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TANZANIA CIVIL AVIATION AUTHORITY
Aeronautical Information Services

AERONAUTICAL INFORMATION CIRCULAR

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This Aeronautical Information Circular is issued for information, guidance and necessary action

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HYPOXIA IN FLIGHT AND ITS PREVENTION

1. Introduction

Several accidents and incidents have occurred in which the aircraft's emergency oxygen equipment has been involved, some of the former with fatal results.

1.1 Many aircraft, in which the crew and passenger compartments are un- pressurized, are capable of flight at altitudes at which breathing ambient air produces a significant and often critical deterioration in the performance of flight tasks. With pressurized aircraft, loss of cabin pressure at any altitude above 10 000 ft will result in some deterioration, while at altitudes greater than 20 000 ft there will be a very rapid impairment of ability unless oxygen is immediately the decompression occurs. Mountaineers and people living at significantly high altitudes may adapt to the rarefied air, but there will not be time for this to occur in the rapid ascent associated with flight. This Circular is intended to alert all pilots to the dangers of Hypoxia (lack of adequate oxygen) and its prevention. Whenever altitude is referred to, this should be understood to mean altitude above mean sea level (AMSL). This is depicted by contours on ICAO standard topographical maps and will indicate, at the flight planning stage, those parts of a route where oxygen could be required.

2. Physiological Considerations

2.1 The energy essential for living processes is obtained by the oxidation of complex foodstuffs, and thus oxygen is one of the most important materials required for the maintenance of normal function by living cells. The cells of the brain are particularly sensitive to lack of oxygen. Total cessation of the oxygen supply to the brain results in unconsciousness in 6-8 seconds and irreversible damage ensues if the oxygen supply is not restore within 4 minutes.

2.2 The supply of oxygen to the tissues is normally maintained by the blood which picks up the gas in the lungs and delivers it to the tissues. The concentration of oxygen in the blood leaving the lungs, and hence the supply of oxygen to the tissues, depends upon the partial pressure (molecular concentration) of oxygen in the lung gas which is closely related to the partial pressure of oxygen in the air inhaled. Although the concentration of oxygen in the air is constant at all altitudes, the partial pressure of oxygen in it falls directly in proportion to the reduction of atmospheric pressure which occurs with ascent to altitude. Thus the partial pressure of oxygen in the air at 18 000 ft (0.5 atmosphere) is about half that at sea level. Because of the presence of water vapour, the partial pressure or oxygen in air in the lungs is further reduced. However, the affinity of the red cells of the blood for oxygen, enables the partial pressure of oxygen in the cells of the brain to be maintained at half normal. At this pressure, the oxygen supply to the tissue is inadequate to maintain normal function, and the condition known as Hypoxia arises.

3. **Breathing Air at Altitude**

3.1 The intensity of the hypoxia induced while breathing air varies with the altitude, the duration of the exposure and the rate of ascent. The other major factor affecting the intensity of hypoxia at altitude is the degree of physical exercise; exercise markedly intensifies the effects of a given degree of hypoxia. Finally there is considerable individual variability in the symptoms and effects of hypoxia. Generally, the higher the altitude, the more marked the symptoms. Rapid rates of ascent, however, allow higher altitudes to be reached before severe symptoms occur. In these circumstances, unconsciousness may occur before any or many of the symptoms of hypoxia appear.

3.2 Effects of Slow Ascent to Altitude

3.2.1 It is convenient to consider first the effects of slow ascent:

(a) **Flight Levels up to FL 100**. Seated individuals (unless carrying out heavy exercise) have few symptoms, apart from some loss of night vision. Their ability to perform most complex tasks will be unimpaired, however, speed with which they can react to novel conditions can be shown in the laboratory to be impaired at an altitude of 8 000 ft. The marginal impairment of performance produced in normal healthy individuals, by breathing air at altitudes up to 10 000 ft, is considered acceptable;

(b) **Flight Levels between FL 100 and FL 150.** Resting individuals have little or nothing in the way of symptoms, but their ability to perform skilled tasks such as aircraft control and navigation is impaired, the impairment increasing with altitude above 10,000 ft. Individuals are frequently unaware of the hypoxia or of the impairment of performance which it produces. Indeed, they are performing better than usual. Physical exercise, particularly at altitudes above 12 000 ft frequently produces mild symptoms, especially breathlessness. Exposure to these altitudes for longer than 10-20 minutes often induces a severe headache;

