CABIN ENVIRONMENTAL CONTROL IN COMBAT AIRCRAFT

Ranjit Kumar

In a man-machine complex such as a modern high performance combat aircraft optimum efficiency of both must be ensured. Deficiency in either will limit exploitation of their potential which is not desirable for mission completion. In the flying environment there are many factors that tend to limit man's performance, the control of which is of paramount importance. The aim of this presentation is to provide a general view of the nature of these problems and highlight the requirements of cabin environmental control.

Problems Related to Reduction in Barometric Pressure

Some of the most important medical problems associated with flight are directly related to reduced barometric pressure and the attendant reduction in partial pressure of oxygen. In order to operate at altitudes beyond the tolerance limits of man, the most logical way of ensuring protection is to provide, within the aircraft cabin, an atmosphere at a pressure compatible with the physiological needs of human body regardless of the flight altitudes, i.e., by cabin pressurisation.

The main physiological considerations for the design of a pressure cabin and the level of pressurisation are based on thresholds and critical altitudes for hypoxia, decompression sickness, expansion of trapped gases in the body cavities, rates of change of cabin pressure during ascents and descents, and the possible harmful effects in the event of sudden cabin depressurisation. The ideal level of pressurisation from the physiological angle would be to maintain sea level conditions which would eliminate all these problems. In actual practice, departure from this becomes a mandatory operational requirement. The factors that will determine the extent of departure from the ideal need serious consideration while designing the modern combat aircraft.

Hypoxia : Studies on the effects of hypoxia on the cognitive functions have shown significant performance reduction beyond an altitude of 3,000 m. Progressive impairment of alertness, memory, computational ability and attention is noted between 3,000 m and 4,500 m. Recent memory and night vision are adversely affected between 1,800 to 2,400 m. Consequent to these observations, 2,400 to 3,000 m was agreed as an accepted standard for cabin altitude. Recent studies have shown impairment of the ability to learn a novel task between 1,500 and 2,400 m. In view of these findings, a cabin altitude of 1,500 to 2,100 m is gaining more acceptance. Another factor that determines the maximum acceptable altitude is the rate at which judgement and performance decline in case an aircrew has to revert to breathing air due to a fault in oxygen system, depletion of oxygen or leakage in an ill fitted mask. In case of failure of oxygen supply, the time available to recognise and to take remedial measures decreases from 10 to 12 min at 6,100m to 3 to 5 min at 7,600 m and 1 to 1.5 min at 10,000 m. Since the harmful effects of hypoxia are very severe above 6,100 m it is now regarded as a standard limit for crew and most of the modern combat aircraft are maintained around this maximum.

With the advent of air to air refueling, the endurance of aircraft can be greatly extended. The conventional aircraft depend upon compressed oxygen or liquid oxygen. Accepting a marginal degree of hypoxia means economy in the use of aircraft oxygen stores. With the conventional LOX or GASOX systems, a reduction of weight and frequency of charging are the main considerations, and a cabin altitude of 1,500 m with crew breathing air may be acceptable in a combat aircraft.

Decompression sickness : This is rarely seen below 6,700 m. Without adequate denitrogenation the incidence rises above 7,600 m and becomes increasingly likely above 9,100 m. Hence, the cabin altitude should not exceed 6,700 m. For mission completion the crew may have to stay at a higher altitude and in such cases they should be adequately protected with oxygen breathing prior to flight.

Expansion of trapped gases : Gases in the abdominal viscera may cause discomfort and pain on exposure to reduced barometric pressure. These are not serious in most people but can be extremely uncomfortable and even incapacitating at altitudes beyond 7,600 m. Limiting the maximum cabin altitude below this will prevent symptoms in healthy air crew.

Another important consideration is the degree of ease or difficulty in equilibrating the pressure of trapped gases in the middle ear as per rates of cabin pressure change during ascent and descent. Very high rates of ascent can be tolerated by the trained military pilots but during descent a pressure change of more than 136 mb is the maximum acceptable.

Sudden Failure of Pressurisation : Pressurised cabin has been universally adopted as a means of protection against hypoxia, decompression sickness and symptoms due to expansion of gases. Failure of cabin pressure, accidental or due to enemy action, must be regarded as probable and considered. The harmful effects of rapid decompression to the occupants depend upon the areaof defect, volume of the cabin and the ratio of cabin pressures before and after the decompression.

In military aircraft, decompression can be very rapid following loss of the canopy as a result of enemy action or deliberate jettisoning. To limit the injurious effects of rapid decompression, a low pressure differential is recommended. Cabin pressure can be reduced during high altitude flying without the danger of hypoxia or decompression sickness by using appropriate oxygen equipment and maintaining the cabin at a pressure below the threshold of decompression sickness. The most desirable cabin pressure represents a compromise between the ideal for an intact cabin and what is necessary as a preparation for rapid decompression. The possible hazards of hypoxia, decompression sickness and barotrauma introduced with low differential pressure cabin must be weighed against those of explosive decompression. A low differential pressure cabin is used to reduce the harmful effects of rapid decompression provided it does not compromise safety and comfort. With a low differential cabin and using oxygen throughout the sortie, maximum cabin altitude of 6,700 m can be achieved. Most present day combat aircraft are provided with low pressure cabin.

Problems Related to Thermal Environment

Thermal environment in the cabin is an important factor for optimum pilot performance. Both heat stress and cold stress impair performance. Complex equipment for personal cooling like air ventilated suits, liquid cooled suits and head cooling have been devised and none of them have been found to be completely satisfactory. There is no satisfactory standard specification for thermal requirements in military aircraft. Unlike in the West, in our country, the main thermal problem is heat stress. The thermal environment should enable the crew to function under all operating conditions with a range of personal flying clothing assemblies. Air temperature control, air flow and distribution should be physiologically acceptable. Conditioned air should be supplied to the cabin so as to maintain the mean skin temperature at 33 deg C. Most of the modern aircraft have manual and automatic control which maintains cabin temperatures of 15 to 35 deg C. There should be provision for air distribution directed towards feet, torso and head and shoulder region.

Noise and Vibration

Noise and vibration can result in discomfort and physiological strain besides making conversation impossible. Certain types of vibration interfere with visual performance. By providing good sound proofing and properly fitting helmets, the noise levels can be greatly reduced. Vibration level should be reduced to levels compatible with comfort and efficient performance.

Conclusion

It is easier to specify the ideal cabin than to provide it. The cost of weight / power penalties to achieve the ideal may not be justified. Compromises may be worth while at the cost of a little discomfort and an acceptable physiological strain on the occupants.