THE MEDICAL EVALUATION OF AIRCRAFT

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Introduction

In a well designed aircraft human and mechanical elements should be so integrated as to enable it to carry out its intended role with efficiency and safety. In aviation, to-day, the achievements of the aerodynamicist and the aeronautical engineer have pushed the machine to the limits of human capability, and in some instances have outstripped it. One of the chief objectives of Aviation Medicine is to define these limits, and to so adapt and so condition the human element, that efficient and safe performance beyond these limits is rendered possible, if necessary. No team evaluating aircraft can therefore be complete without a doctor trained in Aviation Medicine, and it will be incumbent on him to define the human limitations, and to assess how far the specifications have been met in the final man-machine product, or how much more premium efficiency can be given over comfort and safety. In fact, it is most desirable that medical participation be associated with the production of an aircraft from the design stage.

For the purpose of evaluation, the worst conditions that may possibly be encountered together with the maximum endurance of the aircraft should be taken into consideration. It is also essential to bear in mind that the aircraft should be capable of being flown by an average pilot, who has undergone a standardised pattern and period of training.

In the following paragraphs an attempt has been made to discuss briefly the requirements of a modern aircraft from the medical point of view. Certain general considerations are first outlined. The special requirements of different classes of aircraft are dealt with later.

General Considerations

Crew Stations. The crew cabin and crew stations should be so designed as to permit crew members to work as an integrated team. They should be able to communicate with each other without undue effort. There should be sufficient space between the crew stations. The ceiling should be high enough to permit easy entrance and exit. Each member should be able to perform his duties efficiently at his seat, *e.g.*, the flight engineer should be able to see the engines and propeller tips.

In aircraft which are required to be airborne for long periods of time, arrangements must exist for the alternate crew to relax and feed.

Controls. The average pilot should be capable of operating the controls under adverse conditions. The manner of operation of the control should simulate as far as possible the actual movement of the operated part, *e.g.*, forward movement of the throttle should result in greater power and vice versa. Important controls that may be operated accidentally in an emergency should not be grouped together. Switches should be located according to their importance and frequency of use. Since visual identification may not always be possible, the "blindfold" principle, *i.e.*, reliance on the tactile and kinesthetic sensations, is resorted to, and variety of shape and form help in the identification of controls under conditions of poor illumination. Standard shapes with standard colours provide both visual and tactile cues, *e.g.*, red may be associated with round, and white with oval knobs.

Controls should be so placed that they can be operated by natural actions and with little effort. The controls most frequently used should be located directly in front of the body. A pilot of average build should be capable of operating the controls manually in the event of failure of powered control. In aircraft with long endurance, the pilot should be relieved of tedium and fatigue by the installation of an autopilot.

Instrument Display. The arrangement of the panel instruments is planned to simplify the pilot's task. Flight instruments should be grouped together in the centre of the panel, with the most frequently referred to instruments, *e.g.*, the gyro compass, and the critical instruments for instrument approach like the I. L. S. cross pointer, occupying central positions in the group. Flight instruments which display a pictorial representation of the spatial situation, such as the artificial horizon and I. L. S. cross pointer, should indicate in the same frame of reference, *e.g.*, either "earth reference", depicting the change in the outside world as a result of the aircraft movements, or "aircraft reference", simulating the aircraft movement in relation to the fixed environment. The mixing of these two frames of reference in the same instrument display is hazardous and may lead to confusion.

Engine instruments should be systematically grouped on one side, arranged by engines vertically and by function horizontally. The pointers are set in symmetry, so that any asymmetry indicating that something is amiss, is quickly noticed.

Dial markings and pointers should be of sufficient size and shape to permit easy and accurate readings under the worst visibility conditions. Warning lights should be located near the associated instruments and controls, and it is important that they should be well within the pilot's cone of visual attention.

Visibility from the Cockpit. The windscreen should not distort vision. It should be made of material that transmits about 97% of light and does not easily get scratched and dirty. Aerodynamics demand inclined windscreens, and since this results in light loss through reflection off the inclined surfaces, the angle of incidence, or the angle the incident light rays make with the perpendicular to the windscreen surface, should be limited to 65°, thus permitting an average light loss of not more than 15%.