(c) **Flight Levels between FL 150 and FL 200**. Above 15 000 ft, symptoms of hypoxia occur even in individuals at rest. There is marked impairment of performance, even of simple tasks, together with a loss of critical judgement and willpower. Thinking is slowed, there is muscular in coordination and marked changes in the emotional state. Individuals may become pugnacious or morose, or may become physically violent. Again, they usually have no insight into their condition, an effect which makes hypoxia such a potentially dangerous hazard in aviation. Individuals frequently feel light-headed, with a tingling in the lips and limbs. Physical exertion greatly increases the severity of all the effects. It often causes unconsciousness.

(d) **Flight Levels above FL 200**. Breathing air at altitudes above 20 000 ft. results in severe symptoms even in individuals at rest. Mental performance and comprehension decline rapidly and unconsciousness occurs with little warning. In individuals seated at rest, the time between cessation of supplemental oxygen and serious impairment of consciousness is 10-15 minutes at 20 000 ft, 2.5-6 minutes at 25 000 ft and 1.5-3 minutes at 30 000 ft. Any exertion at altitudes above 20 000 ft. rapidly produces loss of consciousness.

4. Effects of Rapid Decompression

4.1 The previous paragraphs describe the hypoxia induced by either slow ascent whilst breathing air or cessation of supplemental oxygen at a given altitude. The severity and rate of onset of hypoxia when it is induced by a sudden failure of the pressure cabin of an aircraft (i.e. time of decompression to above an altitude of 20 000 ft. less than 1.5 minutes) is considerably greater than when the hypoxia is induced by cessation of supplemental oxygen at the same altitude. Thus serious impairment of performance will occur within 1.5 minutes following a rapid decompression whilst breathing air to 25 000 ft. Oxygen breathing must be commenced within a few seconds of the beginning of a rapid decompression at altitudes between 15 000 to 30 000 ft. if no impairment of performance due to hypoxia is to occur. Rapid decompression to altitudes above 30 000 ft. will result in transient impairment of performance even if 100% oxygen is breathed as the decompression commences.

4.2 These facts emphasize the importance of the correct use of oxygen equipment in the event of the decompression of a pressurized aircraft; This 1esson is even more important in small pressurized aircraft where loss of window will result in a very rapid decompression of the cabin and hence the very rapid development of hypoxia.

4.3 It must be remembered that the effects of hypoxia outlined in the previous paragraphs apply to healthy, normal individuals. A proportion of passengers may be suffering, either knowingly or unknowingly, from conditions which reduce their tolerance of hypoxia below that of the normal healthy individual. Individuals suffering from certain diseases of the heart or lungs do not tolerate well the hypoxia induced by breathing air at altitudes greater than 5 000 - 6 000 ft.

5. Use of Oxygen

5.1 General

5.1.1 The hypoxia induced by breathing air (21% oxygen) at altitude is combated by increasing the concentration of oxygen in gas breathed. Breathing 42% oxygen at 18 000 ft.(0.5 atmosphere) maintains the partial pressure of oxygen in the lung gas and the oxygen supply to the tissues at the same levels as produced by breathing air at ground level. The limit to the enrichment with oxygen comes when the gas is 100% oxygen. Breathing 100% oxygen at 34 000 ft. is equivalent to breathing air at ground level, whilst breathing 100% oxygen at 40 000 ft. is equivalent to breathing air at an altitude of 8 000 - 10 000 ft. Some form of positive pressure breathing or a pressure suit is required to prevent significant hypoxia above 40 000 ft. even when breathing 100% oxygen.

6. Oxygen Equipment

6.1.1 Pilots of public transport aircraft on the Tanzania Register should be familiar with the requirements of the Air Navigation Regulations relating to the supply and use of oxygen. (Fifth Schedule).

6.2 Pilots of non-public transport aircraft (whether such aircraft are un-pressurized or pressurized) intending to fly above an altitude of 10000 ft. must also ensure that they are conversant with the type of equipment carried, the capacity of the system, and be able to carry out the necessary checks and drills appropriate to the equipment.

