Aircrew Oxygen Requirements in High Altitude Transport Aircraft

SQUADRON LEADERS A. C. BRYAN, W. G. LEACH, and WING COMMANDER R. A. STUBBS

ONE of the popular pastimes associated with the operation of high altitude transport aircraft has been guessing at what aircraft altitude the pilot should start wearing an oxygen mask. The Federal Aviation Agency has laid down 25,000 feet.[1] While this is safe, it imposes some burden on the aircrew, and has been hotly debated. Other guesses put the altitude at 30,000 feet, 35,000 feet, 40,000 feet, and Never.

To join the game, one should hold firm opinions on how likely these aircraft are to lose cabin pressure, what the rate of decompression will be, how quickly and efficiently the pilot will respond to the situation, and how much the constant wearing of a mask will affect operational efficiency. The game can be made more involved by adding the average age of pilots, their knowledge of oxygen equipment, and by mentioning decompression sickness, air embolism, or expanding bowels.

It has had to be a "game" because the many variables in the situation make it very difficult to plan realistic experimental work on which to base a safe and reasonable opinion.

This report, therefore, confines itself to a comparison of the ability of subjects to perform emergency procedures after a rapid decompression to either 35,000 or 40,000 feet simulated altitude in a decompression chamber. In either case, the decompression from 8,000 feet to the ultimate altitude took fifteen seconds. Also, in either case, mask-donning was delayed for five seconds after reaching the ultimate altitude. This rate of decompression and the imposed delay before initiating emergency procedures, does represent a rather calamitous situation, but this was done deliberately.

Engineers argue that these rates of decompression are unrealistic because they represent approximately the result of a window failure, while the windows are probably the strongest part of the fuselage. With modern design, penetration of the fuselage leads to a relatively slow decompression. However, if the fuselage is going to be penetrated, the penetration could occur at a window leading to a more rapid decompression.

It can also be argued that the delay, twenty seconds from the start of the decompression before initiating emergency procedures, is excessive, and that a pilot's reaction would be instantaneous. However, it was felt that an arbitrary delay was necessary because a decompression chamber cannot reproduce an aircraft emergency—only the pressure change. In a chamber: (1) The subject is inevitably alert. (2) Decision time is eliminated. They knew exactly what was happening. (3) The emergency procedures they had to

From the RCAF Institute of Aviation Medicine, Toronto, Canada.

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carry out were recently practiced until they were swift and faultless. (4) Their oxygen equipment was readily available, carefully fitted and checked. These conditions do not necessarily apply in an aircraft. The crew is not expecting a decompression. The decisions may not be straightforward. Cabin-pressure-warning indicators vary, but several are coupled with some other warning system. There may or may not be a lot of noise. The condensation of water vapor has been confused with fire. Furthermore, the pilot can expect some physiologic impairment: some hypoxia is inevitable, sudden distention of the gut can cause syncope, symptoms of hyperventilation occur very rapidly after a rapid decompression. Also, a man not accustomed to oxygen systems can get into considerable difficulty with an unused system. He must be able to don the mask rapidly in a crisis—without accidentally disconnecting himself or switching off his regulator. (Both situations have occurred). There is also a natural danger that when something is wrong with the aircraft, the aircraft is treated first. By the time the pilot appreciates that there is something wrong with himself, it is almost too late for him to help himself. Therefore, whatever the "reaction time" is—in practice it could be nearer twenty seconds than instantaneous.

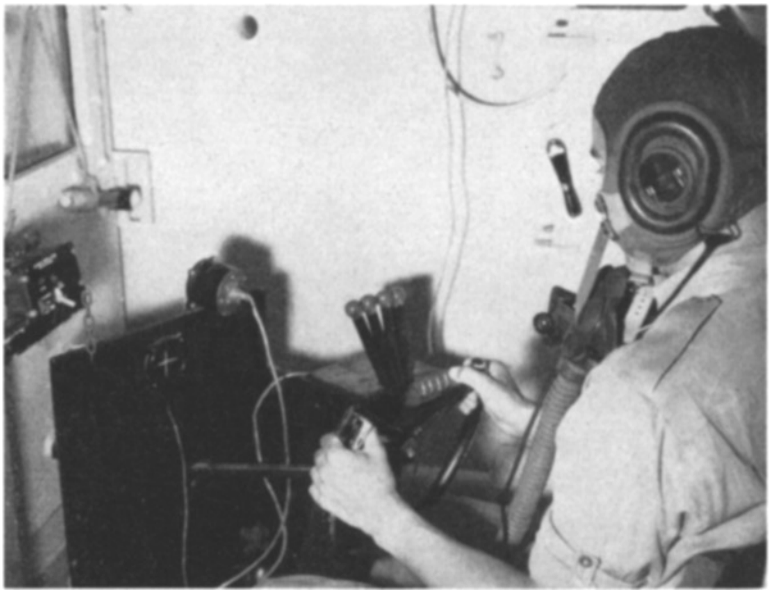

Fig. 1. Subject seated at flight simulator within low pressure chamber prior to decompression.

