Some problems of high speed travel

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Summary

Some aspects of high speed flight are examined to investigate whether increase in speed implies any lowering of safety standards. The problem of circadian dysrhythmia is discussed and methods of attenuating its effects are explained and some new hypnotic drugs are mentioned. The risk of decompression has been quantified and predictions have been made for risks in commercial service. Cosmic radiation in supersonic aircraft is unlikely to limit commercial operation or significantly increase risks to passengers and crew. The supersonic boom is likely to limit the terrain over which supersonic aircraft can operate and regulations covering engine noise on the ground could restrict some flights.

Introduction

This paper will examine some civil problems affecting both crew and passengers of high speed aircraft. It used to be a 6-8 week sea cruise by liner to Australia but in 1974 one can fly from London to Sydney in 28½ hr. When Concorde starts operating commercially, the flight time is expected to be 15 hr. Then New York will be only 3½ hr away and Buenos Aires 9½ hr away, flying at Mach 2.2 (1350 m.p.h.). Travel at this speed will accentuate some of the problems experienced in jet aircraft in 1974. Probably the most widespread of these is circadian dysrhythmia, colloquially called 'jet lag'.

Circadian dysrhythmia

Circadian dysrhythmia is caused by the desynchronization of the normal sleep and wakefulness cycle of the body with local time. The problem presents itself to travellers as lowered efficiency and malaise, the inability to sleep during local sleeping hours after a journey and fatigue when one is required to be alert. This problem is even more pressing for the crew who have to rest in an allotted time so as to be fit to fly the aircraft again.

Physiologically there is good evidence for an endogenous circadian rhythm (Mills, 1966). The rhythm persists under constant conditions of light and dark, e.g. underground, and the rhythm tends to persist even when new phases or cycles are imposed. Circadian rhythm is acquired early in infancy

and persists with some changes throughout life. It affects practically the whole physiological machine: respiration, thermal regulation, cardiovascular function, adrenocortical activity, the reticulo-endothelial and renal systems, even the parasites we may have in our bodies respond to our own circadian rhythm. Pathology also follows a rhythm, mortality rate is highest very early in the morning and psychotic episodes show inherent periodicity. With such a widespread control on so many functions, little wonder that well-being is easily lost when one's circadian rhythm is forced to change.

How can one minimize these effects? Passengers should start long journeys well rested and emplaning drills should be minimized, vaccinations and other medical procedures should be completed some 6-8 weeks before the journey. Smoking and alcohol ingestion in flight should be minimized and only light meals taken. The appropriate clothing should be worn and passengers should be encouraged to sleep when possible by the extinction of lights. At the destination, one should allow at least a day or a full night to permit some acclimatization to the local time and the knowledge that physical fatigue is a potent sleep inducer can be of assistance. Indoctrination on the hazards of circadian dysrhythmia can help but this aspect is seldom mentioned.

With crews, lack of sleep can become cumulative. Preston, Ruffell-Smith and Sutton-Mattocks (1973) found progressive sleep loss in cabin crews on long flights, and older personnel tended to lose sleep more than others. Transmeridian routes were more likely to produce gross sleep disruption and sleep periods soon became fragmented. The authors found that hotel managements could assist in serving breakfast in the evening, dinner in the morning and by avoiding disturbance from hotel cleaning staff, sleep was not disrupted. One solution for this problem is to base crews abroad for periods of up to 3 months but this has drawbacks usually of a managerial or trade union nature.

