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AIR CONDITIONING OF AIRCRAFT
AT HIGH ALTITUDE



PREPARED BY
Committee A-9, Aircraft Air Conditioning Equipment

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AIR CONDITIONING OF AIRCRAFT

AT HIGH ALTITUDE

INTRODUCTION

1. PURPOSE: The purpose of this information report is to clarify the special problems involved in the air conditioning of civil transport aircraft during high altitude flight, as they relate to the physical and physiological limitations of the human body. This publication is intended to present only the currently available knowledge on this subject, with the realization that further research and study is rapidly supplementing and refining this knowledge. Revisions to this report will be prepared from time to time to include this information.
2. This paper is limited to the special problems of air quantity, purity, movement, pressure, temperature, humidity and oxygen supply which arise from the requirements of the human body during high altitude flight, together with the associated aircraft design problems.
 - 2.1 Within the purposes of this paper, high altitude is defined as altitudes between 25,000 feet and below 50,000 feet.
 - 2.2 It is considered that all requirements for air conditioning of aircraft as presented in SAE ARP 367 and 85B exist in high altitude flight, in addition to the special requirements discussed in this paper.
 - 2.3 It is considered that medical aspects of the physiological problems will be treated only briefly in this report. It is anticipated that Aviation Medicine personnel will be consulted for detailed analysis of specific problems.

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AIR CONDITIONING OF AIRCRAFT AT HIGH ALTITUDE

1. GENERAL CONSIDERATIONS:

1.1 Pressurization:

- 1.1.1 The design of aircraft structure, including windows, doors and hatches must be such as to make the possibility of an uncontrolled decompression in flight as remote as the possibility of a major structural failure.
 - 1.1.1.1 Windows shall be sufficiently redundant as to preclude the uncontrolled loss of pressure as a result of the failure of a single panel.
 - 1.1.1.2 Window design factors must consider the deterioration of materials involved due to aging, cleaning agents, insecticidal spray solvents, weather, high and low temperatures, and damage due to aircraft equipment.
 - 1.1.1.3 Maintenance inspection procedures must be such as to insure an acceptable margin of safety in window strength during exposure to deterioration in service.
 - 1.1.1.4 Attachment means and operating mechanism of doors and hatches should be such as to prevent inadvertent opening during flight.
- 1.1.2 Pressure within the cabin should be such as to maintain a cabin pressure equivalent to or greater than that at 8,000 feet, during flight at the maximum cruise altitude of the aircraft.
 - 1.1.2.1 Control of cabin pressure must be by a means not vulnerable to single failures resulting in depressurization.
 - 1.1.2.2 The source of pressurization must be duplicated to such an extent as to eliminate the possibility of a single failure resulting in loss of pressure. Flight should not be continued at altitudes above 25,000 feet with only one pressure source in operation.
 - 1.1.2.3 In the event of failure of any one of the cabin pressure sources, there should be sufficient remaining air input to maintain a 10,000 foot cabin altitude, or better, at the minimum airplane cruising altitude for a fuel consumption rate per ton mile which is 110% of optimum for the airplane. In no event should the failure of one pressure source result in inability to maintain a 10,000 foot cabin altitude at 25,000 foot flight altitude.
 - 1.1.2.4 With the loss of one pressurization source, when operation must be continued for an extended period of time, cooling and ventilation must be such as to maintain essential equipment in operable condition and permit safety of emergency flight procedures.
- 1.1.3 A loss of cabin pressure at high altitude encompasses possible physiological and physical hazards.
 - 1.1.3.1 Rapid decompressions may produce discomfort and injury to humans because of the rapid expansion of gases within the body, such as within the lungs, sinuses, intestines, etc.

- 1.1.3.2 Exposure to high altitude may result in aeroembolism, the liberation from solution within the body of nitrogen due to rapid and/or extreme pressure decreases.
- 1.1.3.3 Lung hemorrhage may result from pressure differential changes during decompressions in the order of 650 psi per second when maintained over three quarters of an atmosphere of pressure (11 psi).
 - 1.1.3.3.1 The critical altitude at which aeroembolism is likely to occur, regardless of the rate of pressure change, is 30,000 feet. Symptoms may arise, however, at altitudes as low as 23,000 feet. Physical activity will increase the probability and severity of symptoms.
 - 1.1.3.3.2 The frequency of occurrence and/or severity of aeroembolism is not significantly affected by the use of oxygen during decompression. Improvements due to the use of oxygen can be obtained only by breathing of a nitrogen free atmosphere for some time prior to decompression. Thirty minutes of this preparation is the minimum time sufficient to show decrease in frequency and severity of aeroembolism.
- 1.1.3.4 Damage to ears and sinuses on rapid decompression is not likely due to the relative ease with which air can escape from the sinuses and inner ear.
 - 1.1.3.4.1 With rapid descent of the aircraft seeking lower altitude following decompression, ear and sinus difficulties may be expected. These may range from temporary pain to temporary deafness and possible rupture of the ear drum. This pain, which may be extreme, and the damage, which is usually reparable, must be accepted to prevent more serious impairment due to hypoxia.
- 1.1.3.5 Frostbite is a possible hazard after decompression, with possible uncontrolled ventilation at temperatures approaching -70°F.
- 1.1.4 Personal injury may occur as a direct result of the sudden outrush of air during the decompression. The passage of air may hurl unattached objects about the cabin, and if sufficiently violent may carry personnel through the decompression opening.
- 1.1.5 Hypoxia will result from exposure to low barometric pressures of high altitudes. The low partial pressure of oxygen in the air under these conditions makes it impossible for the oxygen requirements of the body to be met. Unconsciousness and death will occur with marked rapidity if protective measures are not taken.
 - 1.1.5.1 The times to the onset of hypoxia, unconsciousness and death are greatly reduced when exposure to reduced barometric pressure of high altitude is combined with the effects of rapid decompression.
 - 1.1.5.2 Curve A of Figure B shows the time reserve before loss of consciousness (useful) and before unconsciousness supervenes for the average subject breathing air when rapidly decompressed from a low cabin altitude to high altitude in approximately one second. The data presented are from tests using an initial altitude of 8,000 to 10,000 feet. Both of these experimentally determined curves reach an asymptote of 10-12 seconds at approximately 45,000 feet altitude.