METHOD

One hundred and eight subjects were used in this study. The majority were RCAF Transport Aircrew and Canadair CL44 Flight Test Personnel undergoing transport aircraft aeromedical indoctrination. In addition, twenty-nine Trans Canada Airline Pilots volunteered as test subjects. They all passed a routine physical examination. Several had minor medical disabilities: two inguinal hernias, one with a history of renal hypertension for which a nephrectomy had been successfully performed ten years previously; one who had a patent ductus arteriosus ligated ten years previously. A number of the subjects were overweight. Seventeen were over forty years, and the oldest was fifty-two.

On the first day, the subjects were given an aeromedical indoctrination course with a routine decompression chamber run to a simulated altitude of 30,000 feet (ascent 4,000 ft./min.), with a brief exposure to hypoxia.

On the second day, the subjects were put in a small parasite chamber, seated in a chair with a safety harness, flying a small simulator (Fig. 1). This was a console with four dummy throttles and four switches (representing thrust reversers) and an ILS dial which could be offset by an outside operator and could be corrected by the subject manipulating a control column.

Oxygen masks connected to an MD1 regulator were at the "ready" position. Two types of mask and suspension were used: (1) The Pate Suspension on an A-13A mask, hanging on the chest from either an inner cloth helmet or headset. (2) The Puritan "Sweep On" Suspension, hanging on a bracket within easy reach of the right hand. (Headsets were not worn by these subjects because they interfered with rapid donning).

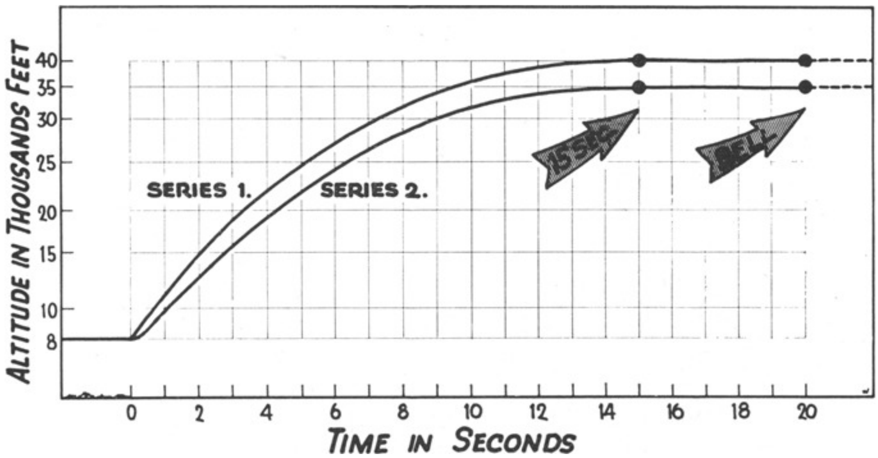

Fig. 2. Rate of decompression to terminal altitude using human subjects.

The subjects were taken to 8,000 feet at 4,000 feet per minute. No attempt was made to "soak" them at 8,000 feet because waiting usually produced considerable anxiety. The parasite chamber was connected to a large reservoir chamber and by operation of the valves, the subject was decompressed to the terminal simulated altitude (40,000 feet or 35,000 feet in fifteen seconds) (Fig. 2).

Five seconds after reaching the terminal altitude, a bell was rung and a light came on. In response to this, they had to: (1) Don the oxygen mask. (2) Select "100%" oxygen and "emergency pressure" on the oxygen regulator. (3) Close the four dummy throttles. (4) Close the four dummy switches. (5) Correct the deviations in the ILS needles. When the subject had control of the ILS, descent was initiated at 8,000 feet per minute or slower, if ear trouble developed.

All the subjects had carefully fitted oxygen masks, and were given considable practice in carrying out their emergency procedure.

RESULTS

Series 1 (8,000 to 40,000 feet).—Of the seven subjects, one became unconscious and failed to complete his emergency procedure. This subject donned his mask rapidly and managed his oxygen regulator. He reached for his throttles but lost consciousness before closing them. He was unconscious for ten seconds and on recovery, immediately started "flying" the ILS. However, it was forty-five seconds later that he realized he had not closed the throttles or toggle switches.

