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Medical Evaluation of Cosmonauts: "Acceleration"

KULDIP RAI

MN GUPTA

Large acceleration stresses are encountered by cosmonauts at different phases of space flight. Their magnitudes and durations are discussed highlighting certain physiological effects to determine tolerance limits. During launch and re-entry the choice of supine G has been explained. The acceleration test profile used at IAM for cosmonaut evaluation with results of 9 subjects have been presented.

Introduction

Large acceleration stresses are encountered by cosmonauts during launch and re-entry. With the latest design techniques of space craft the stress of acceleration has been reduced a great deal. However, in case of any malfunction, especially during re-entry the forces could still be very large. Thus cosmonauts are tested for their tolerance to +Gx +Gz upto certain laid down limits to ensure safety.

The problem of Og during orbital phase of flight is always present. Its physiological effects on cardiovascular system can reduce the tolerance to +Gz and to +Gx to some extent during re-entry and landing.

Acceleration stresses in space flight

In orbital flights around the earth the acceleration stresses likely to be experienced can be divided into four distinct phases :-

(a) Launch (b) Orbit (c) Re-entry (d) Landing

The four phases of acceleration stress differ in their magnitude and duration of the stress.

(a) *Launch :* To understand the magnitude of the stress during launch, an idea of the orbital velocities to spacecraft is needed. Orbital velocities at 300 to 1000 Km altitude are in the region of 7.9 to 8 Km/Sec or 17,000 to 18,000 mph. To attain this velocity multi-stage liquid fuelled rockets are used. One type of three stage rocket, acceleration profile is shown in Fig 1 and another in Fig 2. In Fig 1 the maximum acceleration is 8 g for a few seconds with less than 30 seconds above 5 g. In Fig 2 the maximum acceleration is 4 g with total acceleration for about $4\frac{1}{2}$ mts. Fig 2 shows the type of acceleration experienced by cosmonauts in current space craft.

Wg Cdr Kuldip Rai MD, MNAMS (Av Med)
Sqn Ldr MN Gupta (AMD) Graded Specialist

(b) Orbit : In the orbit the centrifugal force of the vehicle balances the gravitational pull, thus producing 0g environment for the occupants of the spacecraft.

(c) Re entry : Acceleration stresses are produced due to the sudden drag and deceleration during re-

ACCELERATION VS TIME IN LARGE 3 STAGE ROCKET MOTOR

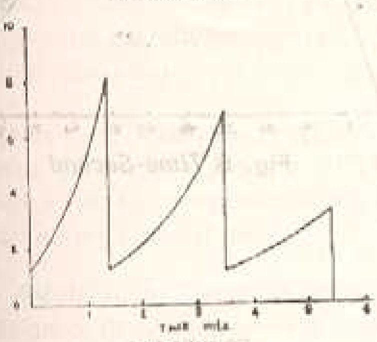
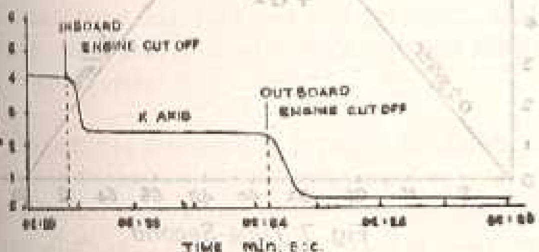


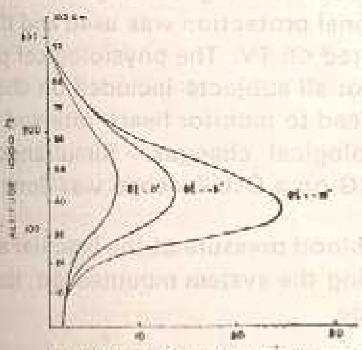
Fig. 1



LAUNCH ACCELERATIONS (APPOLLO 7 MISSION)

Fig. 2

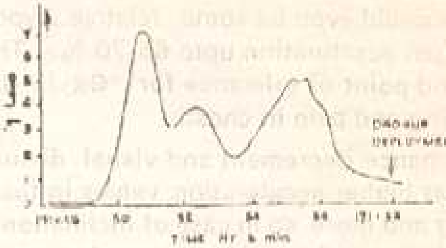
entry to the denser atmosphere starting at around 200,000 feet. The acceleration experienced is dependent on the angle of entry into the atmosphere. High angles, produce very large acceleration, at 10° it is about 25 g. (Fig 3). To keep the magnitude of these accelerations within limits the re entry angle is planned to be less than 1°, so that only about 8 to



RE-ENTRY OF SPACE CRAFT ACCLN WITH ALTITUDE & ANGLE OF RE-ENTRY

Fig. 3

9 g is imposed. Apollo 10 re-entry accelerations are shown in Fig 4. In controlled re-entry the acceleration will always be around 8-9g, but in case of



RE-ENTRY ACCELERATIONS FROM LUNAR MISSION (APOLLO 10)

Fig. 4

loss of control and larger angles at re entry it could be about 20 g for 8 Secs or so. Aero dynamic shape of the space craft could also modify the re-entry accelerations.