Vision over the side of the cockpit should not be less than 50° below the horizontal, except when the wings interfere. Forward visibility over the nose should be at least 15° below the horizontal. Vision above the horizontal should be 35° to 40° in a transport, and the maximum possible in military aircraft. Laterally, the pilot should be capable of seeing at least 110° on each side without moving his head.

There should be an efficient, defrosting, de-icing and wiping system to retain good visibility through the windscreen under all conditions. Structural bars or frames should be eliminated as far as possible from the windscreen and canopies ; if unavoidable they should be less than 2 ins. in width.

Inside the cockpit, knobs and instrument markings should contrast sufficiently with the general cockpit background, so as to ensure adequate visibility under all operating conditions.

Cockpit Illumination. By day, at very high altitudes, the reversal of light phenomenon may cause the interior of the cockpit to darken, and the reading of instruments may have to be facilitated by artificial white light. A lighter coloured cockpit interior also helps visibility inside the cockpit under these conditions.

By night, cockpit lighting should aim at an even illumination of the entire instrument panel, providing good and easy readability of pointers and scales with the minimum light. The colour of the light should be red, of a wave length not less than 640 millimicrons so that night vision is preserved. Likewise orange phosphor paints should be used for pointers and scales, which are flouresced by ultra violet light. Rheostat control should be provided for all lights. A battery operated lighting should also be installed for use in emergency. Incidental light, from the passenger cabin and other sources, should not reach the crew compartment.

Noise and Vibration. Noise and vibration can cause discomfort, annoyance, irritability and fatigue in both aircrew and passengers. It is therefore important to control the level of noise and vibrations inside the cabin. In transport aircraft, an overall noise level of 80 to 85 db is the maximum permissible for passenger comfort. In military aircraft, the level is normally much higher, of an order of 100 to 110 db. Suitable protective devices incorporated in helmets decrease the interference effect on speech and the other ill effects.

The vibration amplitudes have to be maintained at levels, which do not cause a noticeable amount of subjective discomfort. Between 10 and 20 cps., the amplitude should not exceed 0.005 cm. At lower frequencies the tolerable amplitudes are higher, and for higher frequencies lower.

Noxious Gases and Vapours—These are no longer major hazards. Nevertheless, the cockpit or the cabin may be contaminated to harmful degrees in some cases. Under normal conditions of flying, concentrations above the permissible limits of the noxious gases and vapours should never be permitted. The common gases and their permissible concentrations are :

Carbon monoxide	... up to 50 parts/million
Oxides of nitrogen	... up to 100 parts/million
Gasoline vapours	... up to 500 parts/million
Carbon tetrachloride	... up to 72 parts/million

Temperature, Humidity and Ventilation—It is necessary to control the temperature inside the cabin to maintain the crew and equipment at temperatures compatible with efficient operation, and to ensure passenger comfort. The feeling of thermal comfort of an individual depends on the temperature, humidity and air velocity. A temperature of 68 to 72° F, with a relative humidity of 50% is considered desirable. The rate of temperature change should not exceed 5° F per min.

Air supply into the cabin has to be uniform and without draughts. The selected temperature is preferably maintained by thermostatic controls, automatically adjusting to varying conditions. An auxiliary manual over-ride, to maintain suitable temperatures, in case the automatic system fails, is also necessary. The fresh air flow requirement is 1.2 lbs per min. per person.

Duplication of the air supply system is necessary to cater for failure of the primary system, and the ventilating system should supply at least 0.5 lb per min. per person, even in the event of a failure. The air velocity within the passenger and crew compartments is kept below 400 ft per min. Air used for recirculation should be freed of smoke and unpleasant odours.

EMERGENCY ARRANGMENTS

i) *Escape from Aircraft*—In all military aircraft, provisions must exist for the crew to escape from aircraft. In modern high speed aircraft, escape has to be aided by installing an ejection seat. It must be ensured that the ejection seat is capable of use under the most adverse circumstances. An adequate number of escape hatches should be provided at suitable places for the use of crew and passengers when the aircraft crash lands or ditches, and the crew and passengers should be able to abandon the aircraft quickly. The hatches should also be easily accessible to ground rescue parties, and capable of being opened from the outside, when the occupants of the aircraft are unable to come out on their own.

ii) *Survival Packs*—Depending upon the terrain over which the aircraft fly, there should be adequate provision for rescue and survival equipment.