The use of hypnotics is more contentious. It has been shown (Borland and Nicholson, 1974; 1975; Borland, Nicholson and Wright, 1974) that nitrazepam (mogadon) is not a drug of choice for aircrew as it has a long half-life (30 hr), and one can

demonstrate residual effects on skilled performance some 19 hr after the ingestion of 10 mg. Flurazepam (dalmane), although it has a shorter half-life, also has residual effects for 16 hr after the ingestion of 30 mg. Heptabarbitalone (medomin, 200 mg) and methaqualone (melsedin, 150 mg) are better, but not without some disadvantages. Heptabarbitalone is a barbiturate with a short half-life (10 hr), and does affect performance for at least this period. Methaqualone is excreted at a variable rate but can persist for 10 hr and affect reaction time, although little effect on skilled performance can be demonstrated 10 hr after ingestion. It is better for aircrew to try to sleep without the use of hypnotics or alcohol but, if drugs must be used, heptabarbitalone and methaqualone are probably the best to use, after an adequate trial has been instituted off duty. For passengers the problems are less severe and some non-habit-forming hypnotic could be used with good effect to alleviate the fatigue of long aircraft journeys.

High altitude

In order to fly fast, aircraft must fly high where the air density and aerodynamic drag are less. Modern jet aircraft cruise just below the tropopause (38,000 ft) but supersonic aircraft will fly considerably higher, up to 60,000 ft. At this altitude loss of cabin pressure is likely to be more dramatic. Breathing 100% oxygen will give protection up to 40,000 ft and above this altitude, oxygen under pressure must be administered to maintain oxygenation. At 63,000 ft oxygen at a high pressure is required with counter pressure to the body by means of a special garment. With a pressure in the cabin equivalent to 8,000 ft altitude, the sequelae of explosive decompression caused by defects in the cabin walls were examined by Nicholson and Ernsting (1967). Assuming that the aircraft had initiated a descent one minute after cabin pressure was lost, a 4-in. diameter hole would cause the cabin altitude to rise to 30,000 ft. This is unlikely to be serious; transient unconsciousness could occur if oxygen was not breathed immediately, but consciousness would soon be regained on the descent. With a 6-in. diameter hole, the cabin altitude would rise to 42,500 ft and the altitude would exceed 25,000 ft for 6½ min. If oxygen was administered immediately, severe hypoxia would be avoided although unconsciousness would be likely. With an 8 in. diameter hole, the cabin altitude would rise to 53,500 ft and would be above 25,000 ft for 7½ min and above 40,000 ft for 4 minutes. The risk to passengers in the 8-in. diameter hole case would be considerable as the time at altitude is sufficient to cause severe hypoxia which could be fatal, even if oxygen was administered immediately.

These predictions were tested by exposing animals

to similar decompression profiles as would occur in a supersonic aircraft with these defects in the cabin wall. With a 4-in. diameter hole, the animals became unconscious but made a normal recovery. With the 6-in. diameter hole, unconsciousness supervened early at 40,000 ft and three of the four animals either succumbed then or died later. The animals that survived initially showed gross neurological and behavioural abnormalities before death which suggested widespread brain damage. With the 8-in. diameter hole, the animals failed to recover.

The requirements for the Concorde state that cabin altitude should not exceed 15,000 ft following a failure in the pressurization system which would occur once in 10^3 – 10^5 flying hours. The cabin altitude should not exceed 25,000 ft after a remote failure (1 in 10^6 – 10^7 flying hr) and should only exceed 25,000 after an extremely remote failure (less than 1 in 10^7 flying hr). Recent investigations into the integrity of the Concorde fuselage indicate that the failures which are likely to be hazardous will be extremely remote (Preston, 1972). Multiple air supplies to the cabin together with small discharge valves and small diameter windows (less than 6 in diameter) should further safeguard the passengers. For the crew, special quick donning mask assemblies that will supply oxygen at high pressure have been devised and these will maintain the oxygenation of the crew so that the appropriate descent manoeuvres can be executed. The passengers will be supplied with drop-down oxygen masks automatically lowered when the pressure in the cabin falls below the equivalent of 14,000 ft.

Radiation

The atmosphere functions as an extremely efficient attenuator of the most harmful radiation that strikes the earth. Galactic radiation consists of high energy particles (protons and helions) and heavy particles (Fe., Mg., etc.) These normally disintegrate as they meet the upper atmosphere and few reach the surface. The distribution of cosmic radiation is affected by the earth's magnetic field, thus the density of the radiation is greatest at the magnetic poles. Crew and passengers on supersonic aircraft at altitudes above 60,000 ft could run some risk of radiation, albeit very slight. It has been estimated that an average dosage of 1.5 mrem/hr can be expected on trans-atlantic routes. Trans-Siberian routes would involve flights at 79° north where 1.55 mrem/hr or 3.9 mrem/flight would be expected.