Tumbling with high rates of rotation and variable acceleration could be experienced after re entry. This is usually prevented by jets and stablisation parachutes opening at around 100,000 to 70,000 feet altitude.

(d) Landing phase : The accleration imposed depends on the type of landing parachutes in use and the type of terrain. However these are impact accelerations not larger than 8-9 g in most type of space craft.

(e) Emergency Escape : Requirements of emergency escape in a space flight are quite complex in different phases of flight. But acceleration experienced could be in in the region of 20 g sustained for 1 Sec or so.

Physiological Effects

As the accelerations experienced during launch and Re-entry are of high magnitude and of considerable duration, it was realised that +Gz would impose serious restriction on effective function. Thus man is so positioned that ± Gx acceleration is experienced by him, since the tolerance in this axis is much higher. The tolerance in +Gx mode is higher than—Gx, and thus this mode has been used by both the Americans and Russians in their space craft. +Gx acceleration is that, where the inertia due to the acceleration acts from front to back. It is also known as SUPINE G. The most pronounced and marked effects of +Gx are on the respiratory system causing reduction in Tidal Volume and the reserve capacities of the lungs. Due to disturbance of Ventilation perfusion ratio in large portions of the lung there could even be some relative hypoxaemia with oxygen desaturation upto 65-70 %. The commonest end point of tolerance for +Gx is difficulty in breathing and pain in chest.

Performance decrement and visual disturbances are seen at higher acceleration values in the region of 18-20g and more so in case of inclination of seat from the horizontal position. Increasing seat inclination produces a larger +Gz component and thus produce more visual symptoms. In most space craft seats with 10° inclination are being used. To increase the tolerance further, contoured couches are also used.

During launch and re entry the position of the space craft and of the seat inside is so arranged that the occupants undergo +Gx. The tolerance to —Gx being lesser than +Gx, it is normally avoided.

Effects of Og

The effects of Og can b divided into short term (less than 3 weeks) and long term (more than 3 weeks). In short term periods, the effects are minimal, except for the cephaloid shift of blood with certain amount of CVs readjustment and changes in electrolyte and fluid balance. Problems of locomotion, restraint and co-ordination are very peculiar to this environment.

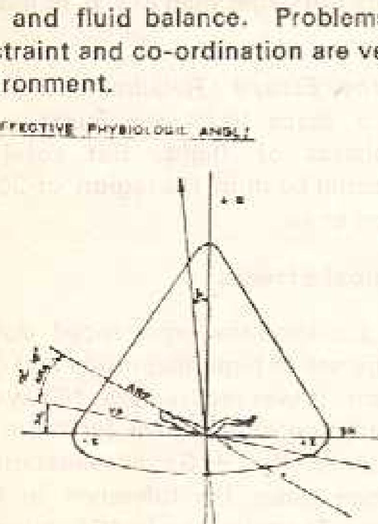


Fig. 5

Test Profiles used at IAM

For selection of our cosmonauts the two test-profiles used were as shown in Fig 6 & 7.

Aero-Medical Evaluation of Cosmonauts Acceleration

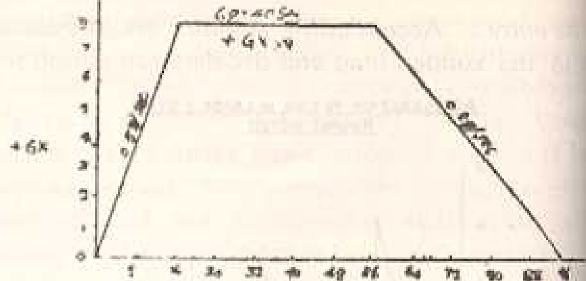


Fig. 6 *Time-Second*

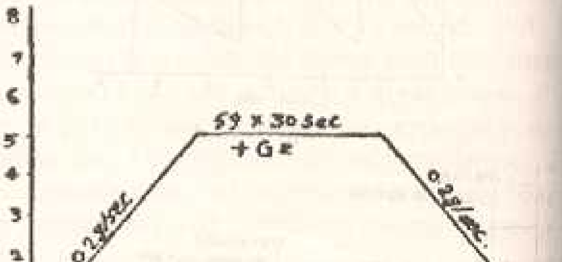


Fig. 7 *Time-Second*

(a) *+Gz Acceleration Tests :* The Human cent fuge at IAM was used for these tests. The centrifug gondola has an upright aircraft seat with the bac rest having 13° angle with the vertical. The hea is supported in an adjustable head rest. Adjustab rudder pedals are provided for foot support. It has shoulder and lap strap harness.