Transport Aircraft

In case of transport aircraft, in addition to what has already been covered, certain other points merit special consideration. These are now discussed.

Seating Arrangement—Forward facing seats have been found to be the most accepted arrangement, in spite of the fact that in the event of a crash landing these afford no protection to the head and the trunk. The obvious advantage of backward facing seats is outpointed by the inherent aversion of passengers to sit facing in a direction opposite to the path of flight.

Pressurisation. It is desirable to have pressurised cabins for all flights above 10,000 ft., but for any flight above 15,000 ft. it is obligatory to pressurise the cabin, otherwise oxygen has to be used to ward off adverse effects of hypoxia.

Isobaric control is the system of choice. The cabin altitude is maintained around 8,000 ft., whatever the ambient altitude may be above 8,000 ft.

Rapid decompression is always a potential hazard. If it occurs, it should be indicated to the pilot in the form of an audio-visual warning. Oxygen must always be provided for the crew for such an eventuality.

PASSENGER AMENITIES.

i) *Sanitary.* Adequate sanitary facilities should be provided. The number of toilet compartments required depends upon the carrying capacity of the aircraft, and the duration of flights.

ii) *Food.* Facilities for storing prepared food should be provided.

iii) *Water.* Sufficient quantity of drinking water should be provided.

EMERGENCY MEASURES.

i) *Oxygen system.* In pressurised aircraft flying below 25,000 ft., there is hardly any need for such a system. However, stand by oxygen sets should always be provided for the aircrew for obvious reasons. A small percentage of passengers, who are likely to be more susceptible to oxygen lack, should also be catered for.

In flights above 30,000 ft., the aircrew and all the passengers should be provided with emergency oxygen points. The masks used should be simple to wear and should be stowed in an easily accessible place. In the event of an explosive decompression, with the attendant confusion and panic, some passengers may not be able to put on the masks. The ideal would be a system, in which the oxygen mask presents itself in front of the face of the passenger when required. Above 40,000 ft., oxygen should be supplied under pressure, and a portable oxygen system should be provided for members of the crew.

ii) *Fire fighting equipment.* Adequate fire fighting equipment must be provided. The ideal would be to have many small but efficient fire fighting units. These units should be capable of operation even by inexperienced passengers, and should be distributed all over.

iii) *Escape.* The importance of the escape hatches has already been emphasized. The escape hatches should be away from the fuel tanks, and be easily accessible to the passengers as well as to the ground rescue teams. Luminescent signs should indicate the position of these hatches, so that even in an emergency the passengers can be easily guided to them.

Casualty Transportation. No aircraft is usually specially manufactured for this purpose. However, every passenger aircraft should have provisions to be used for transporting the sick and wounded. The ideal would be to use pressurised aircraft, modified to carry rows of stretchers, fitted in tiers. When other than pressurised aircraft are used for this purpose, it should be ensured that the interior of the aircraft is insulated to cut off noise and vibrations, and also to minimise the effects of heat and cold.

Military Transport Aircraft. In transport aircraft used for military transportation, comforts and amenities can be partially sacrificed to increase the pay load and operational efficiency. However, parachutes must be provided for each passenger. Under these circumstances, a wind breaker door should be provided in front of the escape hatches, so that the wind blast is cut off.

Military Aircraft

This category of aircraft poses different problems. Whereas, basic considerations of safety are kept in mind, comfort is almost always sacrificed to achieve greater operational performance. Aircraft considered under this category are, fighters, bombers, reconnaissance aircraft.

The Pilots Seat. Construction of the seat should be such that the posture maintained is dynamically and functionally related to the controls and instruments in the cockpit. It should, however, be remembered, that though the seat is never as comfortable as it should be, sitting in the seat, for the duration of the endurance of the aircraft, should not cause discomfort enough to affect efficiency, nor should it give rise to any residual fatigue.

Pressure on the coccyx should be avoided by providing suitable cushioning. The back of the seat should be designed to ensure that it gives adequate support to the trunk, and the spine should not be affected when exposed to positive 'g' forces. Weight of the occupant should be distributed over a wide area of the seat, and the seat should be able to withstand anticipated 'g' forces with a sufficient margin of safety.

The harness straps should be strong enough to withstand sufficient loads of 'g' both during voluntary combat manoeuvres and during crash landings.