The rest had no apparent difficulty in carrying out the emergency procedure. One subject was much slower in his movements, and another was very hesitant on the ILS as compared with ground level performance. Much of this may be due to the very real situational anxiety, rather than hypoxia. Most of the subjects noted some transient symptoms attributable to mild hypoxia. One subject had severe (but not disabling) abdominal gas pain.

Series 2 (8,000 to 35,000 feet).—One hundred and one subjects were decompressed to 35,000 feet simulated altitude. All completed the emergency procedure without serious difficulty.

However, one subject (two minutes after completing his emergency procedure, during the descent) complained of light-headedness, and then ceased to respond to questions. He did not appear to be hypoxic or hyperventilating. On reaching ground level, he walked unaided into the treatment room. He was confused and fatuous. He complained of an ill-defined visual field defect and had difficulty with language, suggesting an aphasia. Within fifteen minutes he became normal and had no residual physical signs. However, eight hours later he had a grand mal convulsion, accompanied by minor diffuse electroencephalographic abnormalities. There were no further incidents and his EEG returned to normal within two weeks. There is a probability that this man had a cerebral embolism of some description. The case was reported more fully elsewhere.[3]

DISCUSSION

Wearing an oxygen mask in a pressurized transport aircraft is undoubtedly a nuisance. It does, to some extent, interfere with comfort, movement, vision, and communication. It is therefore an obligation to confine the wearing of the mask to altitudes above which it can be proved necessary. If this is not done, pilots will remain unconvinced, and the regulation will have to be policed.

In this study, one out of seven subjects lost consciousness after five seconds at 40,000 feet. In a similar study reported by us,[2] three out of twenty-six subjects lost consciousness. Therefore, if these decompression chamber studies can represent an in-flight emergency, there appears to be a considerable risk of the pilot losing consciousness, if he doesn't have the mask on his face. However, under the same conditions at 35,000 feet, there was no evidence of serious impairment from hypoxia, after donning a mask.

It is believed, therefore, that RCAF

Transport Crews should wear quick-donning masks "at readiness" up to 35,000 feet, but above this, the pilot *must* have his mask on his face at all times. However, all these crews will be subjected to regular aeromedical indoctrination, *including* periodic decompressions to 35,000 feet. We are convinced that this is the only certain way to impress aircrew with the vital necessity of maintaining a high standard of oxygen discipline.

One subject (out of 265 decompressions of this type) developed a cerebral embolism, presumably from decompression sickness. This affects the attitude towards the in-flight emergency, in that a man, crew, or passenger who has been rescued from hypoxia, can still become totally incapacitated. However, because there is no feasible way to pre-select this man, it is a situation that has to be accepted. This also affects the attitude towards decompression chamber indoctrination, since a hazard produced by an in-flight emergency is much more acceptable than a hazard produced in training for an in-flight emergency. The RCAF intends to continue this type of training, until experience has proved the claim that "cabin pressure failure has been engineered out." A casual attitude to the hostile environment outside the cockpit might result in the mass casualties of a passenger aircraft crash. This training has made a considerable impression on aircrew, and the risk is accepted as an obligation to passengers.

The problem of the fitness of the older pilot under these conditions in an aircraft or in a chamber, also arises. The subject in Series 1 who became unconsciousness at 40,000 feet, happens to be the oldest subject (aged fifty-two).

SUMMARY

It is concluded that, if the test conditions are realistic, pilots should wear a mask "at readiness" up to 35,000 feet, and on the face, above this altitude.

ACKNOWLEDGMENTS

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REFERENCES

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2. Rapid Decompression in Transport Aircraft. IAM Report #58/3. May 1958.
3. F/L F. F. Archdekin, S/L W. G. Leach, S/L A. C. Bryan, Dr. J. W. Scott, and G/C W. R. Franks: An Incident of Decompression Sickness with CNS Manifestations and Reversible EEG Changes. Presented to Canadian Fed. Biol. Sciences 3rd annual meeting, June 1960.

Public Health Notes

Diphtheria. A slight break in the downward trend of the disease occurred for the first time in fifteen years. About 78 per cent of the 934 cases were reported in the South Atlantic and South Central states. The number of cases in children under five remained unchanged; noted was an increase in both the five to nine and ten to fourteen age groups. Suggested was that immunity may be waning in some school children following primary immunization in early childhood.

Rabies. Two of the human rabies victims last year were bitten by dogs and two by bats; the source of the disease for the remaining two was unknown. Rabies in domestic animals continued to decline, but increased sixfold in wild animals, mainly foxes and skunks. The disease was confirmed by laboratory tests in eighty-five bats.—*MD,* November, 1960.