Solar flares occur in cycles and produce X-rays which are difficult to screen in aircraft. Warnings of intense solar activity are given by observatories and other forecasting centres and the aircraft will carry radiation meters which will monitor the ambient radiation received by the aircraft and occupants

so that changes in radiation should not remain undetected. Exposure rates in excess of 10 mrem/hr will alert the crew and 50 mrem/hr will require descent to lower altitudes (Preston, 1972).

The International Commission on Radiation Dosage advises a limit of 5 rem/year and a maximum of 3 rem in any three months for radiation workers, and 0.5 rem/year for others (Preston, 1972). This allows almost sixty round trips per year on the Atlantic route which is unlikely to be exceeded by many passengers. Aircrew are at a greater risk, and it has been estimated that a pilot achieving 160 return flights on the Atlantic route could accumulate a dose of 1.3 rem in one year, which is well below the limit for radiation workers although it is above the level for the general public. Stewardesses who become pregnant are not normally allowed to work after the third month. Thus the fetal radiation is unlikely to exceed 1 rem. Crews may have to wear film badges and undergo blood tests, as do workers where there is a risk of radiation, but radiation is unlikely to hamper supersonic transport operations.

Noise

For passengers of supersonic aircraft the flight is likely to be smooth and quiet. However, when the aircraft is travelling at supersonic speed an area of 50 miles wide underneath the flight path will be subjected to the additional disturbance of the supersonic boom. When cruising at altitude, the disturbance will be slight but this can increase in intensity when the aircraft accelerates or turns and boom over-pressures of 3.6 lb/ft² have been predicted. The effects of the sonic boom have been investigated by many workers and the data have been summarized by the Sonic Boom Panel of the International Civil Aviation Organization (1970).

The sonic boom is unlikely to damage the ear, nor is it likely to cause chronic physiological effects. Eardrums can be ruptured with explosions having an over-pressure of 150 lb/ft² and aural damage is unlikely below this figure. Tinnitus can occur with over-pressures of 95 lb/ft² and hearing loss has been reported above 30 lb/ft². The 'startle' effect of sonic booms can be annoying and tests of sonic booms at the rate of 10–15/day on a community unrelated to aviation showed that 100% of the population found the booms unacceptable when the over-pressures were 3.6 lb/ft². When the over-pressures were reduced to 2 lb/ft², only 40% deemed them unacceptable. Sleep was interrupted, for old persons more so than for the young, infants were alarmed but children were seldom disturbed in these tests. Community reactions usually centred around the fear of damage to property and were also related to the degree of news media coverage.

The effect on property in these tests was slight and was confined to extension of plaster and paint cracks and broken glass windows. The damage claims for broken glass was in the order of 1 claim for 10⁶ population per flight but only a third of those claims were judged valid.

In other tests directed at Oklahoma City, Chicago and St Louis, U.S.A., the paid claims amounted to \$220 per 10⁶ boom-person exposures. Older property deteriorated faster but it was difficult to correlate the hazard of sonic booms with those of the local environment, e.g. heavy lorries, etc.

Sonic booms on animals showed a range of effects from minor startle reactions in cattle to pandemonium and crowding in chickens. There were no measurable effects on egg or milk production or food consumption.

The likelihood of sonic booms starting avalanches of snow is thought to be low.

It has been recommended that the effects of sonic booms on sleep, sick and aged people and persons at sea should be further investigated. Clearly much more work is required before supersonic aircraft are allowed to fly over populated areas.

In this paper, a few aspects of high speed travel have been examined in order to answer the question whether travel is safe. The yearning to fly faster and go further in less time will always be with us, but this should never imply less safety. One of the safest ways to travel is by air and supersonic flight should be as safe as subsonic flight.

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