Pressurisation—Explosive decompression is always a great hazard in pressurised military aircraft, *e. g.*, hit by enemy fire at altitude can cause serious consequences, unless the exigency is already anticipated and catered for. The adverse effects of explosive decompression largely depend upon the pressure differential maintained. For fighter aircraft a pressure differential of not more than 3.5 *p. s. i.* is recommended. In long range bombers a higher pressure differential should be provided. But in both cases provision should exist to decompress the cabin to a lower pressure differential before engaging in combat. Depending upon the ambient altitude that the aircraft can climb up to, suitable flying clothing must be provisioned, *e. g.*, whereas flights up to 48,000 ft. can be undertaken with a pressure demand oxygen system and a mask only, flights above 56,000 ft. necessitate the use of a partial pressure helmet, a pressure jerkin, etc.

Oxygen System—The actual system installed shall depend upon the maximum altitude and duration of the flight expected of the aircraft. For flights up to 40,000 ft. the conventional economiser or diluter demand systems with a tight fitting mask have been found adequate. For flights between 40,000 ft. and 48,000 ft. a pressure demand system is sufficient. However, when flights above this altitude are undertaken, the oxygen system should be able to supply oxygen under sufficient pressure to enable the use of partial or full pressure flying assemblies. Emergency oxygen outfits must be provided along with the ejection seats to tide over a crisis at altitude, arising out of system failure or ejection at a great height.

Escape facilities—In military aircraft, abandoning the aircraft in an emergency is a situation kept in mind from the moment of conception of its design. However, it must be ensured that the provisions made, should be operable under the worst conditions of flight. When a conventional bail out through an escape hatch has to be made, provision must be made to cut out the wind blast by installing a wind breaker door. However, most of the problems of escape now centre around the ejection seat, the universally accepted aid for abandoning high speed aircrait of to-day. The ejection seat should be mounted to ensure adequate clearance of aircraft structures.

PROBLEMS DUE TO SPEED AND HEAT

i) Except for low speed, piston engine aircraft, all modern aircraft necessitate the use of an anti-'g' valve to afford protection against adverse effects of centrifugal forces. The valve should provide adequate protection without causing too much discomfort. Anti-'g' valves with low and high gradients are available and are ideal for use in high speed interceptors. The high gradient gives greater protection but causes discomfort, if used for any length of time, and is therefore, used in actual or simulated combat conditions.

ii) The problem of heat and cold defies a satisfactory solution. As far as possible the airconditioning unit should be able to protect against the ill effects of intense heat at ground level and low level phases of flying, as well as cater for the extreme cold of the phase of high altitude flying. Bomber crews and those who wear high altitude flying assemblies are faced with another problem.

The clothing of such pilot takes a long time and some arrangement is necessary, whereby some relief can be afforded from the intense heat. Provision for ground cooling of the canopy and an air ventilated suit provides considerable relief. When air ventilated suits are to be used, arrangements should be made for supply of air from the aircraft.

RESCUE AIRCRAFT (HELICOPTERS)

These aircraft are essentially meant for rescue and transportation of marooned and injured persons. Certain problems peculiar to these aircraft are now described.

Noise and Vibrations. The cockpit is poorly sealed and the aircraft is frequently flown with doors open. Noise and vibration, penetrating into the cockpit and cabin, are annoying and tiring to both crew and passengers. Attempts should be made to reduce the noise by covering the walls, the ceiling and floor with pads of sound absorbing material.

Disorientation. There is an absence of visual cues due to absence of reference points on the airframe outside the cockpit. The rotating blades throw intermittent or flickering shadows through the cockpit. Both these factors predispose the crew and passengers to disorientation and the unpleasant situations that result. The location of the control switches and instruments in the roof of the helicopter should be avoided. The less the pilot has to look up the better.

Casualty Transportation. The method of loading and unloading of casualties should be easy. Arrangements should be made to protect the patient from heat or cold by providing an adequate cover. Oxygen may be required for passengers and should be available. A two way communication between the passenger-cabin and the cockpit must be provided.

Conclusion

In conclusion, the aim of such an evaluation should be to afford passengers the maximum possible comfort, and to ensure that the stresses of flight on the aircrew are kept within human physiological limitations, and that they are capable of efficient performance to meet the demands of the operational requirements with a reasonable degree of comfort. It should also be ensured that there is an adequate margin of safety in the event of emergencies.

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