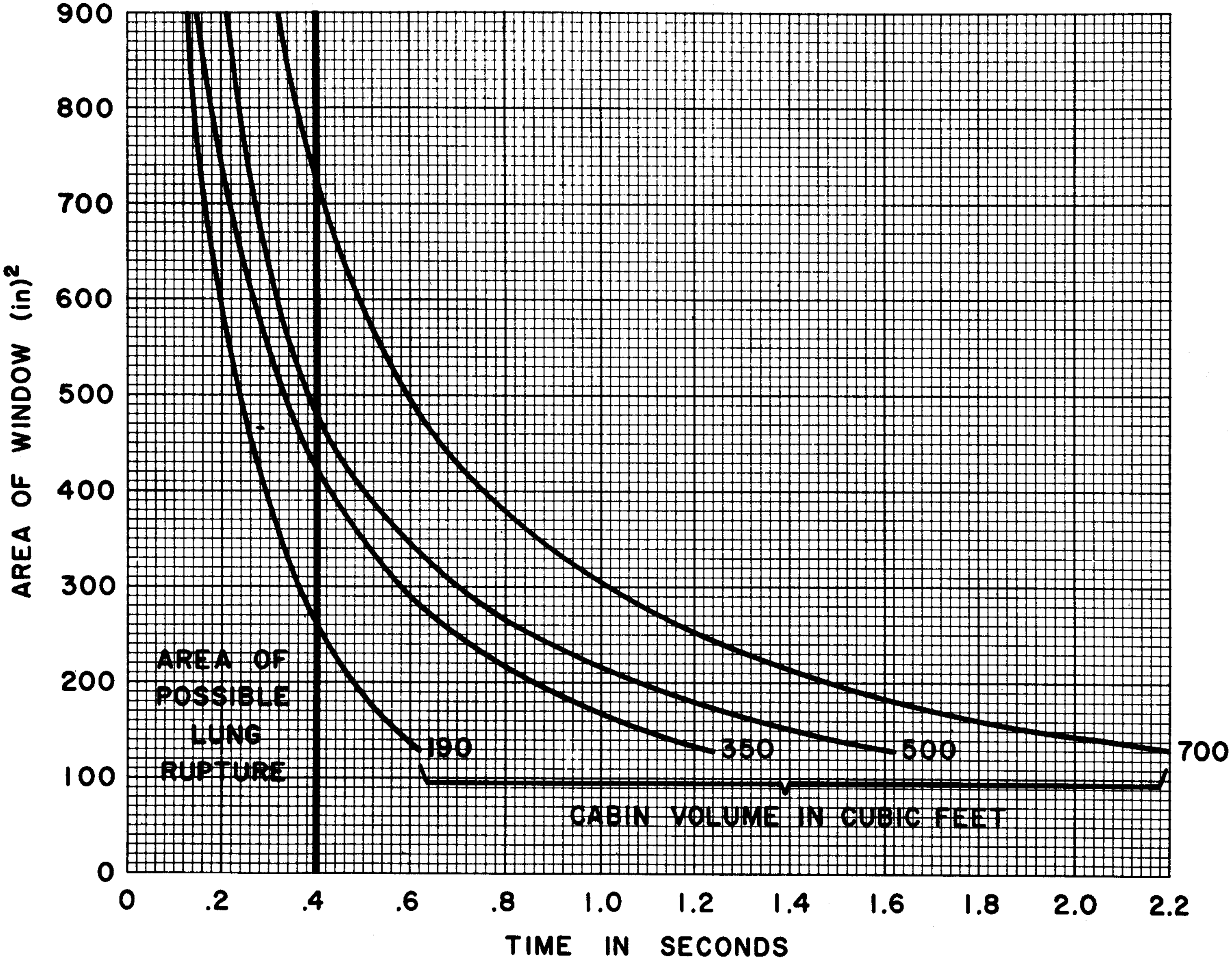

FIGURE 4. Experimental decompression times for 4 volumes of light aircraft with various window sizes (8,000 ft. to 41,500 ft., 433mm Hg differential pressure).

FIGURE 5. Representative sequence pictures of decompression ejections.

A. 180-lb. dummy holding 13-lb. infant near a 134 sq. in. window, 250 cu. ft. volume, 8.55 psi pressure differential. Infant ejected (.55 seconds).

B. 180-lb. dummy holding 13-lb. infant and looking out of a 240 sq. in. window, 250 cu. ft. volume, 8.55 psi pressure differential. Both ejected (.85 seconds).

FIGURE 6. Representative sequence pictures of decompression ejections.

A. 31-lb. 3-year-old child sitting near a 132 sq. in. window, 190 cu. ft. volume, 8.55 psi pressure differential. Child ejected (.35 seconds).

B. 13-lb. infant sitting 5 inches from a 274 sq. in. window, 190 cu. ft. volume, 8.55 psi pressure differential. Infant ejected (.15 seconds).

FIGURE 7. Representative sequence pictures of decompression ejections.

A. 47-lb. 6-year-old child sitting 6 inches from a 274 sq. in. window, 500 cu. ft. volume, 8.55 psi pressure differential. Child ejected (.40 seconds).

B. 180-lb. adult sitting 9 inches from a 500 sq. in. window, 700 cu. ft. volume, 8.55 psi pressure differential. Dummy ejected (.94 seconds).