The candidates were exposed to the profile o 0.2g/Sec rise with 5g peak for 30 second and dece ration 0.2g/Sec. During the exposure no Anti suit or personal protection was used and the subje was monitored on TV. The physiological paramete monitored for all subjects included on channel EC with CM 5 lead to monitor heart rate and to stu any morphological changes. Simultaneous mon toring of ECG on a Oscilloscope was done.

Indirect blood pressure at the brachial artery wa recorded using the system mounted on the arm o the centrifuge.

Respiration was recorded from subjects usin P/2 mask connected to Fleish Pneumotachograp with a PT-5 transducer and the Heillige recorder of the centrifuge. Rate and depth of respiration were studied. Volumetric measurements were not done.

Subjects were given practice on the variable angle peripheral lights system (Gradeps) and reaction time was recorded on the Hellige multi channel recorder for finding out any peripheral light loss to determine tolerance limit.

The subjects were in constant touch on Intercom and their faces were visible on the CCTV monitor. Subjects were asked to communicate any complaints or discomfort during the trial run.

(b) +Gx Acceleration Tests : A new horizontal seat was designed, developed and fabricated by the technical staff of IAM for trials. The back rest, adjustable head rest, seat rest and an additional leg support were provided with thick cushion with proper harness system.

The seat was designed to provide 90° thigh angle as well as the knee and ankle angles. The seat back was mounted at an angle of 10° from the horizontal. Proper anchorage and location of the seat in the gondola was ensured and a number of other systems in the centrifuge gondola had to be shifted and refitted. The rudder pedals and the PLL system were removed. The TV Camera was mounted on a new frame at an angle to ensure that the face of the subjects was visible on TV during the trials.

Physiological monitoring of one lead ECG, (CM-5), Respiration for rate and depth and blood pressure was carried out. Details as explained already for +Gz exposures.

Intercom facility was available through the microphone of the P/Q mask worn by the subjects. But it was felt that at high +Gz exposures the subject may not be able to speak properly. Hence an additional light switch (dead man switch) was provided as a microswitch on a hand grip control. The subject kept the micro switch pressed so long he felt comfortable which kept on special light on the central console. If the subject would feel uncomfortable or become unconscious the micro switch would be released and the light would go off. The controller would then operate emergency deceleration control immediately. This was considered an essential safety precaution.

The +Gx profile used for the cosmonaut selection at IAM are shown in Fig 7.

Results

The salient features of these trials are listed below:

+Gz trials upto 5g for 30 Secs

Twelve subjects ranging in age from 29 to 40 years were tested. They were all experienced cambat fighter pilots and had extensive experience of +Gz. They had no difficulty or discomfort during these exposures. Only one subject showed momentary PLL with recovery very soon. In the ECG records one person showed sinus arrhythmia. No other significant ECG changes were seen, except tachycardia of a moderate degree. Respiratory monitoring showed increased rate with reduced tidal volume in most subjects. All subjects were considered fit for their tolerance to +Gz stress.

+Gx trials upto 8g for 40 Secs

Nine subjects ranging in age from 32 to 40 years were tested. All of them tolerated the stress with mild to moderate difficulty in breathing and heaviness of the chest. None of them experienced any pain or discomfort.

They showed increased rate of respiration with reduced tidal volume. Respiratory rate of 40/mt was seen in one case. Tachypnoea persisted even after the trial run for a short period.

Moderate tachycardia (HR 120/mt) was seen in all cases However one subject showed a heart rate of 156/mt at 8g. In all cases the heart rate was seen returned to resting levels after the test. No case showed bradycardia or significant arrhythmias in our series. Two cases had occasional ectopic beats and two cases changes in T wave pattern. All the ECG changes were analysed and considered insignificant.

Blood pressure readings showed a fall of both systolic and diastolic values during the test run.

All the subjects were found fit for their +Gx tolerance.

Summary

+Gx stresses during orbital flights in space craft have been enumerated and discussed. The test profiles utilised for testing cosmonauts have been described. Our experience of testing 9 subjects under the above stress have been presented.