6.3 Special attention must be directed to the emergency drills laid down by the manufacturers. Passengers should be briefed before flight on the use of the oxygen masks, particularly the importance of fitting the mask properly so as to permit normal breathing. Passengers should also be briefed on emergency actions in the event of oxygen failure and the action to be taken should they see another passenger occupant having difficulty with breathing. Passengers traveling with small children in pressurized aircraft should be advised that in the event of pressurization failure they should don their own oxygen masks before attending to the children. Smoking must not be permitted aboard the aircraft when the oxygen system is in use and for at least a few minutes after the flow has been shut off.

6. 4 Un pressurized Aircraft

6 4.1 Pilots should be breathing oxygen whenever the aircraft altitude equals or exceeds 10 000 ft, should check the fit of their masks, the flow of oxygen and the amount of oxygen available in the aircraft storage system. The commander should monitor the state of the passengers and crew, who should be supplied with oxygen according to the scales laid down in the Air Navigation Regulations.

6.5 Pressurized Aircraft

6.5.1 Pilots should study the aircraft's Flight Manual or the manufacturer's Handbook on type, be conversant with details of the pressurization system fitted to the aircraft and with the requirements of any associated emergency drills. These drills have been formulated with operational techniques in view, e.g. handling characteristics and structural considerations. They include familiarization with the methods of measuring cabin pressurization in order for the commander of the aircraft to ensure that all crew and passengers are instructed when to use oxygen.

6.6 The Air Navigation Regulations also makes specific provision for operational requirements, crew training and tests, and emergency procedures for the use of oxygen in relation to public transport flights. Pilots of non-public transport aircraft must also ensure that they are fully conversant with oxygen equipment fitted to the aircraft. Prior to flight above 10 000 ft. amsl pilots should check the fit of their masks, the oxygen contents, that their masks are connected to the oxygen supply and that the oxygen is at the recommended selection for the standby role. The masks should be stowed so that they can be donned rapidly and with ease.

6.7 In the event of a decompression of the cabin altitude above 10 000 ft, the prevention of hypoxia by the pilot is of paramount importance since the survival of all on board depends upon his subsequent action. The first group of actions to be taken by the pilot(s) in the event of a decompression must be the rapid donning of the oxygen mask followed by a check of the mask fit and to ensure that oxygen is being breathed. The second action is to initiate immediate rapid controlled descent to as low an altitude as the local terrain and consideration of fuel supply allow. (Although oxygen equipment is installed for use by passengers in some aircraft, there is good evidence that a high proportion (50%- or more) of passengers will not use such equipment properly, even when the masks are dropped in front of them. In decompression chamber studies, subjects breathing air were severely incapacitated by exposure to a profile consisting of decompression from 8 000 ft. to 25 000 ft. in one minute, followed by one dwell at 25 000 ft. and a subsequent descent at 40 000 ft per minute to 8 000 ft. Aerodynamic performance and the presence of structural damage will dictate the maximum rate at which descent should be carried out at the maximum safe rate to below an altitude of 10 000 ft (provided the local terrain allows). The amount of oxygen on board the aircraft may be provided according to a rapid capability, except when an aircraft is forced to remain at a flight level where oxygen is required due to high surrounding terrain. These parts of the route should be identified at the flight planning stage. Descent at high rates may well give rise to ear discomfort or pain in a high proportion of passengers, particularly at altitudes below 20 000 ft. At high altitudes, the need to reduce the time for which passengers are breathing air (i.e. those who have not made effective use of the oxygen system) should override considerations of the risk of damage to the ears.

6.8 Although descent at very high rates may even produce a tear in the ear drum, this type of injury nearly always heals rapidly and completely and has no long term effects. From the physiological considerations presented in the previous sections, pilots will appreciate that if an emergency condition arises, there must be an -immediate and meticulous response to the prescribed drills. It is imperative that flight crew perform all preflight normal functional checks of the oxygen system. Their lives and those of their passengers may depend upon having a serviceable system.

7. Practice Release of Pressure

7.1 On some smaller types of pressurized aircraft, it is possible to dump the cabin pressure by operating a quick release valve and hence to simulate an emergency situation for crew training. This method is unnecessarily violent and should not be used. For crew training purposes, a slower method of reduction of cabin pressure should be used and aircraft should not be deliberately depressurized above an altitude of 15 000 ft. For systems testing purposes however, the Airworthiness Flight Test Schedule for the aircraft type will detail the procedure to be used where depressurization is necessary at higher altitudes.

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